



COOPERATIVE RESEARCH CENTRE
FOR TEMPERATE HARDWOOD FORESTRY

ANNUAL REPORT 1993/94



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



CENTRE OBJECTIVES

- develop improved forest management systems to increase and sustain wood production in hardwood forests in an environmentally sensitive way
- improve the quality and the quantity of wood from hardwood forests to ensure its market suitability for efficient value added processing by Australian industry
- couple the separate but complimentary expertise of the Parties to focus their research and development activities in a co-ordinated fashion
- develop a national centre of excellence for training in temperate hardwood forestry with emphasis on postgraduate research training in tree Genetic Improvement and Resource Protection

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For Temperate Hardwood Forestry**



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BORAL TIMBER



forest resources



CSIRO
AUSTRALIA



Forestry Tasmania
GROWING OUR FUTURE

NORTH FOREST PRODUCTS



UNIVERSITY OF TASMANIA

Participating Organisations



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Obituary



Mr John Allwright AO

Members of the CRC were saddened by the death in March this year of the Chairman of the Board, Mr John Allwright AO. John fully embraced the concept of Cooperative Research Centres and played a major role in the establishment of this CRC and had been its Chairman since its inception.

Educated at Clemes College, Hobart and Dookie Agricultural College, Victoria John ran an intensive vegetable, cereal, beef and sheep enterprise at the historic Exton House property near Westbury, northern Tasmania.

John played a significant role in the success of many rural enterprises in Tasmania. He was President of the Tasmanian Farmers and Graziers Association (1980-83) and Tasmanian Farmer of the Year in 1981. He gained national and international recognition as president of the National Farmers Federation from 1988 to 1991 during the worst rural recession since the 1890s. Renowned for his negotiating skills and pragmatism, John was a conciliator who brought people together but was persistent in reaching a solution when necessary. He tackled the United States on the harmful effect of their Export Enhancement Program and played an important part in the GATT talks in Montreal in 1988 and in Brussels in 1990. As President of the National Farmers Federation he was successful in building linkages between politicians, the bureaucracy and the farming community. John had the ability to talk with farmers and rural groups and then translate their concerns into policy.

John was a strong supporter of scientific research in agriculture and was appointed a member of the Council of the University of Tasmania in July last year. His agricultural interests were far ranging. Not only did he play a major part in the development of poppy farming in Tasmania - an industry worth \$35 million a year, he was Chairman of the Private Forestry Council. He was also the Chairman of the Board of Management of the CRC for Soil and Land Management in South Australia. He was named Tasmanian of the Year in 1992.

John was a great Australian, a fighter for the man on the land, a skilled lobbyist but also a gentleman of compassion and friendliness. He will be greatly missed by many individuals and organisations across the country.

Executive Summary

Professor J Reid
Director

The Cooperative Research Centre for Temperate Hardwood Forestry has completed its first three years of operation in a strong position to fulfil its mission to enhance the productivity and sustainability of temperate hardwood forestry. This is being achieved by focussing on four major programs, three in key research areas for the industry,

- Genetic Improvement
- Soil and Stand Management
- Resource Protection

and a fourth dealing with our research transfer and training role for postgraduate students and industry staff,

- Education and Communication.

The research programs are now fully developed and continue to produce results of international standing and of direct relevance to our industry sector. Highlights during 1993/94 include:

- A major analysis of the performance of 450 families of *E. globulus* sp *globulus* across a range of sites in Australia
- The prediction of breeding values and genetic parameters for *E. nitens* and *E. globulus* using BLUP/REML methodology
- The use of RAPD markers to analyse variation patterns within *E. globulus*
- The isolation and quantification of gibberellin, IAA and ABA levels by GC-MS from the cambial region
- Determination of seasonal variation in leaf photosynthetic response to temperature and its effect on the prediction of wood yield
- Demonstration that at moderate levels of water stress the water relation characteristics of *E. globulus* leaves are more tolerant than leaves of *E. nitens*
- Determination that blanket fertilisation at the time of planting may be wasteful due to the lack of response shown on some sites
- Intensive monitoring of *Chrysophtharta bimaculata* and natural enemies to provide detailed information on insect dynamics, distribution and oviposition patterns

The Centre has continued to develop its national role as a Centre of training for forestry research staff by expanding the number of honours and postgraduate students to 33. These students have been favourably received by industry and some have been offered positions even prior to completion of their studies. This quality is also demonstrated by their ability to obtain highly competitive

postdoctoral positions (eg Dr M Battaglia, ARC fellowship). The growth in numbers has focussed on two key areas with identified deficiencies in Australia at the start of the Centre, genetic improvement and tree breeding of eucalypts, and protection of the forest resources from predation by both vertebrate and invertebrate pests.

Our leadership in the training of tree breeders was also demonstrated by the demand for positions at a short course run by Drs Borralho, Hodge, Potts and Ms Raymond on advanced methods in quantitative genetics applied to tree breeding. Entry to the course had to be limited to invitations to key industry and research personnel from around the country. Representatives included people from all states, major forest industries such as North Forests, APM, ANM and Forest Resources, and CSIRO, Universities and State forestry organisations.

Two important changes have occurred to the Management of the CRC. Firstly, the Office of the Chief Scientist has appointed a Visitor to the CRC. He is Professor Harold Woolhouse, Dean, Faculty of Agriculture, University of Adelaide. He will provide advice on the strategic directions for the Centre. Professor Woolhouse visited the Centre in May for a Board meeting at which he outlined his role. He also talked with most project leaders and attended a short symposium organised by the Centre on some key research outcomes of the research programs.

Secondly, we have recruited an eminent Australian, Mr John Kerin, as the new Chairman of the Board of the CRC. He replaces our inaugural Chairman, Mr John Allwright, AO, following his untimely death. Mr Kerin is a former Treasurer and Minister of Primary Industry and Energy in the Australian Government. He has a broad knowledge of the problems facing primary industries across this country and provides a national focus for the Centre.

Strong interaction with a number of other organisations including the CRC for Hardwood Fibre and Paper Science, the CSIRO Division of Forestry and the Southern Tree Breeding Association (STBA) and with world renowned scientists brought to the Centre on the Visiting Scientists Scheme has enhanced research conducted at the Centre. Interaction between the Centre's Genetic Improvement Program and the STBA has allowed a national analysis of trials of *E. globulus* based upon the CSIRO family collections made in 1987 and 1988. The analysis was based on trials grown across temperate Australia including Tasmania, Victoria, South Australia and Western Australia and provides the first ranking of families of this important species across a range of environments. This analysis has provided clear evidence that a single breeding program will provide maximum gains for this species and highlights the potential benefits of well founded interactions between research organisations.

The Visiting Scientist Scheme has resulted in a substantial increase in our research strengths and international profile. Professor Eberhard Voit, a specialist in modelling biological systems from the Medical University of South Carolina, developed new modelling techniques to predict forest growth and yield in collaboration with Dr Peter Sands. This novel approach will be useful in the development of forest management procedures.

Dr Gary Hodge, a specialist in genetic evaluation from the University of Florida, analysed trials to improve strategies for selection in *E. globulus* and *E. nitens*. Dr Myron Zalucki from the CRC for Tropical Pest Management at the University of Queensland, visited the Centre over summer. During his visit he carried out growth experiments with *Chrysophtharta bimaculata* larvae on a range of *E. regnans* families with known insect susceptibilities. He also interacted closely with a number of the students and helped analyse *C. bimaculata* spatial distribution data collected by members of the Resource Protection Program.

In conclusion, after three years of intense activity the Centre has become a national leader in its designated area by providing innovative solutions and developing collaborative projects in key areas of plantation forestry. We have been successful in achieving most of the initial goals set for the Centre in 1991 when it was established as one of the first group of CRCs.



The new building housing the CSIRO and CRC for Temperate Hardwood Forestry on the campus of the University of Tasmania.

Management The Board

The **Board of Management of the CRC** (Figure 1) is comprised of an independent Chairman, the Director and Deputy Director of the CRC and the Chief Executive or his representative from each participating body. There have been two changes to the Board in recent months. Firstly, we have a new Chairman of the Board of the CRC, an eminent Australian, Mr John Kerin. He replaces our inaugural Chairman, Mr John Allwright AO, following his untimely death on March 6, 1994.

John Kerin is currently Chairman of the Meat and Live-stock Corporation and is actively involved with organisations concerned with research, small business, trade, technology transfer, the environment and financial management. John Kerin was born at Bowral, NSW in 1937 and grew up on the family's farm where he worked until he was 33, when he joined the Bureau of Agricultural Economics in Canberra as an economics research officer. His academic achievements include a BA from the University of New England, a BEc from the Australian National University and an Honorary Doctorate in Rural Science from the University of New England in 1992. Mr Kerin was the Member for Macarthur in the Australian Parliament 1972-1975, then a Member for Werriwa from 1978 until 1993 during which time he was Minister for Primary Industries and Energy, Treasurer, Transport and Communication and Trade and Overseas Development.

Secondly, there has been a change in representative for North Forest Products on the Board; Mr Allan Jamieson replaced Mr Ian Whyte.

The Board determines policy and sets guidelines for the efficient running of the Centre.

Structure

The **Management Structure** of the CRC is headed by the Board and links are depicted in Figure 2. Operation of the four programs is directed through three committees: the Management Committee, the Industrial Research Coordination 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 Administrative Officer, Program Managers, the Director and the Deputy Director.

Mrs Shelley Caswell	-	Administrative Officer
Prof Jim Reid	-	Genetic Improvement Program, Director
Dr Phil West	-	Soil and Stand Management Program, Deputy Director

Figure 1 Board of Management of the CRC

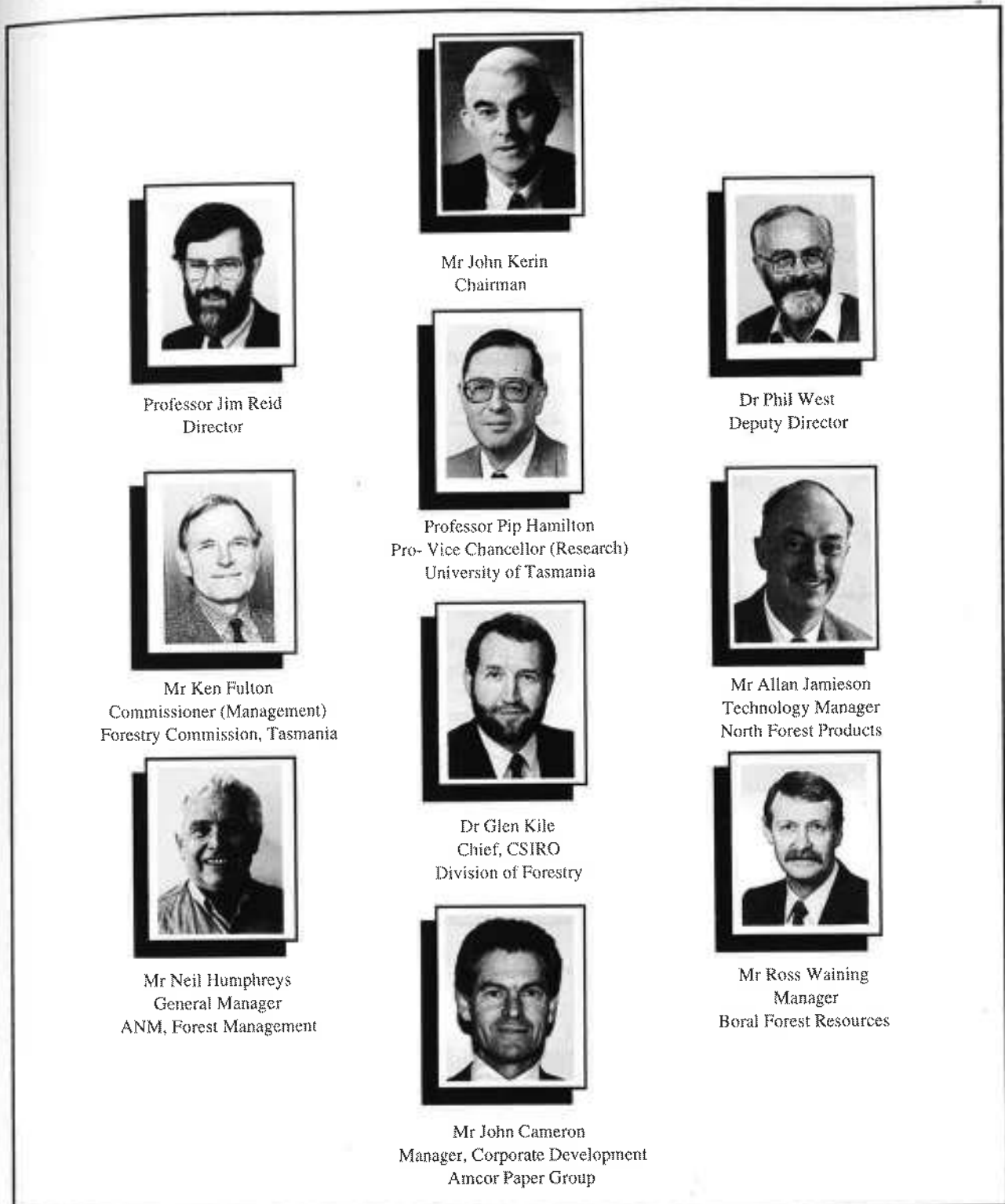
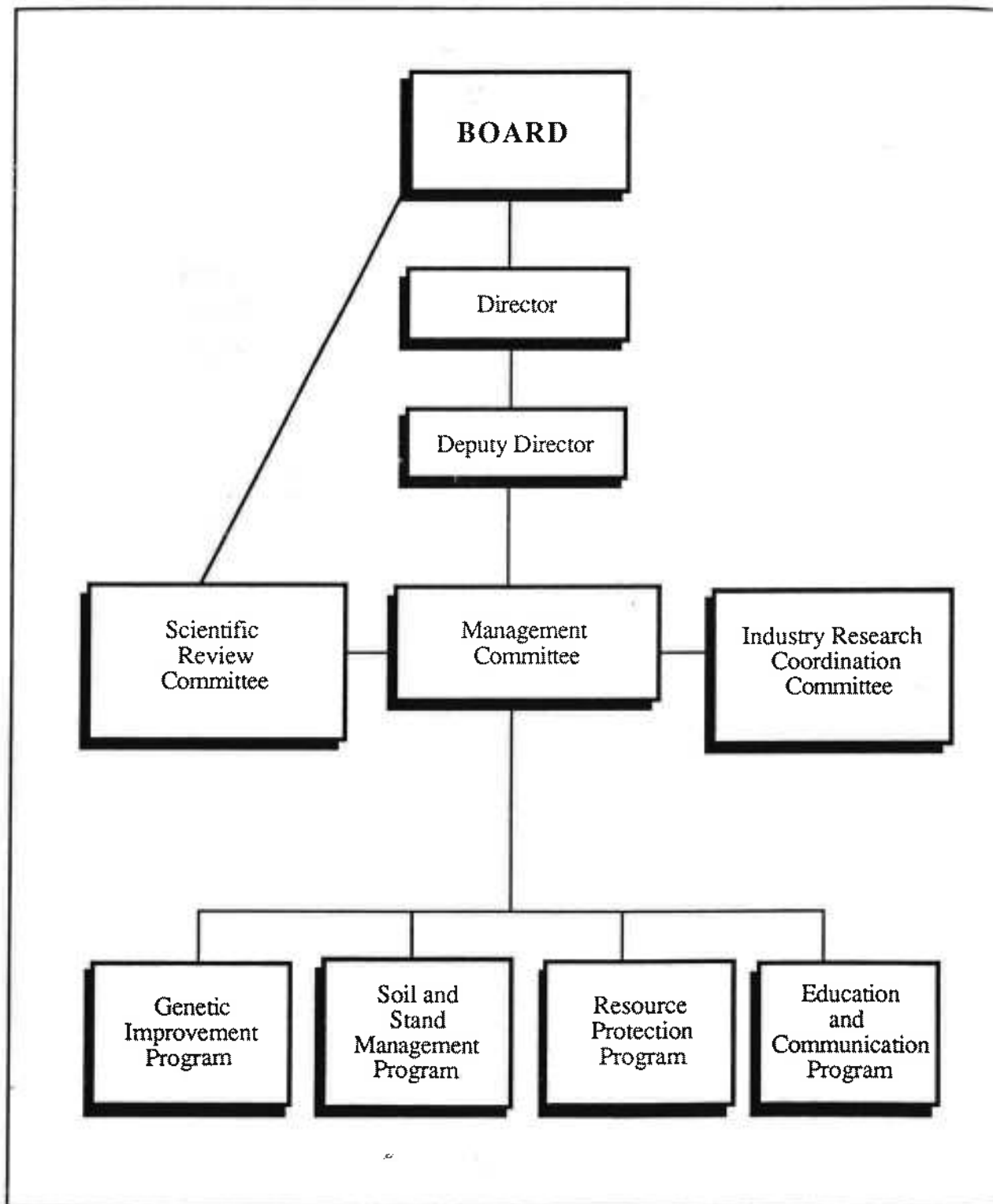


Figure 2 Management Structure of the CRC



Industry Research Coordination Committee

- Dr John Madden - Resource Protection Program
- Dr Neil Davidson - Education and Communication Program

The **Industry Research Coordination Committee** is comprised of Senior Research Scientists from all participating organisations and sets the research priorities for the Centre. This committee is chaired by a leading industry researcher, Mr Peter Volker from ANM Forest Management and its members are:

- Dr Humphrey Elliott - Chief, Division of Silvicultural Research and Development, Forestry Tasmania
- Dr David de Little - Research Manager, North Forest Products
- Mr Peter Volker - Research Manager, ANM Forest Management
- Mr Peter Naughton - Research Manager, Forest Resources
- Mr Phil Whiteman - Development Manager, APM Forests
- Prof Jim Reid - Director, CRC
- Dr Phil West - Deputy Director, CRC
- Dr John Madden - Program Manager, CRC Resource Protection
- Mr Robin Cromer - Program Manager, Hardwood Plantations, CSIRO Division of Forestry
- Dr Neil Davidson - Program Manager, CRC Education and Communication
- Dr Geoffrey Gartside - Co-Director, CRC for Hardwood Fibre and Paper Science, Clayton, Victoria.
- Prof Bob Hill - Head of Department, Plant Science University of Tasmania

Scientific Review Committee

The **Scientific Review 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 Garth Nikles | - | Officer in Charge Treebreeding,
Queensland Dept of Primary
Industries, Forest Service
(Genetic Improvement) |
| Dr Russell Haines | | Director of Primary Industries -
Queensland Forest Services
(Genetic Improvement) |
| Dr Lindsay
Barton Browne | - | Honorary Fellow, CSIRO
Division of Entomology,
Indooroopilly
(Resource Protection) |
| Dr Sadanandan
Nambiar | - | Chief Research Scientist, CSIRO
Division of Forestry, Canberra (Soil
and Stand Management) |



Research Genetic Improvement Program



Prof Jim Reid talking to students at a field experiment.

Program Manager
Prof J B Reid

Introduction

This program aims to achieve gains in plantation productivity by improving the genotypes of planting stock. This requires two major research thrusts. Firstly, the genetic resources available must be identified, reliable estimates of relevant genetic parameters determined and these used to develop efficient breeding strategies. Secondly, once genetically superior material has been identified, it must be transferred to plantations as quickly as possible either by seed or by vegetative propagation. These two needs form the basis of the two sub-programs of this Program, Genetic Resources and Propagation Strategies.

Major achievements

- Analysis of the performance of 450 families of *E. globulus* ssp *globulus* across five sites in Tasmania indicated that ssp *globulus* could be divided into 12 main races. However, most variation was within families and genotype x environment interactions across Australia suggested that the most efficient breeding strategy was a single national program.
- Breeding values and genetic parameters were predicted for *Eucalyptus nitens* and *Eucalyptus globulus* for growth and frost tolerance, using powerful statistical techniques that take all pedigree relationships into account (BLUP/REML methodology).
- Inclusion of the characteristics of native stands from which seed was derived was used to improve the accuracy of selection and hence the breeding values derived for *E. globulus* using BLUP models.
- A strong genetic correlation was demonstrated between pilodyn penetration and basic density at breast height in *E. nitens* providing a cheap and rapid means of including basic density in selection indices.
- RAPD markers have confirmed that most variation in *E. globulus* occurs within localities including families and that there is a major latitudinal cline in the RAPD phenotype between southern Tasmania and mainland localities of ssp *globulus*.
- A major advanced generation crossing program between *E. nitens* and *E. globulus* has been completed.
- The improved micropropagation procedure developed by the CSIRO and the CRC is being evaluated by our industry partners for its commercial potential.

Sub-program 1

Project 1

*Project Leader
Dr N Borralho*



Dr Nuno Borralho and Dr Gary Hodge.

- Gibberellins, IAA and ABA have been identified and quantified by GC-MS from the cambial region of *E. globulus* and *E. nitens*.

Genetic Resources

Breeding programs aim to evaluate the available genetic resources, select the best natural seed sources and progressively improve these via selection and interbreeding of superior trees to produce planting stock of constantly improving genetic quality. Breeding programs rely on the development and critical evaluation of alternative strategies which aim to optimise the rate of genetic gain within the biological constraints of the species. These rates of genetic improvement are controlled by four major factors:

- the amount of variation present in the population,
- the degree of genetic control of the trait,
- the generation interval,
- and the intensity of selection employed.

Four research projects have been established within this sub-program to try and address these issues and to explore novel ways of increasing the economic return from breeding programs. All are broadly based and interactive.

Breeding strategies, genetic parameters and prediction of breeding values

Introduction

The aim of any breeding program is to improve the economic value of the forest and its products. Accordingly, the role of this project is to improve the way breeding programs are carried out by our industry partners. To accomplish this goal one requires:

- reliable estimates of genetic and environmental variance and covariance for the economically important traits and the effective use of this information to carry out selections.
- better strategies for deployment of temperate hardwood species so that gains in selection are transferred to the field, and in particular, improvements in the availability of vegetative propagation techniques.
- the development of a set of rules which can be applied to current and future breeding decisions, such as; mating designs, field experimental protocol and assessment of traits.

a) Genetic variation in eucalypts

This research aims to identify the sources of variation observed in temperate eucalypts growing in plantations.

Outcomes

- Provenance variation was studied in *Eucalyptus globulus*, *E. regnans* and *E. delegatensis*. Significant provenance differences were found in an extensive study involving growth performance of up to 31 provenances of *E. globulus*, but provenance-site interactions were small and did not justify the development of regionalised programs. In a separate study involving performance of 450 families of *E. globulus* across five sites in Tasmania, the classification of *E. globulus* ssp *globulus* into 12 main races was suggested. Many larger provenance differences and provenance-site interactions were detected in *E. regnans* and *E. delegatensis* than in *E. globulus*.
- A large analysis is being conducted on the growth traits of more than 80,000 progenies from 600 open pollinated base population parents of *E. globulus* ssp *globulus*. This analysis includes 25 trials in Australia, Chile, Portugal and Spain. This represents the largest genetic analysis of *E. globulus* to date and an opportunity to study the genetic variation of the species across a wide range of environments. In addition, genetic parameters, such as heritabilities and genetic correlations were estimated for a number of open- and controlled-pollinated progeny trials of *E. nitens*, *E. globulus* and *E. regnans* using economically important traits such as growth, wood and pulp quality, frost tolerance, insect resistance, field survival and propagation ability.

Goals

- Extend the study of genetic variation and site x genotype interactions in the *E. globulus* base population, now completed for growth traits in Tasmania, to other states in Australia and overseas.
- Improve the classification of races in *E. globulus* by including wood traits and performance at more sites, and develop a similar classification for *E. nitens*.

b) Prediction of breeding values

Recent advance in selection theory and computing algorithms, in particular the Best Linear Unbiased Predictions (BLUP) allows a more efficient use of the information (genetic and environmental) for selection of trees. Of particular importance is the development of appropriate models of analysis to accommodate effects due to unknown male pedigree, selfing, race, competition, site and age. Other research projects in the CRC are determining

these effects. Studies of the application of BLUP Mixed Models to tree selection are also underway.

Outcomes

- Inclusions of native stand characteristics as an extra fixed effect in the model improved the accuracy of selection and the across race comparison of open pollinated progeny from parents in native stands.
- Construction of the *Eucalyptus globulus* base population database.
- Prediction of breeding values for growth in the *E. globulus* base population in Australia, carried out in collaboration with the Southern Tree Breeders Association.
- Prediction of breeding values for frost tolerance in *E. nitens* and *E. globulus*.

Goals

- Compare the selection accuracy between univariate models (a single trait across ages and sites) and multivariate models (different traits per age and site) in eucalypt selection programs.
- Express breeding values in a compatible way for use in standard growth models.
- Establish a set of recommendations of BLUP models suitable for national selection of *E. globulus* and *E. nitens*.

c) Breeding objectives

Appropriate breeding objectives need to be defined, and to attain these objectives the relative importance of the traits used for selection need to be clearly determined, before the genotypes are ranked and deployed in the field.

Outcomes

- The breeding objectives of a *Eucalyptus* forest and pulp production system were evaluated. Although volume was found to be an important trait, the cost savings from indices that included only volume were always much less than one-half, and sometime as low as one-quarter, as much as those from indices integrating volume and wood traits. It was shown that these savings have substantial implications for company profitability. These initial results need to be extended to other production systems based on temperate eucalypt plantations. An application for an APRA(I) PhD scholarship on this area was approved.

Goals

- Improve our estimates of economic weights of volume, pulp and wood density to production systems that include pulping and paper making processes.
- Study the economic importance of other traits such as field survival, branching, bark thickness and wood and pulp quality.
- Consider round wood production systems as an alternative breeding objective.

d) Deployment strategies

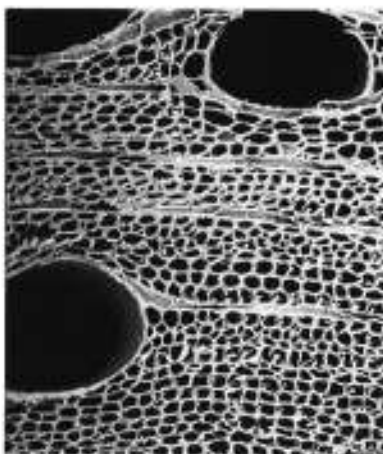
The only way to benefit from breeding is to have an effective deployment system. In temperate eucalypts, the most common systems of deployment are grafted, clonal and seedling seed orchards. Recent developments in clonal propagation methods, including both stem cuttings and tissue culture have been successful but large scale propagation can only be achieved on a few of the desired genotypes. To exploit the obvious benefits of vegetative propagation specific selection and cloning strategies need to be developed.

Outcomes

- Simulated gains from alternative strategies of selection and propagation have shown that cloning of the best forwardly selected trees or bulk propagation of their crosses returns greater gains than propagation of the best field tested families or crosses between the best progeny tested parents. Subsequent clonal testing and selection of best clones adds considerable gains providing family juvenility can be maintained for several years. Propagation constraints such as maturation and poor rooting ability makes bulk propagation of families more attractive. However, benefits from vegetative propagation are maximised when a combination of family and individual cloning is used.
- Correspondence between performance of vegetative propagules and seedlings, as expressed by the correlation between related individual or family means was investigated. Expected values were derived and bias due to propagation effects (C-effects) were tested using simulated data. Results show that correlations between seedling and propagules are expectedly poor even in the absence of propagation effects due to poor accuracy of the means. Bias due to propagation effects is only significant when these effects are common to specific clones, and covariance between them and breeding values is zero or negative. The magnitude of the correlations and observed bias depends on the type of comparisons.

Project 2

Project Leader
Ms C Raymond



Cross section of wood showing large vessels and small fibres.

Goals

- Compare the relative merits of alternative deployment strategies, particularly through vegetative propagation.
- Study the genetic variation of propagation traits in temperate eucalypts and their relationship with selection traits. Evaluate the economic importance of propagation traits in a breeding program and study the possibility of incorporating propagation traits in a selection program.

Genetic variation in fibre and pulp traits

Introduction

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). This linkage enables the flow of both information and wood samples between the two CRC's and for the establishment of joint projects.

Specific aims of this project include:

- development of non-destructive sampling techniques for wood properties based on an understanding of within tree variation in wood and fibre traits,
- evaluation of new screening techniques for wood properties via correlating these techniques with known results and evaluating their practical use in the field,
- determine suitable sampling designs and sampling strategies, including choice of field trials, for wood property assessments,
- development of genetic parameter estimates for wood, fibre and pulping traits and their correlations with growth and stem form to allow incorporation of these traits into breeding strategies.

Outcomes

- A PhD program has been established to examine changes in wood density with age in families of *E. nitens*. Three hundred trees have been sampled from each of 2 sites and basic density determined for discs taken at 1.3m. Pilodyn penetrations taken at the same height were found to be strongly genetically correlated with basic density of discs. However, basic density was not found to be correlated with tree diameter at 1.3m.
- Establishment of a joint project with the CRC-HFPS with wood sections from the 600 trees sampled above to be

processed through the X-ray densitometry scanner (Silviscan-E) in Melbourne.

- A survey of existing literature on genetic parameters for wood, fibre and pulping traits in temperate eucalypts was completed and showed that basic density, pulp yield and fibre lengths are all moderately to highly heritable.
- Linkages between the centres strengthened by reciprocal visits.

Goals

- In collaboration with ANM, core sample an *E. regnans* progeny trial at Burnie. Patterns of within tree variation in density and fibre length will be examined to determine representative sampling positions. Trees from 50 families will then be cored to allow for estimation of genetic parameters and for selection of families for a mechanical pulping study.
- Process *E. nitens* sections through X-ray densitometry equipment at CRC-HFPS to allow for determination of age-age correlations in wood density.
- Determine representative sampling position for use of pilodyn in *E. nitens* and *E. globulus*. Within tree variation patterns for density and the correlation between pilodyn penetration and density will need to be evaluated across a range of ages and sites.
- Using existing data, examine sampling strategies to determine numbers of trees per family required to give reliable estimates of family means.

Project 3

Project Leader
Dr R Vaillancourt

Molecular genetics

Introduction

Work on this project will lead to the application of molecular marker technology to tree breeding. Our overall goal is to take advantage of recent technical advances that have enabled the rapid generation of molecular markers, including Restriction Fragment Length Polymorphism (RFLPs) and Random Amplified Polymorphic DNAs (RAPDs). RFLPs and RAPDs can be used to study genetic variation in native and breeding populations of *Eucalyptus*, for identifying and fingerprinting clones, for studying inbreeding depression and heterosis, and for tagging loci controlling commercially useful traits.

a) Develop DNA marker technology for *Eucalyptus*

The first objective of this project was to develop genomic and organellar DNA markers and show their usefulness for several species. We have developed protocols that allow extraction of

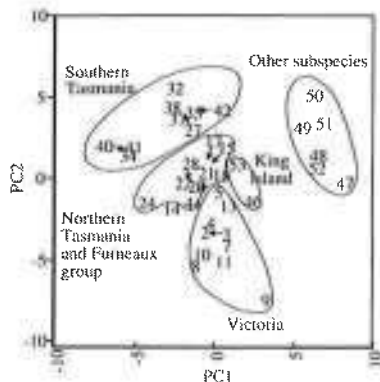


Fig. 1 Principal components analysis of RAPD phenotypes in *Eucalyptus globulus*. Principal components one and two account for 12.2% and 10.2% of the total variation respectively. Localities have been grouped into Southern Tasmanian, Northern Tasmanian and Furneaux group, Victorian, and other subspecies. The term "other subspecies" refers to *ssp. maidenii*, *ssp. pseudoglobulus*, and *ssp. bicostata*, all other localities are of *ssp. globulus* (Figure courtesy of K Nesbitt).

DNA even from difficult species such as *E. gunnii*, which has tough leaves with high polysaccharide and phenolic (tannin or anthocyanin) content. We have also adapted the RAPD protocol to increase its reliability using *Eucalyptus* DNA. Using RAPD markers and chloroplast DNA markers we have initiated:

- a comprehensive survey of genetic variation in *E. globulus* using both genomic (RAPDs) and chloroplast markers (cpDNA);
- a cpDNA survey of series *Viminalis* which contains many important temperate eucalypt species (*E. globulus*, *E. nitens*, *E. dunnii*, *E. gunnii*); and
- a phylogenetic survey across the whole *Eucalyptus* genus using cpDNA markers.

Outcomes

- Using 173 trees from all four subspecies of *E. globulus* and 162 RAPD markers a survey of genetic variation showed that most of the genetic variation was within locality.
- A major latitudinal cline in RAPD phenotypes differentiated southern Tasmanian localities from other *ssp. globulus* localities on mainland Australia (Figure 1).

Goals

- Complete the population survey of *E. globulus* using cpDNA.
- Complete the phylogenetic surveys of series *Viminalis* and genus *Eucalyptus*.

b) Inbreeding depression and heterosis

Molecular markers can be used to study inbreeding depression and heterosis. Both of these phenomena have been shown to have significant effects on tree performance. We are studying both of these genetic phenomena to understand their causes and to predict their occurrence. The objectives of this project were developed in collaboration with Dr Brad Potts and Dr Nuno Borralho.

Outcomes

- Cluster analysis of RAPD data differentiated two provenances of *E. globulus* and showed that RAPD markers are useful in establishing degree of relatedness (Figure 2). We attempted to predict heterosis (specific combining ability) in crosses between these trees using genetic distance. We found that specific combining ability could not be predicted using genetic distances calculated from RAPD data.

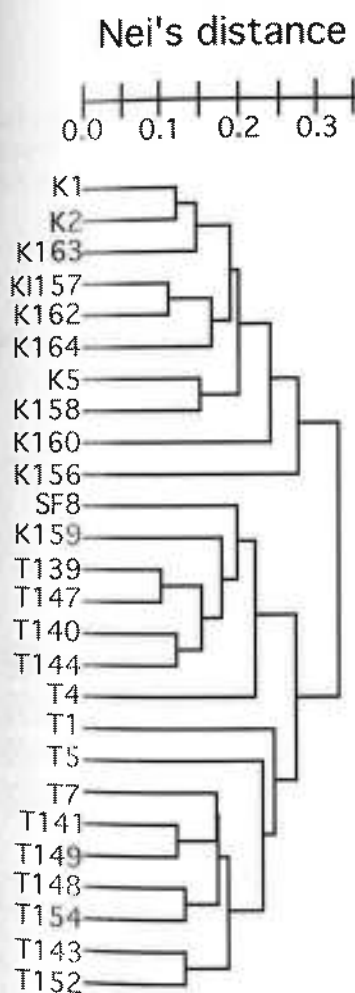


Fig. 2 UPGMA dendrogram based on Nei's distance between 26 *Eucalyptus globulus* trees of three provenances, King Island (K, followed by parent number in dendrogram), South Flinders Island (SF8) and Taranna (T, followed by parent number) using 99 RAPD markers.

Goals

- Measure the level of inbreeding for *E. globulus* trees that differ in their degree of isolation (stand density) using isozymes and study the correlation between level of inbreeding and the frequency of abnormalities in the seedlings and performance (inbreeding depression) of the open-pollinated progeny.

c) Testing the application of Marker-Assisted Selection (MAS) in tree breeding

In Marker-Assisted Selection (MAS), anonymous genetic markers are used to tag Quantitative Trait Loci (QTL). QTLs provide a measure of the inheritance of quantitative traits, and once QTLs are found it is possible to follow their inheritance through generations without any field testing. MAS is a breeding tool that could be especially useful with traits that can be measured only very late in the life of a tree or traits that are very expensive or difficult to measure. It could also make possible the use of the backcross breeding strategy in forestry. To test if MAS could be applied to *Eucalyptus* we are attempting to:

- tag QTLs controlling frost tolerance and other characters in the F₂ of a cross between *E. gunnii* and *E. globulus*: and
- tag QTLs for growth rate in F₁s from a cross within *E. globulus*.

Outcomes

- Among the first RAPD markers to be scored in the *E. gunnii* x *E. globulus* cross, a small but significant proportion of RAPD markers showed significant deviation from expected segregation. This will complicate constructing a complete linkage map in this cross (Figure 3).

Goals

- Complete the *E. gunnii* and *E. globulus* project by collecting data on at least 100 RAPDs and a few RFLPs markers and perform QTL analysis using analysis of variance (an approach with no assumption of Mendelian inheritance) as well as with interval mapping.
- Construct a linkage map in the F₁ progeny from a cross within *E. globulus* in collaboration with CSIRO Forestry in Canberra (Dr G F Moran and Dr M Byrne). Perform QTL analysis using growth rate as well as other quantitative variables. Establish the conservation of linkage groups between *E. nitens* and *E. globulus*.

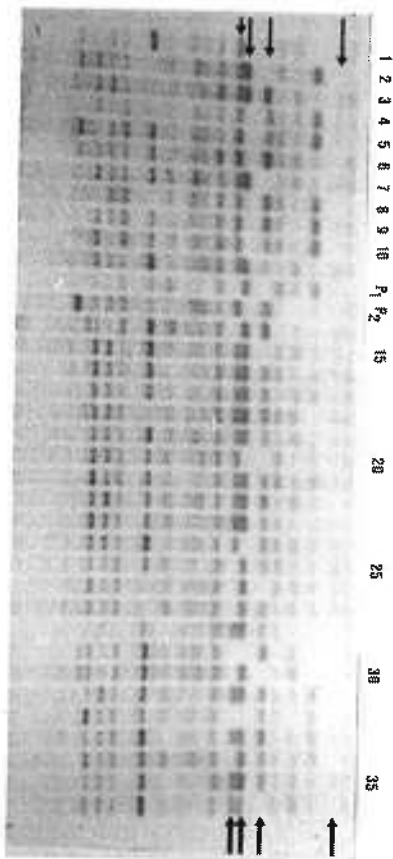


Fig. 3 Segregation of RAPD markers in the F₁ (lanes 1-11) and F₂ (lanes 14-36) from a cross between *E. globulus* (P1) and *E. gunnii* (P2).

d) Genetic control of leaf phase change in *E. globulus*

The aim of this research is to isolate genes involved in the control of vegetative phase change in eucalypts. We are using leaf material since it is easily sampled and there is a dramatic difference in adult and juvenile leaf morphology in *E. globulus*. The technique used is differential mRNA display and involves the amplification of subsets of mRNA from both types of leaves, their separation by electrophoresis and direct comparison for differences in mRNA between adult and juvenile leaf forms.

Outcomes

- The technique of mRNA differential display was adapted successfully to eucalypts. Many differences were found between adult and juvenile leaf forms using the mRNA technique (Figure 4).

Goals

- The next step in this project is to clone and sequence the differentially displayed genes.

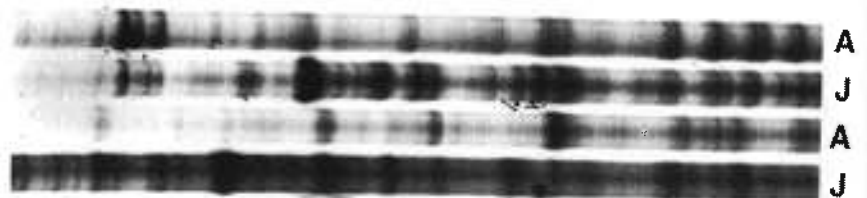


Fig. 4 Autoradiograph showing genes that are differentially expressed between adult and juvenile leaves of *E. globulus*. Lanes containing RNA from adult are marked A and those from juvenile leaves are marked J. Each set of two lanes represent a different set of primers used for PCR amplification and thus may represent different mRNAs (Figure courtesy of J. Presser)

**Project 4
Project Leader**

Dr B Potts

Hybrid breeding

Introduction

There is considerable international interest in the use of interspecific hybridisation as a breeding strategy in *Eucalyptus*, yet little of the genetic information to effectively assess or use a hybrid breeding strategy is currently available. While there are reports of hybrid vigour in interspecific hybrids of *Eucalyptus*, intraspecific controls are usually absent or insufficient and it is difficult to assess whether similar genetic gains could be achieved simply through the removal of inbreeding by outcrossing within species.

The CRC has brought together one of the largest collections of pedigreed F₁ hybrids of *Eucalyptus*. With this material, the hybrid breeding project aims to provide the fundamental genetic and biological information necessary to properly assess and use hybrid breeding strategies with the temperate eucalypt species.

(a) Barriers to interspecific hybridisation

There is some evidence to suggest that cross success and the vigour of F₁ hybrids may decrease with increasing taxonomic distance between the species which could preclude many otherwise desirable F₁ combinations from direct commercial exploitation. This subproject is investigating the barriers to the production of hybrid seed and plants and in particular the relationship of cross-success and heterosis with the genetic/taxonomic distance between parents.

Outcomes

- Compared to outcrossed controls of pure species, significant post-mating barriers to the production of *E. gunnii* x *globulus* and *E. nitens* x *globulus* F₁ hybrids have been demonstrated.
- A comparison of the two year performance of selfs, open-pollinated, intra- and inter-provenance crosses of *E. globulus*, *E. nitens* x *globulus* F₁ hybrids and intra-provenance crosses of *E. nitens* on several sites has shown an optimum level of divergence associated with inter-provenance crossing. Inbreeding effects appear to be stable across sites whereas the relative performance of parental species and their hybrids was site dependent.
- The performance of the *E. nitens*, *E. globulus* and their F₁ hybrids is currently being assessed at four years of age and the success of a wide range of other types of interspecific F₁ hybrids is currently being reviewed.

Goals

- Assess the four year performance of *E. nitens*, *E. globulus* and their F₁ hybrids across multiple sites.
- Review the success of a wide range of other types of interspecific F₁ hybrids in trials in Tasmania.

(b) The inheritance of traits in F₁ hybrids

Traits currently under investigation include frost, insect and fungus resistance, flowering time and precocity, growth rate and rooting ability. Studies will be extended to wood properties when trials are of sufficient age and efficient sampling techniques developed. Cloning ability is also a key issue as it appears that the effective exploitation of hybrid material will ultimately depend on the concurrent development of effective methods for vegetative propagation.

Hybridisation of *E. gunnii* and *E. globulus* subsp. *globulus* is of particular interest as this would allow the combination of genes of one of the most freezing-resistant species in the genus with genes of one of the faster growing, high pulp yielding species.

Outcomes

- Clonal trials of *E. gunnii* x *globulus* F₁ hybrids and parental controls have now been established on four sites in collaboration with North Forest Products.
- Flowering in the major *E. nitens* x *globulus* hybrid trial was monitored at two weekly intervals over the 93/94 season for a study of the inheritance of flowering time.

Goals

- Complete the studies of the inheritance of flowering phenology in controlled crosses of *E. globulus*, *E. nitens* and their F₁ hybrids and the inheritance of the cloning potential by hardwood cuttings in *E. gunnii* x *globulus* hybrids.

(c) Comparison of genetic parameters and estimates of breeding values in pure breed and hybrid combinations

The choice of strategies for breeding hybrids depends largely on whether genetic parameters and breeding values in hybrid and pure breed populations are stable. For example, can we assume that the best parents in each species will produce the best hybrids or do we have to specifically test and select our parents for their ability to perform in hybrid combination?

Outcomes

- Genetic parameters and breeding values estimated from interspecific F₁ hybrids, open pollinations and controlled intra-provenance and inter-provenance crosses of *E. nitens* and *E. globulus* are currently being compared amongst cross types and environments in a PhD project.

Goals

- Compare hybrid and pure species genetic parameters and breeding values for growth at four years.

(d) The potential of advanced generation hybrid breeding

To provide suitable character combinations it may be necessary to breed beyond the F₁ generation, yet there is little information on character inheritance, correlations between characters or the extent to which hybrid breakdown occurs in advanced generations.

Advanced generation hybrids of *E. gunnii* x *globulus* and *E. nitens* x *globulus* are being studied to determine the barriers to hybridisation (hybrid breakdown) and the inheritance of traits in later generations. Particular emphasis is placed upon determining which traits e.g. frost resistance and growth rate can be recombined in crosses between complementary species such as *E. globulus* and *E. gunnii*.

Outcomes

- The inheritance of early growth and survival, morphology and frost resistance in F₁ and advanced generation hybrids of *E. gunnii* x *globulus* has been studied.
- Most traits were inherited in a more or less additive manner in F₁ and advanced generation hybrids, and in the F₂ family studied there was no association between growth rate and frost resistance.
- Reduced vigour of F₂ hybrid families derived from selfing F₁ *E. gunnii* x *E. globulus* hybrids was shown to be due to the deleterious effects of inbreeding (Figure 5) rather than hybrid breakdown (outbreeding depression).



Ms Andrea Manson (Honours student) inspecting deformities in the F₂ progeny of *E. globulus* and *E. nitens* hybrid cross.

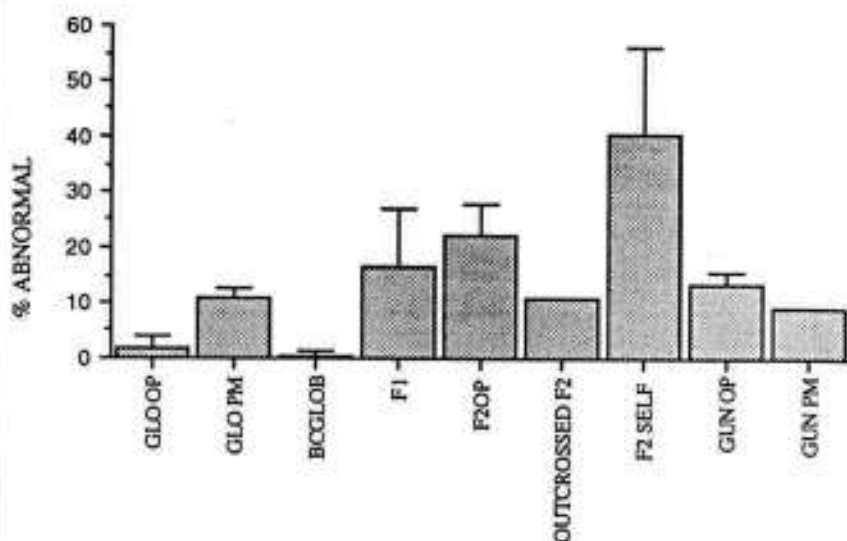


Fig. 5
The percentage of abnormal plants in families of *E. globulus* (GLOOP, GLOPM, *E. gunnii* (GUNOP, GUNPM) and their F₁, F₂ (F₂ SELF, OUTCROSSED F₂) and backcross to *E. globulus* (BCGLOB) hybrids. High levels of abnormalities in the selfed F₂ appear to be due to the effects of inbreeding rather than the hybridisation *per se*.

- 420 crosses for an advanced generation crossing program between *E. nitens* and *E. globulus* have been completed and seed will be harvested at the end of 1994.

Goals

- Establish trials of advanced generation hybrid populations of *E. nitens* and *E. globulus*.

(e) The response of pests to artificial hybrids

The response of fungal and insect pests to artificial F₁ and advanced generation eucalypt hybrids is currently being studied in a PhD project involving assessment of pest loads in field trials and laboratory feeding and inoculation studies.

Outcomes

- Higher insect pest abundance and diversity has been demonstrated on natural hybrids of eucalypts and other species and it is important to extend this work to artificial hybrids in plantations and to differentiate the susceptibility of F₁ and advanced generation hybrids.

Goals

- Examine the insect loads and communities on artificial hybrids in experimental field trials.



Ms Heidi Dungey (PhD student) and Dr Garth Nikles (Qld Dept of Primary Industry) inspect *E. globulus* and *E. nitens* hybrids for insect pest loads.

- Complete studies of the *Mycosphaerella* sp leaf spot fungus damage to *E. nitens* x *globulus* hybrids in field trials and undertake glasshouse inoculation trials.

Sub-program 2

Propagation strategies

Elite genetic material produced in breeding programs must be transferred into operational forestry as quickly as possible either by seed or by clonal forestry (vegetative propagation). Clonal forestry offers the most rapid means of capturing the genetic gains of the selected genotypes in full. The alternative is to stimulate early flowering to increase seed production. Early flowering would also reduce substantially the generation interval in breeding programs. For example, a seedling of *E. nitens* may take six years to flower while a grafted ramet from a reproductively competent ortet may take three to four years. Advances in tree breeding are such that selection of desirable material may occur significantly before flowering (e.g. by the use of molecular markers). Thus delayed flowering represents an increasingly important bottleneck in the breeding process. An advance of flowering of even two years would represent a cut in generation time of over 25 percent which would provide very significant economic and time savings. Two projects have been established in this sub-program to address these requirements.

Project 5

Project leader
Mr V Hartney

Vegetative propagation of selected genotypes

Introduction

Vegetative propagation of selected genotypes is a valuable tool in a tree improvement program as it enables the best selections to be grown in plantations sooner than strategies based on seedlings.

Vegetative propagation of selected clones for clonal plantations enables maximum genetic gain in each cycle of selection. It also enables elite individuals such as trees with high pulp-yield, hybrid-vigour, disease and insect resistance to be exploited in plantations or in breeding programs.

Genetic gains from vegetative propagation can also be exploited at the level of superior families. A collaborative project is proposed (between projects 1 and 5) to investigate the advantages and disadvantages of exploiting gains either at the level of selected families or clones. This project may also determine some genetic parameters in relation to vegetative propagation ability.

Various methods of vegetative propagation are being evaluated; micropropagation, micro-cuttings and somatic embryogenesis. In addition, a PhD student is investigating the physiology of adventitious rooting of *E. globulus*.



Tissue cultured *E. globulus* plantlet with developing root system.



Mrs Naomi Lawrence (PhD student) holding a vial containing tissue cultured *E. globulus*.

(a) Improved micropropagation procedures

The aim is to develop cheap and robust procedures of micropropagation for commercial vegetative propagation of temperate eucalypts.

Outcomes

- An improved micropropagation procedure (IMP) (initially developed by CSIRO as proprietary intellectual property) is being evaluated in tissue culture laboratories of industry partners to CRC.
- Shoot multiplication and root quality have been improved by modifications to media.

Goals

- Evaluate IMP in tissue culture laboratories of industry partners to identify and solve problems associated with commercial development of IMP.
- Improve rooting percentage and root quality of ramets produced by IMP.
- Incorporate IMP into conventional nursery procedures developed for cuttings to see if such techniques reduce costs compared to cuttings.

(b) Somatic embryogenesis

Somatic embryogenesis of temperate eucalypts may be a cheaper method of producing clones than alternative methods of vegetative propagation. This research aims to produce somatic embryos of temperate eucalypts and to compare somatic embryogenesis to other methods.

A post-doctoral scientist has been appointed and he will commence work in July 1994.

(c) Auxin metabolism and root initiation

The role of auxins (IAA and IBA) in adventitious root initiation of *E. globulus* is being studied using gas-chromatography and mass-spectrometry.

Easy and difficult-to-root clones are being selected for rooting ability from several families of *E. globulus*. These clones will provide material for comparative physiological studies.

Project 6

Project Leader
Prof J Reid



Dr Omar Hasan (Post Doctoral Fellow with the CRC) pricking out *E. globulus* seedlings.

Outcomes

- Studies of IBA metabolism have demonstrated that *E. globulus* can convert exogenous IBA to IAA.
- Some early stages of adventitious root initiation in *E. globulus* have been observed.

Goals

- Investigate auxin levels and their correlation to the stages of adventitious root formation.
- Undertake comparative physiological studies of easy and difficult-to-root clones of *E. globulus*.

Manipulation of breeding systems

a) Control of Flowering

The primary aim of this section of the project is to gain an understanding of the control of flowering in *Eucalyptus globulus* and *E. nitens*, particularly in relation to hormonal signalling and its role in promoting flowering. This knowledge will be used in the optimisation of chemical and environmental regimes that will be capable of inducing early flowering in seedling material and increased flowering and hence seed production in seedling or grafted seed orchards.

In addition, the hormone analysis techniques developed for this primary aim are being assessed for their potential usefulness in determining the roles of hormones in the control of the meristematic activity of the vascular cambium. If feasible, these techniques may allow us to gain an understanding of the control of fibre production and may further be useful in controlling the growth and structure of material in an intensively managed breeding program.

Outcomes

- Paclobutrazol application to seedling material has not been found to have any effect on the rate of capsule retention or the gross morphology of capsule development in *E. globulus* seedlings. This fact in combination with the increased flowering observed following paclobutrazol application has led to an overall increase in capsule production on treated material in comparison to the non-treated controls. There is no evidence for a reduction in pollen or seed viability or seed weight resulting from paclobutrazol treatment. The promotive effect of foliar applied paclobutrazol on bud production remained evident in the second reproductive season following application.

- Factors associated with reduced pot size have been observed to promote flowering in both seedling *E. globulus* and grafted *E. nitens* material, while warm overwintering temperatures have been shown to reduce flowering in similar material.
- The hormone analysis techniques developed for use with shoot tissue have been successfully used to identify and quantify gibberellins in the cambial tissue of *E. globulus* material. This represents the first such work in any hardwood species. Auxin (IAA) and abscisic acid (ABA) have also been identified and quantified in these tissues.
- Preliminary work has demonstrated the existence of a longitudinal gradient in active gibberellin levels in cambial tissues of the lower regions of the trunk. This may be associated with rapid changes in the morphology of differentiated fibre cells within this region. Despite contrary suggestions in the literature, we have found no evidence for a longitudinal gradient in IAA levels over the length of the trunk.
- Collaboration with the CRC for Hardwood Fibre and Paper Science resulted in visits to the University of Melbourne School of Forestry in Creswick, Victoria. Their newly developed image analysis system was used to measure fibres from normal and paclobutrazol treated trees. Recently perfected techniques for preparation of thin wood sections for light microscopy were employed to view cross sections of the same material.
- An Agricultural Science Honours student (Mark Jackson) has begun work on microbial breakdown of paclobutrazol in soil. This study will include an attempt to isolate soil micro-organisms capable of paclobutrazol catabolism, with the possibility of producing a bioremediation scheme for paclobutrazol treated soil.

Goals

- Attempt to elucidate a role for the plant hormones auxin, abscisic acid and the gibberellins in mediating the effects of cold or water stress on flowering.
- Establish the effectiveness of other plant growth inhibitors (CCC and prohexadione-Ca) in promoting precocious flowering in *E. globulus* and *E. nitens* seedlings, as possible replacements for paclobutrazol in cases where its persistence of activity is undesirable.
- Determine the effects of season, age and paclobutrazol application on IAA, ABA and gibberellin levels in the vascular cambium of *E. nitens* trees and collaborate with the CRC for Hardwood Fibre and Paper Science in quantifying xylem element attributes.

- Attempt to ascertain the effects of microbes on the breakdown of paclobutrazol. If early results are positive, attempts will be made to isolate active species/strains. These may constitute a means of eliminating paclobutrazol from soil when its residual activity is not desirable.

(b) Inbreeding

The consequences of inbreeding may influence many stages of tree breeding programs. Inbreeding depression and an inflation of variances usually arise from inbreeding, although these effects have not been documented in eucalypts for inbreeding levels less intense than selfing. These effects may also be modified by competition and mortality. Open pollination is a relatively cheap and common method used to obtain progeny in breeding programs. However, open pollinated families contain a mixture of inbred and outcrossed progeny. Therefore, breeding values and predicted rates of gain estimated from open pollinated families may be biased if the effects of inbreeding cannot be accounted for. On the other hand, these biases may be avoided if self infertility is heritable meaning open pollinated families free of inbred progeny could be obtained. In addition, selection against inbreds in open pollinated families may result in a change in the proportion of inbred and outcrossed progeny over time. An alternative to open pollination or controlled outcrossing is controlled inbreeding which may offer a more efficient and less expensive method for breeding value estimation and breeding population management. Finally, the introduction of new material into breeding programs may be influenced by the role of inbreeding in natural populations.

Outcomes

- A controlled pollination program has been completed to investigate (i) inbreeding effects at different levels of coancestry, (ii) the relationship between breeding value, open pollinated family and self performance, and (iii) the inheritance of self infertility. Seed will be collected in early 1995.
- Two stages of differential selection against inbred progeny have been identified. Relative to outcrossing, there is a poorer survival of selfs within 3 months of planting (the establishment phase) and when the plantation is older than 4 years (presumably after intense competition has developed).

Goals

- Quantify the effect of outcrossing, selfing and open pollination on mortality and later age traits, and describe the biases of genetic parameters due to competition and mortality in *Eucalyptus regnans*.

Soil and Stand Management Program

- Determine the influence of stand structure on outcrossing rate using isozyme markers.
- Establish two field trials to determine (i) the heritability of self infertility, (ii) the effect of different levels of coancestry on genetic parameters, and (iii) the relationship between breeding value, the performance of open pollinated and self families.
- Assess the effect of proximity dependent crossing in *Eucalyptus globulus* at 2 years of age.
- Describe the effect of selfing and open pollination on field growth for *Eucalyptus nitens*.

Program Manager
Dr P West

Introduction

This program examines forest growth and yield in relation to environmental factors, particularly temperature, the availability of water and nutrients and soil physical properties.

Through understanding these processes, it aims to develop a complete description of the plantation ecosystem and develop silvicultural tools for the forest grower to maximise wood yield at minimum cost and with minimum environmental impact.

Major achievements

- Determination of seasonal variation in leaf photosynthetic response to air temperature and its effect on model predictions of wood yield.
- Showing that water relations characteristics of leaves of *E. globulus* indicate that it is more tolerant of moderate levels of water stress than *E. nitens*.
- Showing that the "canonical S-system" modelling approach may have value as part of plantation ecosystem models where forest processes are poorly understood.
- Showing that growth response to thinning may be substantially reduced if a vigorous weed understorey develops in a thinned stand.

Project 1

Project Leader
Dr C Beadle

Plant production and water use

Introduction

This project investigates the photosynthetic and water-use characteristics of individual leaves, single trees and canopies of



Dr Mike Battaglia (Post Doctoral Fellow with the CRC) measuring the photosynthesis of frost affected trees at Surrey Hills. The tree in the foreground is enclosed in plastic and insulative batts to prevent frost.



An *E. nitens* seedling after a -7.5° frost in a plantation at Surrey Hills.

Eucalyptus globulus and *E. nitens*. These variables are being studied in relation to nutrient availability, leaf area index and canopy development, air temperature, available water, pruning strategies and competition in stands managed for pulpwood, sawn timber and veneer.

(a) Chilling injury and acclimation to temperature

Models being developed by Project 4a to estimate canopy photosynthesis have shown that the degree of leaf acclimation to the temperature environment can effect assimilation rate substantially.

Effects of air temperature on photosynthesis of *E. globulus* and *E. nitens* by mature leaves were determined monthly in an irrigated plantation. Parallel studies in temperature-controlled glasshouses examined temperature acclimation by four *E. globulus* clones with origins from climatically dissimilar locations within Tasmania.

The effect of night-time frost on the photosynthetic performance of *E. nitens* on the subsequent day was studied both in the glasshouse, using frost temperatures of -1 to -2°C on hardened and unhardened seedlings, and in the field at Surrey Hills where 9-month-old trees in a plantation at Lockwood Creek received frosts of -5 to -8°C .

Outcomes

- The optimum temperature for photosynthesis varied by approximately 5° during the year for both *E. globulus* and *E. nitens* and this was related to seasonal changes in mean daily temperatures.
- The temperature optima for *E. nitens* and *E. globulus* were similar at each measurement time but the photosynthetic rate of *E. nitens* was less sensitive to temperatures below and above the optimum.
- Seedlings in the glasshouse acclimated at high temperature ($25/30^{\circ}\text{C}$) had significantly lower photosynthetic rates when measured at low temperature (10 and 20°C), while those acclimated at low temperature ($10/15^{\circ}\text{C}$) had significantly lower rates when measured at 30°C .
- There was no significant effect of genotype on photosynthetic responses to temperature or of acclimation temperature on quantum efficiency.
- Night-time frosts of -5 to -7.5°C which occurred in a 9-month-old plantation of *E. nitens* at Surrey Hills, Northern Tasmania caused the maximum rate of photosynthesis to decrease by 15-20 % on the following day. There was no

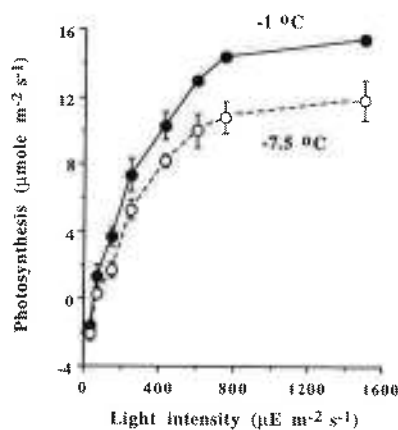


Fig. 6 Photosynthetic light response curves for *E. nitens* trees artificially protected from frost (receiving -1°C) and those exposed to frost (receiving -7.5°C) during the preceding night, conducted in a 9 month old plantation at Lockwood Creek, Surrey Hills.

visual evidence of frost injury to the leaves. Assessment of frost hardening showed no tissue damage at -5°C but significant tissue disruption (assessed by electrolyte leakage) at -8°C . Where three successive -5°C frosts occurred in the field, photosynthesis declined by a further 5-10 % each day.

- Complete recovery of photosynthetic performance occurred when plants that were exposed to night temperatures -5°C were provided with one warm night (above 0°C). However, after a -7.5°C frost, maximum photosynthesis was still depressed by 5-10 % three days later, although the intervening two nights were warm (above 0°C). Photosynthetic light response curves suggest both quantum efficiency and the maximum rate of photosynthesis are effected by frosts of -5°C and below (Figure 6).
- In a glasshouse study hardened and unhardened seedlings of *E. nitens* and *E. globulus* were exposed to frost temperatures of -1 to -3°C , and the extent of reduction and the rate of recovery of photosynthesis was related to hardening, species and frost temperature.

Goals

- Complete an annual study of the temperature acclimation of *E. globulus* and *E. nitens* and define the preferred temperature and slope of the acclimation curve for the two species.
- Incorporate results into the model of canopy photosynthesis being developed in Project 4.
- Conduct an experiment to determine the importance of photoinhibition in the effects described above as chilling injury. Investigate use of chlorophyll fluorescence techniques to assess photoinhibition.
- Study the interactive effects of light intensity and mild frost (0 to -5°C) on photosynthesis.

(b) Growth, water use and water relations of *E. globulus* and *E. nitens*

The assimilation of carbon per unit leaf area is reduced under water-limited conditions. This instantaneous effect is compounded by a reduction in the development of leaf area during the growing season. This study evaluates species differences in growth and physiological responses to repeated stress cycles and compares these to the responses observed in irrigated controls. The irrigated plots are also used to determine how much water is required to maximise growth and optimise water use and to develop a model to predict transpiration.

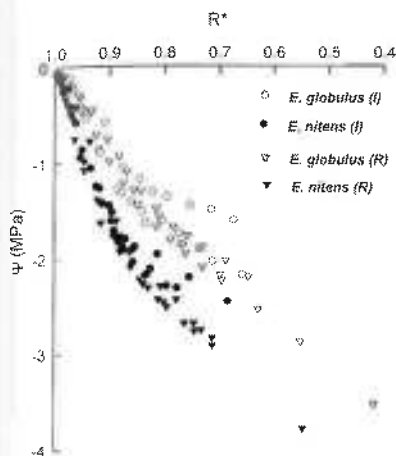


Fig. 7 Water potential (Ψ) of the leaves as a function of their relative water content (R^*). The shallower slope for *E. globulus* indicates that this species can maintain turgor and therefore growth over a wider range of water contents than *E. nitens*.

Outcomes

- Sapwood area is a reasonably stable indicator of leaf area of individual trees and leaf area/sapwood area relationships can be used to distinguish between species and treatment effects on leaf area development.
- The leaf area index at canopy closure in the irrigated treatments of both *E. globulus* and *E. nitens* was 8 at age 3.5 years. This is very high for a broad-leaved species.
- For the period September 1992 to February 1994 the difference in yield between the rainfed and irrigated *E. globulus* was 24.3m^3 and this required an additional 675mm water. The respective figures for *E. nitens* were 25.1m^3 and 725mm.
- *E. globulus* has more elastic cells than *E. nitens*. This enables the former to maintain higher turgor at lower tissue water content and higher growth rates than *E. nitens* under conditions of moderate water stress (Figure 7).

Goals

- Analyse the effect of repeated cycles of drought on the development of leaf area index to crown closure.
- Develop a model of stomatal conductance for use in conjunction with a Penman-Monteith estimate of transpiration.
- Evaluate the relative importance of boundary and stomatal conductance in controlling transpiration.

(c) Physiological responses to green pruning

Green pruning removes a proportion of the photosynthetic and nutrient capacity of the canopy. The aim of this study is to investigate physiological responses to a range of pruning treatments and to ascertain whether there are changes in growth patterns, photosynthetic capacity and allocation of nutrients, imposed by pruning.

An experiment has been established on two high quality sites planted to *E. nitens* and aged 4 years. The randomised block design has 3 pruning treatments (0, 50 and 70% initial crown removal based on canopy depth). Pruning was carried out at canopy closure.

Outcomes

- Removal of 70% of the green crown significantly reduced height and volume increment two months after pruning compared to an unpruned control. (Figure 8)



Ms Libby Pinkard (PhD student) measuring the photosynthetic rate of pruned and unpruned *E. nitens* trees.

Project 2

Project Leader
Mr R Cromer

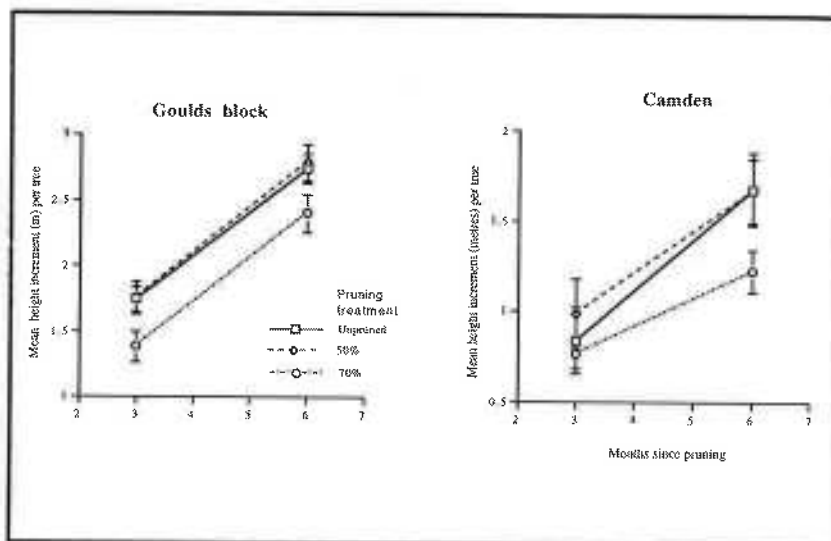


Fig. 8 Changes in height increment 6 months after green pruning at two high quality sites. Note that there was no significant decrease in height with 50% crown removal (based on canopy height).

- Measurements of photosynthetic capacity have shown that levels are significantly higher in some zones of the crown in the pruned treatments compared to equivalent zones in control trees, ten weeks after pruning.

Goals

- Quantify the changes in leaf area development and photosynthetic capacity of the crown in response to pruning.
- Determine the patterns of allocation of N and P in the crown and the significance of nutrient retranslocation to growth.
- Monitor changes in stem shape in response to pruning.

Dynamics of carbon and nutrients

Introduction

The aims of this project are to investigate the accumulation, allocation and cycling of carbon and nutrients in plantations of *Eucalyptus nitens* and *E. globulus*, particularly in response to nutrient availability. Specific nutrient deficiency or toxicity problems that become evident in plantations will also be examined.

a) Responses to N and P fertiliser

Three fertiliser experiments were established with collaborators during 1992 (see Annual Report 1992-93) in which nitrogen (N) and phosphorus (P) were applied in fixed ratios. Experiments

with *E. nitens* were established in southern Tasmania (yellow podsollic soils, ANM at Westfield) and in north-west Tasmania (basalt soils, North Forests at Middlesex). An experiment with *E. globulus* was established in north-east Tasmania (duplex soils, Boral Forest Resources at Nabowla).

Trees in all three experiments were measured for height and diameter in August/September 1993 at 10 months-of-age. Five trees were felled from each of three treatments in each trial (15 trees per trial) and separated into above-ground components for determination of dry matter and nutrient content. Biomass and nutrient content of roots was obtained for four of the trees at Westfield.

Automatic weather stations were installed at Westfield on June 1 and Nunamara on September 15, 1993. North Forests provides data from a similar station near Middlesex.

Outcomes

- Growth of *E. globulus* increased significantly ($p < 0.05$) in response to application of a combined N + P fertiliser on the duplex soils at Nabowla but at other sites *E. nitens* showed no response to the same fertiliser additions (Figure 9).

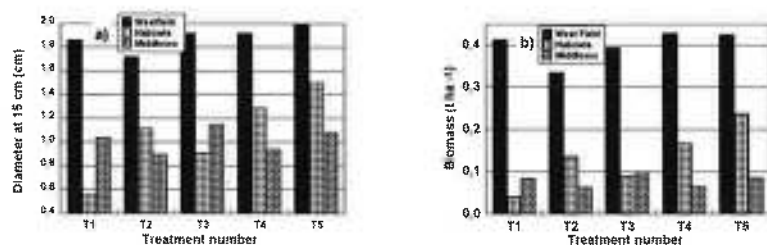


Fig. 9 Growth of 10 month old trees in a) diameter at 15 cm and b) above-ground biomass at three sites ; Westfield (*E. nitens*), Nabowla (*E. globulus*) and Middlesex (*E. nitens*), in response to five fertiliser treatments with a fixed ratio of N to P (1:1 for Middlesex and 2:1 for the other sites), where applied rates of N were; T1= 0, T2 = 75, T3 = 150, T4 = 300 and T5 = 600 Kg ha⁻¹ elemental N.

- Tree growth was most rapid at the Westfield site (430 m elevation) and slowest at the Middlesex site (600 m elevation; Fig. 9b) and may be related to 2°C lower mean monthly air temperatures of about 2°C recorded at Middlesex.
- Fertiliser treatment had no significant effect on nutrient concentrations in the leaves. However, concentrations of N in stemwood differed among sites ($P < 0.001$) with Middlesex > Westfield > Nabowla (Fig. 10a), and concentrations of P in stemwood increased significantly ($P < 0.05$) with increasing amount of NP fertiliser applied (Figure 10b). Therefore,

stemwood may act as a storage organ for nutrients and provide a useful indicator for nutrient availability at this age.

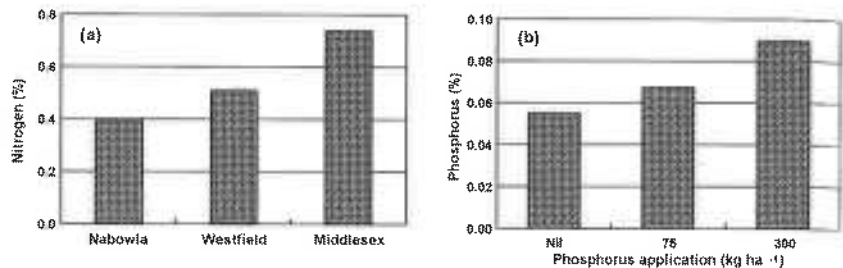


Fig. 10 Concentrations of (a) N and (b) P in the stem wood of trees in fertiliser trails at Westfield, Nabowla and Middlesex (see caption to Figure 9 for treatment details).

- For 10 month old *E. nitens* growing at Westfield, fine and coarse roots accounted for about 80% of total biomass in trees that received fertiliser and about 86% in those without fertiliser (Figure 11). These estimates are substantially higher than other reports in the literature and suggest that allocation patterns may shift from below- to above-ground as trees age.

Goals

- Undertake annual measurement of fertiliser trials and harvest trees for estimates of above- and below-ground biomass.
- Process samples for determination of biomass and nutrient content and determine allometric relationships between tree dimensions and biomass.
- Make final application of fertiliser to trials at 26 months (November 1994).
- Analyse data and report results, initially for IUFRO/CRC conference in Hobart (Feb 1995).

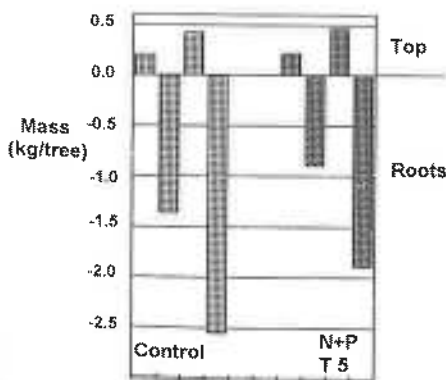


Fig. 11 The above- and below-ground biomass of four 10 month old trees, estimated by extraction of root material from soil cores and harvesting of above ground material.

b) Interactions between N and P

Two complete factorial fertiliser experiments with three rates of N and five rates of P were planted with *E. nitens* in 1993. One trial was planted in collaboration with ANM in September at Tim Shea (adjacent to the Westfield trial) on a gradational yellow podsolic soil. A second trial was planted in October in collaboration with Forest Resources at Nunamara (east of Launceston) on a basalt/dolerite soil.

Outcomes

- The experiments have been planted.

Goals

- Undertake annual measurement of trials (July 1994).
- Apply first year fertiliser treatments (November 1994).
- Maintain trials for future measurement and analysis through to 1997.

c) Copper deficiency in *E. nitens*

Severe malformations occurred in stems and branches of *E. nitens* where fertilisers were applied to trees growing on a previously fertile pasture site in southern Tasmania (Goulds Block; see Annual Report 1992-93). Chemical analysis of foliage indicated the problem was caused by a deficiency of copper and some recovery occurred following application of a copper spray to foliage of affected trees.

An area containing malformed trees of *E. nitens*, about 18 months-of-age at Rubicon, north of Deloraine was subsequently reported by North Forest Products. Although trees at Rubicon exhibited more die-back of branch tips than the copper-deficient trees at Goulds Block, symptoms otherwise appeared similar. Soils in the area affected are podzols with lenses (40-60 cm) of aeolean sand overlying quaternary alluvium that suffer seasonal waterlogging. Foliage samples were taken from trees at Rubicon that were affected to differing degrees and trees were scored for severity of deformity.

Outcomes

- Foliar samples were analysed for nine elements including Cu, B, Zn and Mn but Cu was the only element that was significantly ($p < 0.05$) related to the degree of deformity as shown in the table below:

Deformity index*	1	2	3	4	5	6
Cu foliage (ppm)	3.42	2.73	2.07	2.00	1.53	1.33

*Deformity index : 1=nil, 6=severe

- A paper on copper deficiency in eucalypt plantations was presented by Charles Turnbull to the Australian Forest Growers Conference in Launceston in May 1994.

Goals

- Publish results of observations at Rubicon as a brief note in Australian Forestry.
- Maintain a watching brief on reports of copper deficiency in eucalypts.

Project 3**Project Leader
Dr P Smethurst****Nutrient supply and acquisition****Introduction**

The aim of this project is to understand nutrient supply and acquisition, particularly for N and P and to improve the management of fertilisers and the productivity of the plantations. Already, studies of soil solutions, root growth and the nutrient uptake characteristics of roots have provided an understanding of the variation in growth responses to fertilisation seen at three contrasting sites.

(a) Soil N and P

Measurements during the past year have improved our expectations that we will be able to make meaningful comparisons between contrasting sites in relation to nutrient limitations to tree growth. This has been achieved by examining N and P in soil solution, and integrating these measurements with a knowledge of their replenishment from soil solids, i.e. mineralisation and solid-liquid equilibria.

The soil solution measurements (Table 1) were made on samples collected in autumn 1993. Uptake rates of nitrate and ammonia by *E. nitens* roots were studied in solutions of different concentrations and at different temperatures (Fig 12). Comparisons are being made between several methods of determining P deficiency in *E. nitens*, a root assay (based on the uptake of labelled P by excised roots), soil solution P and tissue P concentrations.

Outcomes

- At Westfield and Middlesex, high concentrations of ammonium or nitrate were present in the unfertilised treatment (Table 1), which is consistent with expectations that N availability is enhanced by disturbances associated with clearfelling and establishment.
- Although P concentrations were low in controls at Westfield (0.48 μM ; Table 1), P supply did not limit growth relative to the fertilised treatments. However, responses to P fertilisers are expected to develop because critical values to maintain growth are much higher than this for other species.
- There was a strong response to the combined application of N+P at Nabowla (Table 1) but this was probably principally a response to P. The concentration of P in soil solution was higher in the unfertilised treatment at Nabowla than at Westfield, however, the sandstone soil at Nabowla is expected to have had little capacity to maintain these concentrations at root surfaces because of the low soil P buffer power which limits the availability of P

Table 1. Concentrations of N and P in soil solution in autumn 1993 (ca. 160 days after planting) and stem volume index the following winter.

Treatment ¹	Ammonium (mM)	Nitrate (mM)	Phosphate (μ M)	Stem Volume Index (D ² H, cm ³)
<i>Westfield Site</i>				
Control	0.56	8.37	0.48	469
Fertilized	3.65	6.62	4.57	467
Significance	***	NS	*	NS
<i>Middlesex Site</i>				
Control	0.25	4.44	0.03	74
Fertilized	5.29	15.83	0.64	54
Significance	***	***	**	NS
<i>Nabowla Site</i>				
Control	0.26	0.55	0.59	15
Fertilized	30.95	1.85	5.34	219
Significance	***	NS	*	*

¹Zero and 600kg N ha⁻¹ were applied to the control and fertilised treatment, respectively. Ratios of N:P were 2:1 at Westfield and Nabowla and 1:1 at Middlesex. Abbreviations for significance are: NS for not significant (P = 0.05), *for P < .05, ** for P < 0.01, *** P < 0.001.

- These results and others from additional experiments by North Forests and APM indicate that blanket 'at-planting' fertiliser prescriptions may be wasteful, and that further empirical and explanatory research is needed to enable site-specific fertiliser prescriptions during this early phase of tree growth.
- *E. nitens* roots were able to take up both ammonium and nitrate. At high concentrations (200-1000 μ M), ammonium uptake proceeded at about double the rate of nitrate uptake and there was no effect of one form on the other. At low concentrations (<100 μ M), nitrate uptake does appear to be inhibited by ammonium (Figure 12). Hence, it is possible that where low concentrations of nitrate existed in the field, ammonium was inhibiting nitrate uptake from the soil solution.
- The rate of both ammonium and nitrate uptake was strongly temperature dependent (Fig. 12), indicating that estimates of uptake rates developed at higher temperatures will need to be reduced for field applications.



Mr Trevor Garnett (PhD student) holding an *E. nitens* seedling used in the study of nitrate and ammonia uptake in roots.

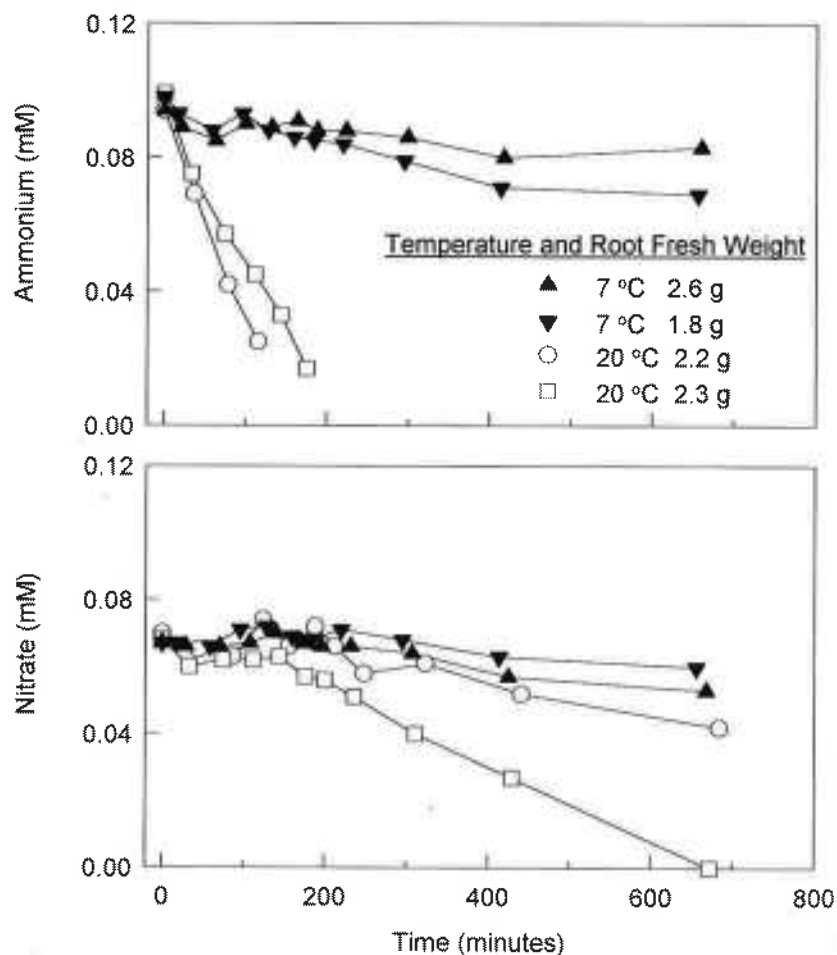


Fig. 12 Depletion of ammonium and nitrate by root systems of *E. nitens* in aqueous nutrient culture at 7°C and 20°C.

Goals

- During the next year we will continue to monitor concentrations of N and P in soil solution at these three sites and two others (see Project 2). Increased emphasis is being given to examining the soil and plant responses to fertilising 1-3 years after planting and more clearly separating the N and P effects.
- Measure loss of soil and nitrogen from cultivated forest soils in simulated erosion events for a range of slopes (PhD research by Paulina Teixeira).
- Further examine the temperature dependence of the inhibition of nitrate uptake by ammonium.
- Determine the interrelationships between N uptake rates, internal plant N concentrations and relative growth rate.

- Commence field studies of N uptake rates using labelled-N.

(b) Root growth in relation to tree nutrition

The spatial variation of root growth was studied on an 11-month-old *E. nitens* plantation at Westfield where two fertiliser treatments had been applied; control (no added fertilisers) and fertilised (addition of N and P at 600 and 300kg ha⁻¹ respectively). Trees were planted on deep-ripped and mounded lines approximately 2m apart within-rows (WR) and 3.75m between-rows (BR). Root samples were taken both within and between rows at fixed distances (0.15, 0.5 and 1.0m) from the base of each tree. Roots were sorted into fine (<1mm diameter) and coarse (>1mm in diameter; Table 2) fractions.

Table 2. Root distribution of 11-month-old *E. nitens* at the Westfield site. Data within a column followed by the same letter(s) are not significant ($P \leq 0.05$).

Sampling site in relation to tree	Root density (cm cm ⁻³)	
	All roots	Fine roots
Within ± 0.15 m	0.150 <i>a</i>	0.137 <i>a</i>
At 0.5 m WR	0.120 <i>a</i>	0.111 <i>a</i>
At 0.5 m BR	0.077 <i>b</i>	0.068 <i>b</i>
At 1.0 m WR	0.050 <i>c</i>	0.045 <i>b</i>
At 1.0 m BR	0.026 <i>d</i>	0.025 <i>c</i>

Outcomes

- Root distribution of *E. nitens* did not differ between fertilised and unfertilised treatments.
- Mean root-length density within 0.15m of the base of the tree was 0.15cm cm⁻³. This declined with depth and radial distance from the tree. More than 50 per cent of root length was less than 0.3mm in diameter.
- Root growth was largely confined to the upper 30cm of soil and roots grew preferentially within the cultivated zone (Table 2). This cultivated zone did not extend beyond 0.5m from trees between the rows.

Goals

- Continue measurements at the Westfield site during the coming year to determine the annual increment in root growth.

- Examine the long-term effects of cultivation on root growth and soil strength.
- Measure the fine root distribution of 5-year-old *E. nitens* to gain an understanding of root distribution in older plantations.
- Determine the efficiency of deep-ripping operations for modifying soil strength and early root growth of *E. nitens* in collaboration with Mr Fang Dong Li (an FAO supported visitor to the CRC).

Project 4

**Project Leader
Dr P Sands**



Dr Peter Sands

Modelling plantation systems

Introduction

This project aims to integrate the work of other projects within the program to provide an overall description of the plantation ecosystem. Through the development of mathematical models of plantation growth, the project will produce management tools for industry to predict forest wood yields under a variety of management regimes and environmental circumstances.

Work this year concentrated on modelling canopy photosynthetic production, applying a new modelling approach useful where the processes involved in a system are poorly understood, determining the growth response to thinning and the biomechanics of tree stem shape.

a) Modelling canopy photosynthesis

Over periods of time from hours to a day, canopy production varies widely in response to environmental variables such as temperature, irradiance and plant water status. Because of this, models of canopy production are complex and require extensive input data. However, empirical observations have shown that annual canopy production is a linear function of radiation intercepted by the canopy. The slope of this relationship, called canopy light utilisation efficiency, is characteristic of a particular species and is modified by factors such as long-term nutrient or water status.

This observation prompted the development of a simple model for estimating daily canopy photosynthesis based directly on the single-leaf, photosynthetic light-response function. This function is characterised by a small number of parameters which change in a definite way in response to changes in environmental or plant variables such as air temperature or leaf water or nutrient status. These parameters are relatively easy to determine experimentally. Thus, the model of daily canopy photosynthesis developed here allows production to be calculated from a small set of experimentally accessible parameters and standard daily meteorological data.

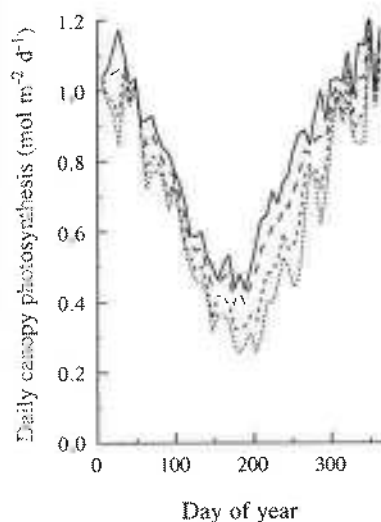


Fig. 13 Predicted seasonal variation of daily photosynthesis by a model canopy for various degrees of seasonal photosynthetic temperature acclimation: complete acclimation (—), partial (---), weak (.....), and none (-.-.-). The area under each line represents annual production and the results show that ignoring acclimation can lead to a 20% under-estimate of production.



Dr Eberhard Voit (Visiting Scientist with the CRC)

Outcomes

- The daily canopy photosynthesis model developed last year was extended to include seasonal variation and the change in single-leaf photosynthetic rate in response to seasonal variations in temperature, see Project 1. The model may then be used to predict annual canopy photosynthesis.
- The annual model was used to explore the sensitivity of the annual light utilisation efficiency (ϵ) to parameters of the single-leaf light response curve, leaf nutritional status and climate. The effects of photosynthetic temperature acclimation were also examined. Acclimation is the seasonal change in the photosynthetic process that occurs so that there is minimal loss of photosynthetic potential as seasonal temperatures change. It was found that ϵ is quite sensitive to effects of temperature and leaf nutrition on light-saturated rate of photosynthesis, and that the extent to which photosynthesis acclimates to seasonal temperature is an important determinant of annual canopy photosynthesis (Figure 13). It was also found that ϵ is sensitive to mean annual radiation and temperature but relatively insensitive to annual ranges.

Goals

- Incorporate in the model the effects on single-leaf photosynthetic rate of soil and plant water status and couple the model to a simple soil-water balance model.
- Apply the model in conjunction with a GIS data base for radiation, temperature and rainfall in Tasmania to attempt to predict potential production at a wide range of sites. This will complement other work in the program attempting to validate Laffan's system to assess site suitability for eucalypt plantations.

b) Canonical S-system model of forest growth

In conjunction with Dr Eberhard Voit, from the Medical University of South Carolina who was a CRC Visiting Scientist for the period September 1993 to May 1994, an alternative approach to modelling complex systems was explored in a forestry context. Canonical S-system models are powerful tools for analysis of systems of interacting processes and are ideally suited to situations where the processes involved in the system are poorly understood or even unknown. Canonical modelling requires no quantitative assumptions about mechanistic processes. It uses only qualitative knowledge of the processes being modelled, that is, knowledge of which variables influence the increase or decrease of other variables. It then uses a standardised mathematical approximation with a rigorous basis (power-law or allometric functions) to represent these influences. Canonical S-system modelling has been applied to a wide range

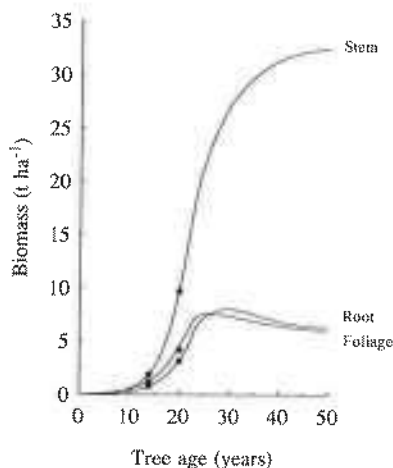


Fig. 14 Development of leaf, root and stem biomass of an unfertilised *Pinus sylvestris* plantation predicted using the canonical model of forest growth (—) and observed values (*) at ages 14 and 20 taken from the literature. Parameters in the model were estimated using only the few observed data. However, the extrapolated results to age 50 years are consistent with general observations on similar *Pinus sylvestris* stands. This suggests the model is a powerful predictor of forest growth despite the very small data set used to build it.

of phenomena including biochemistry and molecular genetics, epidemiology, risk analysis, and population dynamics including self-thinning in forests.

Outcomes

- A canonical model of forest growth was built with compartments for leaf, stem and root biomass and for internal nitrogen and which had soil nitrogen as an external, driving variable. Parameters were estimated using published data from three measurements of annual carbon budgets and fluxes for Scots Pine. The model correctly predicted long term growth patterns of foliage, stem and roots (Figure 14). It also predicted in a realistic way various relationships between biomass compartments and growth rates, relationships which reflect the functional balance between compartments, biomass allocation patterns and the dependence of these relationships on nitrogen status. These relationships are usually built into process models as specific assumptions; in this case they arose as responses of the model.

Goals

- Include nutrient recycling in present model.
- Examine possibility of using the canonical modelling approach as an adjunct to stand based yield prediction and in parts of plantation ecosystem models where processes are poorly understood.

c) Mechanism of growth response to thinning

Thinning experiments were established in 1988 in 8- and 12-year old, high quality, *E. regnans* regrowth forest at one site near Toolangi in Victoria and another near Buckland in southern Tasmania. Thinning at each site was very heavy, with about 75% of the basal area of each stand removed. Over the four years following thinning, a vigorous and dense understorey of cutting grass developed at Buckland whilst little understorey developed at Toolangi. Growth of trees was measured for four years following thinning.

Outcomes

- There was a substantial growth response to the thinning by the trees at both sites. Diameter growth rates of trees in the thinned stands averaged as much as 1 cm/yr faster than those in the adjacent unthinned stand.
- At Buckland, above-ground biomass production was much lower in the thinned than the unthinned stand. At Toolangi, there was little difference between the thinned and unthinned stands (Table 3). It may seem surprising that stand production

at Toolangi was unaffected by thinning when over half the leaf mass of the stand, hence more than half its potential for photosynthesis, was removed during the thinning.

Table 3. Above-ground dry biomass growth rate (tonne/ ha/yr) over each of two growth periods in thinned and unthinned stands at Buckland and Toolangi

Growth period	<u>Buckland</u>		<u>Toolangi</u>	
	1988-90	1990-92	1988-90	1990-92
Unthinned	5.1	8.7	7.6	14.4
Thinned	1.6	4.8	7.9	15.6

- Use of a pre-existing model of forest growth suggested that loss of photosynthetic potential by reducing the canopy mass by thinning may be just balanced by the extra water available at the site because of lower water use by the reduced canopy. This would explain how production at Toolangi was unaffected by thinning. At Buckland, however, the vigorous understorey competed with the trees for water so that production there was lower in the thinned than the unthinned stand.
- The results suggest that unless understorey development following thinning is prevented, the growth response to thinning and the return on the investment in thinning may be much reduced.

d) Biomechanics of tree stem shape

Work in this sub-project aims to develop a model to predict stem shape in large forest trees to assist in predicting sawlog yields from forests.

A glasshouse experiment was carried out to see if stem shape of young trees could be altered by applying a bending stress. Two month old, potted *E. regnans* seedlings were subjected to continuous, static bending for eight weeks, after which the treatment was stopped and trees were allowed to grow freely for another 12 weeks. Their growth was compared with trees which were unbent.

In other work, development continued of a system to measure directly and continuously the bending of tall forest trees in the field. This will allow estimation of the bending stresses to which stems are subjected under natural conditions. The system involves a video camera placed at the base of a tree which views targets positioned at various heights along the tree stem. The

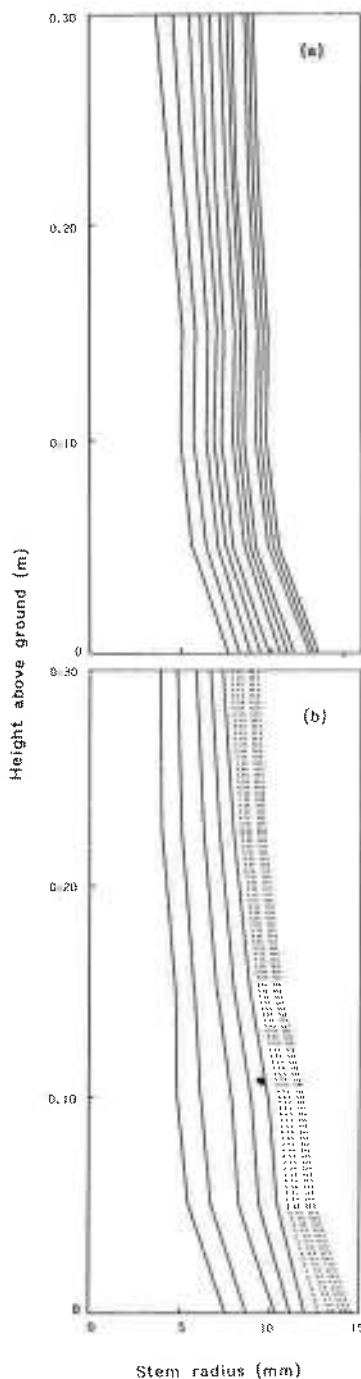


Fig. 15 Average stem profiles, from ground to 30 cm height, at two weekly intervals of *E. regnans* seedlings which were (a) unbent or (b) bent. The dashed lines show how the profiles of the bent trees developed after the bending treatment ceased.

movement of the targets and hence the stem can be measured directly, frame-by-frame, from the video tape.

Outcomes

- Potted seedlings which were bent increased their diameter growth rapidly, ceased height growth and developed a more sharply tapered stem than unbent trees. When bending ceased, the trees slowed their diameter growth, recommenced height growth and reduced their stem taper (Figure 15). The results confirm that bending stress has a substantial effect on tree size and stem shape and that these effects can be observed with seedlings.
- The average diameter safety factor (the ratio of the diameter of the stem to the minimum diameter it must have to allow the tree to stand upright) of bent seedlings was 4.2 and of unbent seedlings was 3.3. This suggests that the increased diameter growth rate of bent trees rendered them at less risk to toppling.
- Static bending tests of a 20m tall tree showed that the video measurement system being developed (see photo) could estimate the horizontal movement of a tree stem to an accuracy of better than 3mm. This accuracy is better than required in practice to allow estimation of the bending stresses to which tree stems are subjected in natural circumstances.

Goals

- Apply the video measurement system in the field to determine bending stresses in tree stems over an extended period.



Photo. The view from the ground by a video camera of targets positioned along a tree stem, ready to measure stem movement in the wind.

Resource Protection Program

Program Manager
Dr J Madden

Introduction

Projects within the program endeavour to more fully understand the biology, behaviour and ecology of major insect and vertebrate pests of plantation eucalypts and develop appropriate strategies for their control. Research is conducted within the parameters of integrated pest management and involves biological control, cultural practices, pesticide evaluation, host tree selection behaviour and the genetics of host tree tolerance/resistance to pest attack.

The program was strengthened during 1993/94 by the two-month stay of Dr Myron Zalucki of the CRC for Tropical Pest Management as Visiting Scientist and the appointment of post graduate students Alastair Hunt and Bradley Howlett.

All projects have proceeded satisfactorily, although experiments in the southern forests were limited by low insect populations.

Major achievements

- Dr Zalucki provided theoretical and research training to the program in insect-tree interactions and insect dispersal behaviour.
- Intensive monitoring of *Chrysophtharta bimaculata* and natural enemy populations throughout the Florentine Valley has provided an extensive set of data relating to insect dynamics, distribution and oviposition patterns.
- It has been demonstrated that psyllid infestation of native plants enhances reproductive performance and larval survival of *Cleobora mellyi*, the most important predator attacking *C. bimaculata*.
- The acceptability of a range of *Eucalyptus* spp to the coreids *Amorbus* and *Gelonus* was confirmed in a series of no choice tests.
- A colony of pademelons has been established within the University animal compound to evaluate browsing preferences for different eucalypt species and families within species.



Chrysophtharta bimaculata

Project 1

**Project Leader
Dr J Madden**



Members of the Resource Protection Program counting egg batches at the Florentine Valley.

Leaf and tree factors affecting eucalypt defoliation

Introduction

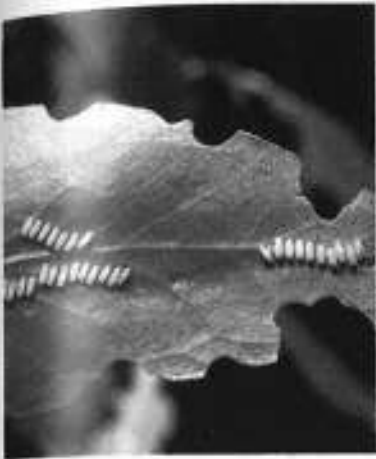
The project aims to identify genetic and environmental factors that influence (a) host tree selection, feeding and oviposition behaviour of adult *Chrysophtharta bimaculata*, and (b) survival and growth rates of *C. bimaculata* larvae. A complete understanding of these factors is essential to assess whether tree breeding for resistance and cultural practices are viable options in the control of this pest defoliator.

(a) Host selection, feeding and oviposition behaviour

The aim of this study is to identify those factors that determine the susceptibility of individual trees and intraspecific families of trees to insect attack. Factors considered include seasonal growth patterns, leaf chemistry and volatile extracts, leaf physical properties and the reflectance of the canopies of potential host tree species. In this regard the growth and defoliation status of trees in nine families of *E. regnans*, which represent extremes of tolerance and susceptibility to insect attack, have been studied over four years and the results related to leaf oil yields of the foliage.

Outcomes

- Oil yields differed significantly ($p < 0.01$) between families but not replicates, while growth (DBH) differed significantly between families ($P < 0.05$) and replicates ($p < 0.01$). Oil yields were significantly ($p < 0.01$) positively correlated with tree growth (DBH) at the individual and family levels. Family means for oil yields were negatively associated with defoliation but the correlation was not significant. However, mean growth for families was negatively and significantly correlated ($p < 0.05$) with defoliation.
- Initial defoliation extends the range in tree growth rates because slower growing trees, which sustain greater attack, are defoliated during spring. In contrast, faster growing trees experienced most defoliation in autumn, at a time when diameter increment is least affected.
- In a single growing season leaf oil yield is positively correlated with growth for all species but between seasons different patterns occur for the two eucalypt subgenera *Monocalyptus* and *Symphyomyrtus*. In general oil yields increase with tree age for *Monocalyptus* species but decrease for *Symphyomyrtus* species.
- A six-point quantitative system has been developed to score individual host trees using (1) leaf development, (2) colour,



Eggs of *C. bimaculata* on an *E. regnans* leaf.

(3) shape and texture, (4) general tree shape, (5) proportion of new leaves in the canopy and (6) site characteristics.

- Beetle catches on traps at three different heights (1.5, 3.0 and 6.0m) had similar seasonal trends but catches at above canopy height were lower than other locations. Beetle catches were highest during the period of beetle oviposition.

Goals

- Refinement of tree scoring system.
- Monitor incidence of attacks in plots of *E. regnans*-*E. delegatensis* regeneration and relate these to the six-point tree scores for each species.
- Initiate laboratory bioassay to assess the behavioural response of adult *C. bimaculata* to eucalypt foliage, foliage extracts and key monoterpenes present in eucalypt foliage.

(b) Survival and growth rates of *C. bimaculata* larvae

The survival and development of the eggs (Figure 16) and larvae

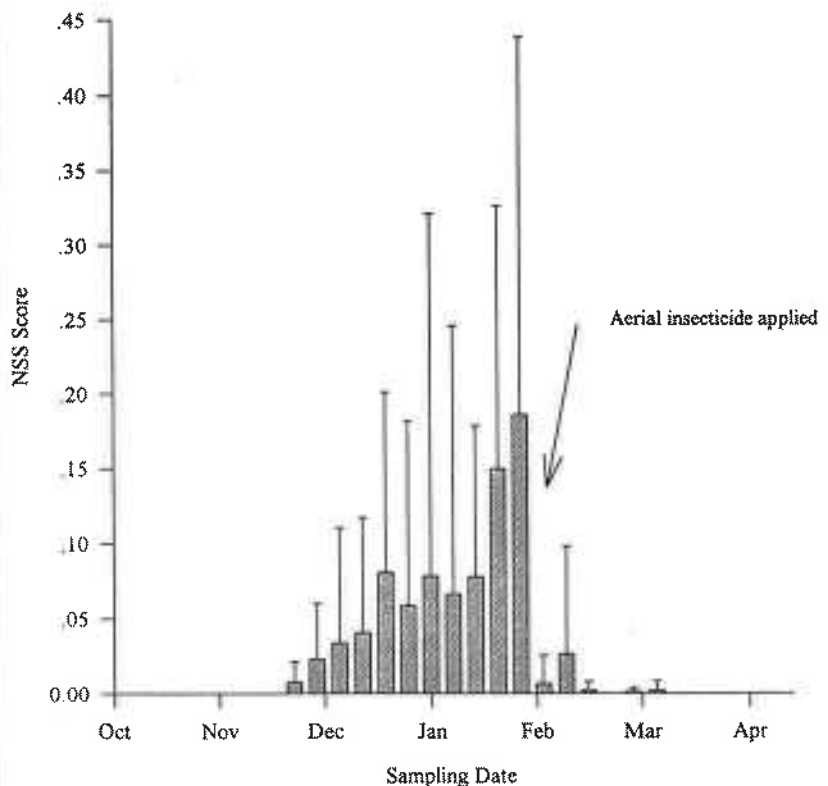


Fig. 16 The mean number of egg batches counted per shoot searched (NSS) for the Westfield Block, Florentine Valley, 1993/94.

of *C. bimaculata* were studied in a trial near Geeveston using trees of nine *E. regnans* families which represent extremes of tolerance and susceptibility to insect attack.

Outcomes

- Protection of egg batches by mesh caging resulted in increased survival in comparison to unprotected batches, indicating the importance of weather effects.
- Significant differences in larval survival were only detected for families at extreme ends of the defoliation scale.
- Larval growth was not affected by family differences or the presence of protective cages.
- Significant differences in leaf toughness and quantities of major monoterpenes were recorded between families.
- The distribution of wild adult *C. bimaculata* over the trial area was patchy with no apparent preferences for individual families.

Goals

- Investigate the influence of leaf age on *C. bimaculata* larval growth and survival.
- Relate changes in leaf toughness, oil components and nitrogen, phosphorus and potassium levels to leaf age.
- Using clonal trials, evaluate the within and between tree variation using the families previously investigated and with known levels of defoliation.

Project 2

Project Leaders
Dr A Clarke
Dr H Elliott
Dr J Madden

Control of insect defoliators

Introduction

The objective of this project is to refine the Integrated Pest Management (IPM) strategy currently used to monitor and protect Tasmania's forest plantations from leaf beetle damage. The main research directions include:

- determining the impact of leaf beetle populations on growth of *Eucalyptus nitens* and *E. regnans* so an economic basis for applying control measures can be established,
- determining the most effective and environmentally acceptable control agents,

- increasing our understanding of the biology and behaviour of *Chrysophtharta bimaculata* and its predators.

a) Impact of leaf beetle populations on tree growth

A study of the growth of *E. regnans* is being conducted in a 5-year-old plantation in the Florentine Valley. Different levels of *C. bimaculata* feeding pressure are being imposed through the use of 4 chemical regimes: (i) an unsprayed control; (ii) stem injection of insecticide; (iii) regular application of pesticide sprays; and (iv) pesticides applied in accordance with the IPM strategy.

An artificial defoliation trial has been established and aims to quantify the growth impact of defoliation by *C. bimaculata* at three levels of severity. It has been established on two year old *E. nitens* and the data obtained will be incorporated into a current growth model for *E. nitens*.

Measurement, protection and maintenance were continued on trials looking at the impact of defoliation on thinned and pruned plantation *E. regnans* and on 24 year old regrowth stands.

Outcomes

- Defoliation of young plantation *E. regnans* by *C. bimaculata* dramatically affected growth rates. Regular insecticidal spraying or stem injection resulted in larger trees (12.7cm in DBHOB diameter) than unprotected (control) trees (8.2cm).
- Permanent growth plots in sprayed and unsprayed plantations were re-measured.

Goals

- Measure and maintain all existing long term trials to quantify impacts on growth of *E. nitens* and *E. regnans*.
- Measure the short-term effect of defoliation on the growth of plantation *E. nitens* and expand trials investigating impact of *C. bimaculata* on *E. nitens* to include imposed natural defoliation.
- Analyse data from trials investigating the impact of *C. bimaculata* on *E. nitens* shoot growth.

b) Control agents

Synthetic pyrethroids are very effective against *C. bimaculata* and are used when insecticides are required, but they have broad spectrum activity and public resistance to their use is building. On the other hand, *Bacillus thuringiensis* var *tenebrionis* (B.t.t) has shown some potential in field trials for controlling

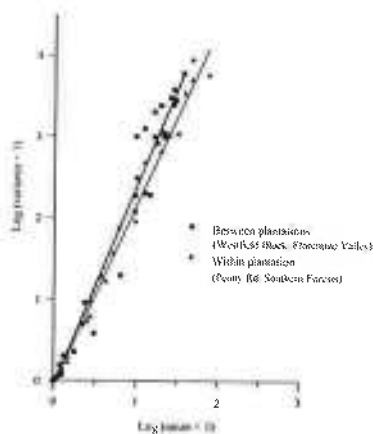


Fig. 17 A plot of log (mean + 1) versus log (variance + 1) for weekly trap catches of *Chrysophtharta bimaculata* at the within- and between-plantation scales. The slopes of the regression lines are measures of the spacial aggregation.



A ladybird instar attacks *C. bimaculata* eggs (photo courtesy of Forestry Tasmania)

C. bimaculata but is currently too unreliable for consistent field use. In this subproject the effects of synthetic pyrethroids and B.t.t. on predators of *C. bimaculata* are being evaluated.

Outcomes

- Spray droplet and volume/ha specifications for the aerial application of insecticides have been refined by a trial which studied the relationship between droplet size and spray coverage, canopy penetration and spray drift.
- The first in a series of aerial spraying trials addressing the question of appropriate spray buffer widths between aircraft and water courses, has been carried out in collaboration with Dr P Davies, Freshwater Systems.
- The impacts of B.t.t. on stream invertebrate fauna were evaluated by Dr P Davies who found that all groups tested were unaffected.
- Measurement has continued of a trial where *E. regnans* is being used as a trap tree in a *E. nitens* plantation.

Goals

- Expand work on B.t.t. including investigation of the availability and effectiveness of further strains, obtaining data on persistence following field application, and refining droplet size prescriptions and other operational factors.
- Carry out further spraying trials in order to determine suitable buffer strip widths between aerial spraying and water courses.

c) Biology and behaviour of *C. bimaculata* and its predators.

A twice weekly sampling program in the Florentine Valley is being used to study the spatial and temporal patchiness of *C. bimaculata* populations (Figure 17), factors affecting site selection by beetles and weather conditions influencing flight and oviposition. Similar studies, but over a larger area, have been conducted in the Southern Forests.

Field studies are also being conducted on the occurrence of coccinellid predators in relation to leaf-beetle populations.

Outcomes

- Data has been collected which will partially address the aim of refining the monitoring system used with the IPM strategy.
- Laboratory studies of the development rates, and instar descriptions, of *C. agricola* have been carried out.

Project 3**Project Leader
Prof M Stoddart**

Thylogale billardierii (Pademelon)
(Courtesy of the Tasmanian
Museum)

Goals

- Continue studies on the behaviour of *C. bimaculata* and its predators and parasitoids.
- Continue collecting data to enable the refinement of the monitoring system used in conjunction with the IPM strategy.
- Continue trials to elucidate the basic biology of *C. agricola*.

Vertebrate browsing in eucalypt plantations**Introduction**

This project aims to:

- determine if browsing intensity by mammals varies between species and provenances of *Eucalyptus*,
- understand the factors that influence destructive browsing of trees by wallaby (*Macropus rufogriseus*), pademelon (*Thylogale billardierii*) and possum (*Trichosurus vulpecula*). This includes determining the sensory basis by which browsers discriminate between tree species: whether the mechanism behind feeding uses olfactory, gustatory or visual cues or a combination of these,
- relate plant chemistry to selective preference by browsers; to identify those chemicals that trigger such sensory responses and result in attraction and feeding, or in aversive behaviour,
- develop appropriate management systems, particularly those that utilise "anti-feed" repellents,
- quantify losses due to browsing in plantation areas and to quantify the subsequent cost incurred if 1080 poisoning is not used as a control measure.

Outcomes

- Results from feeding trials that examined the main feeding periods, quantities of feed consumed and rates of consumption of food using a captive colony of pademelons (*Thylogale billardierii*) suggest that preferential feeding is occurring and that *Eucalyptus delegatensis* and *E. regnans* are eaten before *E. nitens* and *E. globulus* and in larger amounts.
- Observation of feeding behaviour suggests that both visual and olfactory cues are playing a part in selection of food.
- Detailed planning of field trials has taken place.

Goals

Conduct feeding trials at the University which:

- eliminate the physical form of the plant by use of homogenised foliage to remove any visual and textural cues,
- continue observations and recording of feeding behaviour using video and infra-red equipment, to determine primacy of cues,
- continue to examine the species selections *E. regnans*, *E. globulus*, *E. nitens* and *E. delegatensis* using seedlings in pots,
- examine the differential palatability amongst the five seed lots of *E. nitens* being used in the field,
- investigate food selection and food chemistry (the composition of major plant parts and their relation to preference).
- Conduct field trials in NW Tasmania.
- Assessment of damage shortly after planting (Oct 1994).
- Wildlife surveys will be conducted pre-planting, post-poisoning and quarterly thereafter. Line transects and spotlighting will be used to identify which animals are present in the area and approximate abundance. Spool and line tracking, sand-tracking and pellet counts will be used to identify those species causing the damage and to an extent to monitor feeding behaviour.
- Vegetation studies will look at the composition of the surrounding vegetation and its biomass. Quadrats will also be used within the study sites to monitor changes in vegetation between seedlings with time. The study will investigate whether such changes are related to browsing.
- Sub samples of the foliage will be taken for subsequent chemical analyses (to obtain a measure of "quality" of feed and to determine the presence of palatable/unpalatable compounds).

Project 4

Project Leader
Dr A Clarke

Biology of other insect pests of eucalypts

Introduction

This project aims to gather biological information (taxonomy, population phenology and host plant interactions) of non-Chrysomelid pests of intensively managed *Eucalyptus* plantations, specifically coreid bugs (*Amorbus* and *Gelonus*



Coreid bug (*Gelonus*) nymphs on cutting grass (*Ghania grandis*) at Florentine Valley.

species) and Autumn Gum Moth (*Mnesampela privata*). This information will be used to (i) assess the current and potential pest status of these insects in *Eucalyptus* plantations and (ii) provide information valuable to the formulation of insect pest management strategies.

a) Biology of Tasmanian coreid bugs

The aim of this project is to study the population biology and host-plant relationships of Tasmanian Coreidae. These insects attack the growing tips of their eucalypt host, causing tip-wilt and in severe cases a dwarf, multi-branched tree ("shrubbing").

Outcomes

- The taxonomy of the Tasmanian coreids has been clarified. It is now considered that *Amorbus* consists of one species (*A. obscuricornis*), not three as previously considered. *Acantholybas kirkaldyi*, a Tasmanian coreid previously known only from the type description, has been recollected.
- The palatability of a range of *Eucalyptus* species have been tested on *Amorbus* and *Gelonus* in no-choice tests to assess their value as host species for adults and nymphs. Some of the best host-plant species for *Amorbus* are the commercial *Eucalyptus* species *E. obliqua*, *E. nitens*, *E. globulus* and *E. delegatensis*. Based on feeding damage and host range, *A. obscuricornis* is considered the only coreid likely to cause serious damage to plantations.
- The ecology of the species have been studied in some detail, including constant temperature development rates, female fecundity, seasonal population phenology and the range of natural enemies.

Goals

- Conclude studies on: coreid taxonomy; no-choice host plant performance; developmental, reproductive and defensive biology; and natural enemies.
- Commence field experiments which study (i) the role of plant architecture versus other plant characteristics in host-plant selection by coreids and (ii) the role of host plants of differing quality in the population biology of Coreidae.

b) Biology of the autumn gum moth

Larvae of the autumn gum moth (*Mnesampela privata* [Guenée]) feed on leaves of eucalypts belonging to the "blue gum" group, including the commercially cultivated species *E. nitens* and *E. globulus*. Although generally not a major pest in Tasmania, outbreaks can be quite severe and result in total defoliation of

attacked trees. *M. privata* is widespread across temperate Australia and field work will be conducted in Tasmania, Victoria and Western Australia.

Outcomes

- A PhD student, Mr Zoltan Lukacs will commence his studies on this project in September 1994.

Goals

- To plan the structure of the autumn gum moth project, including the strengthening of collaborative links with Drs R Farrow and R Floyd, CSIRO Division of Entomology.
- To begin field studies in the forthcoming season.



Coreid bugs (*Gelonus tasmanicus*)
copulating and female feeding on
E. regnans.

Education and Communication Program

Program Manager
Dr N Davidson

Introduction

The main aims of the Education and Communication Program are to:

- expand postgraduate and postdoctoral research in the areas of tree genetics, forest protection (against predation by insects and vertebrates) and management of plantation eucalypts
- involve CRC scientists, who are not teaching staff in University departments, in supervision at the post graduate level and in teaching in undergraduate courses
- communicate the results of research conducted at the Centre to the industrial partners, to other scientists within the CRC and to the public, through the production of reports, workshops, seminars, and field days
- raise public awareness of the objectives of the CRC and the high quality of the research conducted by it through open days and public displays
- generate a CRC ethos amongst partners who are in some cases remotely located and amongst members of different departments and institutions on the campus at the University of Tasmania.

Major achievements of the program

- We have exceeded our target of 25 postgraduate and Honours students working at the CRC and now have 33 students enrolled (see Table 4), despite 14 students finishing at the end of 1993.
- The running of a workshop "Quantitative Genetics Applied to Tree Breeding" from 24-26 November 1993 in Hobart by the Genetic Improvement Program, and an open day at the Lewisham plantation (on 18 March 1994) by the Soil and Stand Management Program.
- Research Profiles of Scientists at the CRC, a booklet compiled early in 1993, was printed and distributed. The booklet describes the backgrounds, research interests and contribution to the CRC programs of all scientists associated with the CRC.
- A number of initiatives have contributed to the development of a Centre ethos. These include the establishment of a CRC newsletter, the "Research Profiles", visits to company

operations, a seminar series, organised sports matches (eg softball games) and social engagements (eg barbecues).

- A symposium highlighting the principal findings from the CRC research programs was run for Board members of the CRC in April 1994.

Honours and postgraduate students

In the past 11 months the number of students enrolled in Honours and postgraduate degrees with the CRC has increased by 5 to 33, despite 14 students completing at the end of 1993 (see list of thesis titles in the publication list). We now have 24 PhD students, 4 MSc students, 4 Honours students and a Graduate Diploma student divided amongst the four programs; 11 in Genetic Improvement, 8 in Soil and Stand Management, 10 in Resource Protection and 4 in Education (Table 4). The supervision of these students is shared widely amongst many of the partner institutions (Table 5).

CRC Honours scholarships were offered in 1994 to three students who received excellent results in their third year; Paul Chambers, Steven Ogbourne and Mark Jackson.

Undergraduate students

This year there are 12 students enrolled in the four year undergraduate course in Forest Ecology, similar to the intake for 1993 (Table 5). We expect numbers in this course to remain at this level and that students from other courses run by the Plant Science and Agriculture Departments will provide the major source of Honours and postgraduate students for the CRC.

Postdoctoral fellowships

There are now five post doctoral fellows working with the CRC, or soon to be appointed to the CRC.

In the Resource Protection Program, Dr Tony Clarke has played a key role, leading research in project 2 and 4 on the control of insect defoliators and the biology of other insect pests of *Eucalyptus*. A new post doctoral fellow/research fellow will be appointed in vertebrate browsing.

In the Genetic Improvement Program, Dr Omar Hasan is identifying and quantifying gibberellins, auxins and abscisic acid in the cambial tissue of *E. globulus* with the aim of determining their effect on wood properties. A new post doctoral fellow in vegetative propagation will start in late August on a project investigating somatic embryogenesis.

In Soil and Stand Management, Dr Mike Battaglia has been investigating the effect of temperature acclimation and chilling

Table 4a Topics and supervisors of CRC research students 1994

No.	Last Name	First Name	Topic	Scientific Supervisors
1	BULINSKI	James	Effect of plantation design on feeding behaviour of wallaby	Prof M Stoddart
2	CANDY	Steve	Mathematical models to support IPM of leaf beetles	Dr J Madden, Dr H Elliott
3	CHAMBERS	Paul	Genetic control of survival and implications for forest tree breeding	Dr B Potts, Dr N Borralho
4	DINGLE	Joanne	Interactive effects of salinity and waterlogging on eucalypts	Dr N Davidson
5	DUNGEY	Heidi	The susceptibility of eucalypt hybrids to pests	Dr B Potts, Prof J Reid
6	GARNETT	Trevor	Kinetic parameters for uptake of nitrogen and ammonium by eucalypt roots	Dr P Smethurst, Dr N Davidson
7	GREAVES	Bruce	Age to age correlations in eucalypts	Ms C Raymond, Dr B Potts, Dr N Borralho
8	HARDNER	Craig	In-breeding in eucalypts	Dr B Potts, Dr N Borralho
9	HOWLETT	Bradley	Host location by <i>Chrysophtharta bimaculata</i>	Dr J Madden, Dr A Clarke
10	HUNT	Mark	Competition between understorey species and plantation eucalypts	Dr N Davidson, Dr C Beadle
11	HUNT	Alastair	Predators of <i>Chrysophtharta bimaculata</i>	Dr A Clarke
12	JACKSON	Mark	Control of flowering in eucalypts	Prof J Reid
13	LAWRENCE	Naomi	Tissue culture of eucalypts	Mr V Hartney, Dr J Gorst
14	LOUGHHEAD	Sarah	Partitioning variation in seed germination characteristics	Dr M Borralho, Dr N Davidson
15	LUKACS	Zoltan	Biology of the autumn gum moth	Dr J Madden, Dr A Clarke
16	MARSH	Nadia	Browsing of eucalypt seedlings by pademelons (<i>Thylagale bilardierii</i>)	Prof M Stoddart
17	NESBITT	Katherine	Molecular markers in <i>E. globulus</i>	Prof J Reid, Dr A West
18	OGBOURNE	Steven	Molecular biology of phase change	Prof J Reid
19	PATTERSON	Kathryn	The influence of leaf chemistry on grazing of <i>E. nitens</i> leaves by <i>C. bimaculata</i>	Drs N Davidson, J Madden, C Beadle
20	PEACOCK	Ross	Regeneration after cable logging	Drs N Davidson, M Brown, Prof R Hill
21	PINKARD	Libby	The effect of pruning on productivity and resource allocation in <i>E. nitens</i>	Dr C Beadle, Dr N Davidson
22	REID	Catherine	Pre- and post-diapause dispersal of insects	Dr J Madden
23	SALE	Michele	Phylogeny of the genus <i>Eucalyptus</i>	Dr A West
24	STEINBAUER	Martin	Biology of Tasmanian coreid bugs	Dr J Madden, Dr A Clarke
25	TEIXEIRA	Paulina	Soil structure and erosion in eucalypt plantations	Dr R Misra
26	VOLKER	Peter	Estimation of genetic parameters for eucalypt hybrids	Dr B Potts, Dr N Borralho
27	WALL	Sarah	Modelling stem shape of eucalypts	Dr P West, Dr R Misra
28	WARDLAW	Tim	Armillaria butt and root rot of eucalypts	Dr M Line, Dr G Kile
29	WEI	Xianming	Efficiency of selection in eucalypts	Dr N Borralho
30	WHITE	Don	Water relations of <i>E. nitens</i> and <i>E. globulus</i> under cyclical drought	Dr C Beadle, Dr N Davidson
31	WILKINSON	Graham	Genetic variation in <i>E. obliqua</i>	Prof J Reid
32	WILLIAMS	Kristen	Modelling <i>Eucalyptus</i> distribution	Prof J Reid, Dr M Austin, Dr M Brown
33	WILSON	Steve	Early growth and survival of eucalypt seedlings	Prof R Clarke, Mr P Volker

Table 4b Details of research students at the CRC 1994

No.	Last Name	First Name	CRC Program	Field	P/F Time	Start	Finish	Degree	Funding
1	BULINSKI	James	Resource Protection	Vertebrate browsing	Full time	1994	1997	PhD	CRC
2	CANDY	Steve	Resource Protection	Entomology	Part-time	1993	1999	PhD	FCT employee & IFM
3	CHAMBERS	Paul	Genetic Improvement	Tree breeding	Full time	1994	1994	Hons CRC	Hons Schol
4	DINGLE	Joanne	Education	Eucalypt eco-physiology	Full time	1994	1994	Grad Dip (Hons)	Self supporting
5	DUNGEY	Heidi	Genetic Improvement	Eucalypt genetics	Full time	1992	1995	PhD	Uni Res Schol & CRC
6	GARNETT	Trevor	Soil & Stand Management	Tree nutrition	Full time	1993	1994	PhD	CRC
7	GREAVES	Bruce	Genetic Improvement	Eucalypt genetics	Full time	1993	1996	PhD	APA & CRC
8	HARDNER	Craig	Genetic Improvement	Eucalypt genetics	Full time	1993	1996	PhD	Uni Res Schol & CRC
9	HOWLETT	Bradley	Resource Protection	Entomology	Full time	1993	1997	PhD	FFIC
10	HUNT	Mark	Soil & Stand Management	Eucalypt ecology	Full time	1994	1997	PhD	FFIC
11	HUNT	Alastair	Resource Protection	Entomology	Full time	1993	1997	PhD	FFIC
12	JACKSON	Mark	Genetic Improvement	Eucalypt genetics	Full time	1994	1994	Hons CRC	Hons Schol
13	LAWRENCE	Naomi	Genetic Improvement	Tissue culture	Full time	1993	1996	PhD	CRC
14	LOUGHHEAD	Sarah	Education	Eucalypt ecology	Full time	1994	1995	Hons	Self supporting
15	LUKACS	Zoltan	Resource Protection	Entomology	Full time	1994	1997	PhD	CRC
16	MARSH	Nadia	Resource Protection	Vertebrate browsing	Full time	1993	1996	PhD	CRC
17	NESBITT	Katherine	Genetic Improvement	Molecular biology	Full time	1992	1996	PhD	APA & CRC
18	OGBOURNE	Steven	Genetic Improvement	Molecular biology	Full time	1994	1994	Hons CRC	Hons Schol
19	PATTERSON	Kathryn	Resource Protection	Entomology	Full time	1993	1996	PhD	APA & CRC
20	PEACOCK	Ross	Soil & Stand Management	Forest ecology	Part time	1994	1996	MSc	Dapt Plan NSW employee
21	PINKARD	Libby	Soil & Stand Management	Eucalypt physiology	Full time	1994	1997	PhD	FFIC
22	REID	Catherine	Resource Protection	Entomology	Full time	1994	1996	MSc	Self supporting
23	SALE	Michele	Genetic Improvement	Molecular biology	Full time	1992	1996	PhD	APA
24	STEINBAUER	Martin	Resource Protection	Entomology	Full time	1992	1995	PhD	APA & CRC
25	TEIXEIRA	Paulina	Soil & Stand Management	Soil structure and erosion	Full time	1993	1997	PhD	Self supporting
26	VOLKER	Peter	Genetic Improvement	Eucalypt genetics	Part time	1992	1996	PhD	ANM employee
27	WALL	Sarah	Soil & Stand Management	Modelling	Full time	1994	1997	PhD	CRC
28	WARDLAW	Tim	Resource Protection	Pathology	Part-time	1994	2000	PhD	FCT employee
29	WEI	Xianming	Genetic Improvement	Quantitative genetics	Full time	1994	1997	MSc	AJDAB
30	WHITE	Don	Soil & Stand Management	Eucalypt physiology	Full time	1993	1996	PhD	CRC
31	WILKINSON	Graham	Education	Eucalypt genetics	Part time	1990	1994	MSc	FCT employee
32	WILLIAMS	Kristen	Education	Eucalypt ecology	Full time	1993	1994	PhD	DPI-Forestry
33	WILSON	Steve	Soil & Stand Management	Eucalypt ecology	Full time	1993	1996	PhD	APA-Industry (TFRC)

Table 5 Summary of student enrolments in the CRC

I Undergraduate Students				
Degree:	Forest Ecology	First year	5	
		Second year	3	
		Third year	4	
		Fourth year	0	
			12	
II Postgraduate Students				
			Number of Students	
Full/Part Time:	Full time		28	
	Part time		5	
Degree:	Grad Dip with Hons		1	
	BSc Honours		3	
	BAGSci Honours		1	
	MSc		4	
	PhD		24	
CRC Program:	Genetics		11	
	Soil & Stand Management		8	
	Resource Protection		10	
	Education		4	
Supervisor:	Dr M Austin	1	Dr M Line*	1
	Dr M Battaglia	1	Dr J Madden*	6
	Dr C Beadle	4	Dr R Misra	1
	Dr N Borralho	5	Dr BM Potts	5
	Dr M Brown	2	Ms C Raymond	1
	Prof R Clark*	1	Prof J B Reid*	6
	Dr A Clarke	4	Dr P Smethurst	1
	Dr N Davidson	8	Prof M Stoddart*	2
	Dr H Elliott	1	Mr G Unwin*	1
	Dr J Gorst*	1	Mr P Volker	1
	V Hartney	1	Dr A West*	1
	Prof R S Hill*	1	Dr P West	1
	Dr G Kile	1		
	Funding:	CRC (Honours Scholarship)		3
CRC (PhD/MSc Scholarship)			8	
Univ Research Scholarship with CRC top up			2	
APA with CRC top up			4	
APA			1	
APRA - Industry			1	
FFIC			3	
AIDAB			1	
DPI - Forestry			1	
Employed in forest industry			5	
Self-supporting		4		

* University Department Staff

injury on the photosynthesis of *E. nitens* and *E. globulus* (Project 1). Dr Battaglia was successful in securing a three year ARC fellowship at the University of Tasmania starting in July 1994 and in this capacity will continue research on forest ecology and interact with Dr Neil Davidson and Professor Jim Reid from the CRC.

Teaching

Many CRC staff based at the Centre laboratories, at the private companies and Forestry Tasmania are now involved with teaching at the CRC. Five CRC funded staff are 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 Phil Smethurst in Soil Nutrition, Dr Brad Potts in Quantitative Genetics and Dr R Vaillancourt in Molecular Biology. Supervision of Postgraduate and Honours students is now widely distributed amongst CRC partner institutions, such that more than half of the student supervision is performed by CRC staff outside University departments (see Tables 4 & 5).

Communication and Promotion

A very successful workshop on "Quantitative Genetics Applied to Tree Breeding" which attracted participants from throughout Australia was run from 24-26 November 1993 in Hobart by the Genetic Improvement Program. This had to be limited to invited delegates because of demand.



A Centre display at the Double Helix Club day held in the CSIRO Marine Buildings, Hobart. (Photo courtesy of Thor Carter, CSIRO)

An open day was held at a plantation of *E. nitens* and *E. globulus* genotypes Lewisham on 18 March 1994. Results of studies conducted on **water relations** and photosynthesis were described by the researchers involved. The open day was organised by the

Soil and Stand Management Program and attracted 50 participants.

A symposium was held on the 23 May 1994 to inform CRC staff, company representatives and the Board of major research development. The presentations were:

Dr N Borralho	Improving the efficiency of breeding programs
Dr H Elliott	Controlling leaf beetles
Dr B M Potts	Breeding from <i>Eucalyptus globulus</i>
Dr P Smethurst	Plantation nutrient supply
Dr P West	Mechanisms of thinning response
Mr D White	Physiological responses to drought

The CRC and IUFRO (International Union of Forestry Research Organisations) are co-sponsoring a major international conference on eucalypt forestry "Eucalypt plantations: Improving fibre yield and quality" to be held in Hobart in February 1995. CRC staff form the organising committee.

The CRC was invited to contribute a display to the CSIRO's second Double Helix Club day at the Marine Laboratories in Hobart in April 1994. The event, which was designed to stimulate the interest of young people in science, was astonishingly successful attracting over 2000 paying customers. Queues were present throughout the day to see the CRC's displays, which included a microscopic examination of stomata, live leaf eating beetles, F₁ hybrid eucalypt seedlings and free eucalypt seeds. Another display depicting the activities of the CRC was presented at the Elizabeth Matriculation College in November 1993. This was also well received and we intend repeating this exercise using a modular unit that we can easily reassemble at each new location.



Participants at a workshop on "Quantitative genetics applied to tree breeding" held at the Centre.

In association with UNITAS Consulting, the CRC is in the process of marketing international contract proposals for staff in quantitative genetics and eucalypt breeding, led by Dr Nuno Borralho. With this in mind, Dr Brad Potts presented a three day course on 'Reproductive biology of *Eucalyptus* and application to breeding' at the Universidad Austral de Chile, organised by the Cooperative de Mejoramiento Genetico Forestal, Universidad Austral de Chile, Facultad de Ciencias Forestales, Valdivia, which was followed by a one week overview of the cooperative's breeding programs. Dr Chris Beadle contributed to a workshop on photosynthesis and productivity in Thailand sponsored by the United Nations.

CRC Ethos and Interactions

In 1993 we prepared a booklet entitled "Research Profiles of Scientists at the CRC" which describes the backgrounds, research interests and contribution to the CRC programs of all scientists associated with the CRC. In this reporting period the booklet was printed and distributed to all staff and students and has proved to be useful in facilitating interaction.

A three-monthly newsletter, called "Overstorey" was started in 1993. It takes a light-hearted look at the CRC and is comprised entirely of contributions from within the CRC. It has been very popular both for those wanting to submit articles and readers. The credit for this success goes to the organiser, Jane Burrell.

Goals

- Maintain Postgraduate and Honours student intake and develop a new display and brochure to attract students to the CRC.
- To increase the contribution of CRC staff to undergraduate courses in Plant Science, Agricultural Science and Molecular Biology and to encourage University teaching staff to become involved in CRC projects.
- Run a workshop on "Insect pest management in *Eucalyptus* plantations" through the Resource Protection Program
- Run a successful CRC/IUFRO Conference in Eucalypt Genetics in February 1995
- Continue to develop links and interactions between partners and programs within the CRC
- To improve the transfer of research results to industry by involving industry in more short courses and symposia and including research highlights in the CRC newsletter, "Overstorey".

Cooperative Linkages

Interactions with
outside
organisations

During the third year of the CRC's operation links were strengthened both between members of the CRC and with outside organisations.

Genetic Improvement

Strong cooperative linkages exist between the Genetic Improvement Program and the CRC for Hardwood Fibre and Paper Science in Melbourne with Prof Jim Reid serving on their Advisory Committee and Carolyn Raymond being on the Program Coordinating Committees for Programs 1 and 2 of that centre.

The Genetic Improvement Program project 1 (Breeding strategies, genetic variation and estimates of heritabilities and genetic correlations) has developed strong links with the CRC for Hardwood Fibre and Paper Science on the "genetics of growth and wood characteristics in *Eucalyptus nitens* at several ages", with Dr Russell Haines (Dept Primary Industries - Queensland Forest Services) on "Propagation strategies in eucalypts" and with the Southern Tree Breeders Association on the "National selection program for *E. globulus* and *E. nitens*". This latter cooperation is allowing a truly national breeding program to be implemented for the two key temperate hardwood species of eucalypt as well as providing the conduit for deploying research advances in tree breeding developed by the Centre for the benefit of the forest industries.

Project 6 (Manipulation of breeding systems) has developed collaboration with the CRC for Hardwood Fibre and Paper Science to determine the role that hormones play in determining wood characteristics. Dr O Hasan has spent two periods at Creswick utilising techniques and equipment developed by the CRC for Hardwood Fibre and Paper Science for this purpose.

A cooperative research agreement in mapping *E. globulus* is being negotiated between project 3 (Molecular genetics) and Dr G F Moran and Dr M Byrne of CSIRO Forestry in Canberra.

Project 4 (Hybrid breeding) is studying i) the response of the *Mycosphaerella* sp. leaf spot fungi to *E. nitens* x *globulus* hybrids and pure species in collaboration with Dr P Ades and A Carnegie, University of Melbourne, ii) the response of natural *Eucalyptus* hybrids to pests in collaborative study with Profs T Whitham (Northern Arizona University) and P Morrow, (University of Minnesota) and iii) genetic parameters estimated from open-pollinated and controlled crossed progenies of *E. globulus* and *E. nitens* with Dr Gary Hodge, University of Florida (CRC visiting scientist 1993).

Soil and Stand Management

Strong links have been established between the SSM Program and Forests and Forest Industry Council (FFIC) of Tasmania. In project 1 (Plantation production and water use), a study is being conducted on the effect of pruning on assimilation, growth and partitioning of carbon and nitrogen in *E. nitens*, funded by the FFIC. In project 2 (Dynamics of carbon and nutrients), there are links with the FFIC (represented by Michael Laffan) in a study of the erosion hazards of Tasmanian forest soils.

Links have also been established with Dr B Atwell of Macquarie University on studies of N uptake by morphologically different roots of *E. nitens*, and with the Faculty of Environmental Sciences, Griffith University, Brisbane in a study of process-based erosion models, sustainable soil conservation practices and mechanisms of nutrient loss during erosion.

Resource Protection

A review entitled the "Intensive Forest Management Program", which includes studies of the effects of pesticides, herbicides and the poison 1080, is being conducted by the Resource Protection Program in collaboration with Dr P Davies, funded by the Forest and Forest Industry Council.

Contacts have been strengthened with the *Eucalyptus*-entomology group of the CSIRO Division of Entomology, Canberra with joint field trips and seminar presentations. Dr Robert Floyd, of that group, has agreed to act as a co-supervisor of a PhD student.

Interactions continue with the CRC for Tropical Pest Management, Brisbane, particularly with regards to a project studying genetic diversity in *C. bimaclata*. The *C. bimaclata* genetics project was initially funded by a \$5,000 grant by the CRC-TPM. Results to date indicate that *C. bimaclata* populations collected from the central highlands of Tasmania are genetically distinct from other Tasmanian populations.

Genetic Improvement

There is a strong link with the ANM Pulping Research Division where a joint project is underway to determine the optimum within tree sampling positions for a study of the genetic variation in wood properties in *Eucalyptus regnans*.

The cooperative linkages in the Genetic Improvement Program are now well developed in cross project interactions between Breeding strategies, genetic parameters and prediction of breeding values (Project 1) Genetic variation in fibre and pulp traits (Project 2), Molecular genetics (Project 3), Hybrid breeding (Project 4), and Micropropagation (Project 5) as well as in Project 1 of the Resource Protection Program (Leaf and

Interactions between partners

tree factors affecting eucalypt defoliators) where the effect of genetic variation in the host on levels of defoliation by *Chrysophtharta bimaculata* is being studied. There is also interaction between the Genetic Improvement Program Projects 3 and 4 on genetic mapping and QTL analysis of F₂ hybrids of *E. gunnii* x *globulus*.

Soil and Stand Management

Cooperation between the Soil and Stand Management Program and the industry partners is continuing with analysis of fertiliser trials established at a number of sites around Tasmania. There is also strong interaction between Projects 3 (Nutrient supply and acquisition) and 4 (Modelling plantation systems) in modelling of nutrient uptake by tree roots. Dr Smethurst is interacting with Forestry Tasmania as a member of their Soils Advisory Committee and on the Panel for Review of Weed Control Practices.

Strong links have been developed between Project 1 (Plantation production and water use) and North Forests in studies of the effects of chilling injury on photosynthesis and growth of *E. nitens* at high altitude. Similarly links have been strengthened between project 1 and Boral Forest Resources in two studies; one on the competitive effects of *Acacia* on growth of *E. nitens* in plantations (a problem in plantations in north-eastern Tasmania), and the other on the effect of pruning on growth photosynthesis and nutrition of *E. nitens* (with the aim of generating sawlogs from pulpwood plantations).

Links have also been developed with the Department of Agricultural Science, University of Tasmania in studies of microbial biomass (with Dr M Line), and on studies of P fertilisation and P uptake by *E. nitens* (with Dr R Menary).

Resource Protection

There is strong ongoing interaction between the Resource Protection Program, Forestry Tasmania and the forest companies in refining the Integrated Pest Management Program. This was demonstrated through: (i) a season-long sampling program studying coccinellid predators of *C. bimaculata*, jointly undertaken by CRC and Forestry Tasmania entomologists; and (ii) insect sampling by ANM staff for a CRC research program studying beetle distribution patterns. In addition joint research organising meetings were held regularly between CRC and Forestry Tasmania entomologists. Linkages have continued to develop in the vertebrate browsing project, typified by the planting of a large scale trial for browsing studies by North Forests.

Utilisation and Application of Research, and Commercialisation

Introduction

In the last 12 months, 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.

Researchers in the Genetic Improvement Program have quantified the reduction in growth due to inbreeding for *E. globulus*. The impact of inbreeding on breeding strategy can now be modelled and incorporated into company practice. Also, as a result of studies of hormonal control of flowering in *Eucalyptus*, carefully measured doses of paclobutrazol are now being used to promote early flowering in seed orchard trees.

Bruce Greaves has shown that the use of pilodyn measurements will allow estimates of basic density to be included in breeding programs in a cost effective way. These measurements are now being made in breeding populations so that they can be included in selection indices. Theoretical studies have shown that this will provide greater cost saving for pulp production than using only indices involving growth rate.

The CRC for Temperate Hardwood Forestry, in collaboration with the Southern Tree Breeders Association (Southern Australia), is completing a national genetic evaluation of *E. globulus* ssp *globulus* which will provide tree breeders with the first direct comparison of breeding values for growth of around 50,000 trees. The analysis includes more than 500 open pollinated families from 15 sites in Australia, grown from seed collected across the whole natural range of subspecies. The results are expected to be the basis for a national selection and breeding program for the species.

The Resource Protection Program, in close collaboration with Forestry Tasmania, is continuing to develop the Integrated Pest Management Program which is used by Forestry Tasmania and forestry companies to control outbreaks of defoliating insects in their plantations.

In 1992/93 the Soil and Stand Management Program identified Cu deficiencies as the cause of growth deformities in *E. nitens* plantations on sites previously receiving high rates of N and P (eg ex-pasture sites). Subsequent research has shown this deficiency to affect a small but significant number of plantation sites and companies have now employed a policy of minimum fertilisation on ex-pasture sites.

Forestry Tasmania

The CRC, Forestry Tasmania, forestry companies and the Southern Tree Breeding Association have been actively implementing a national breeding strategy for *E. globulus*, and

Partner Perspectives

are commencing the same process for *E. nitens*. Both these species are critically important to the Australian forest industry.

There is an urgent need to develop thinning and pruning regimes to treat young eucalypt plantations being grown for sawlog production. Cooperative work between the CRC Soil and Stand Management Program and Forestry Tasmania involves the testing of various regimes in southern Tasmania, particularly concerning costs and techniques for pruning. A recent workshop at the CRC, organised by the Intensive Forest Management Program of the Forests and Forest Industry Council, produced an interim regime for treatment of several hundred hectares of plantation next year.

Forestry Tasmania welcomes the establishment of a post doctoral position to conduct research into animal browsing.

- Humphrey Elliott

North Forest Products

Some interesting research results have emerged in the last 12 months. In the Genetic Improvement Program, the Australia-wide analysis of *E. globulus* growth data, although not complete indicates that genotype by environment effects may not be large. The pilodyn work is showing good correlations with Basic Density. A study into the genetic gains to be expected from clonal and family forestry was initiated and is indicating that there are advantages in planting vegetatively propagated material, even at a relatively low level of selection. CSIRO's release of its Improved Micropropagation Technique has enabled micropropagation to resume but the technique requires further refinement before it can be used operationally. Hybrid work has continued with the establishment of some *E. globulus* x *E. gunnii* trials.

A much better understanding of the water relations of *E. globulus* and *E. nitens* has come from the Soil and Stand Management Program. Frosting in the field has been shown to reduce photosynthesis on subsequent days, and average winter photosynthetic rates have been shown to be higher than expected. Results from fertiliser trials have been equivocal; CRC trials indicating no response to N and P, but company trials indicating significant responses to both nutrients. Root studies have yielded the surprising result that 85% of the biomass of 2 year old planted trees is underground, and further studies are seeking to establish the veracity of this result. Trials with the aerial application of insecticide identified a rate which gave maximum efficacy and minimal drift. Vertebrate browsing studies are progressing well.

- David de Little,

Boral Forest Resources

Results to date see productivity and relativity in context, and we get particular satisfaction from the efforts being made in the Soil and Stand Management Program relative to both fertiliser work and early indicative work in the thinning and pruning area. The on-going work in the Genetic Improvement Program is strong, with 1993 publications suggesting an ability to focus, and provide for the needs of those industry geneticists. Research on the ecology and population dynamics of defoliating insects and marsupials and their predators is a major task and public concerns about the use of insecticides and 1080 is continually limiting the options for control. However, the Resource Protection Program is making good progress towards developing alternative methods of control.

There were two new projects established this year which are of direct interest to Boral Forest Resources. Libby Pinkard is conducting a PhD project investigating the effect of pruning on the subsequent productivity of *E. nitens*, which will help in deciding whether we can use *E. nitens* for saw logs. Mark Hunt is conducting a PhD project on the effect of competition from *Acacia dealbata* on the growth of *E. nitens*, which we suspect is a problem in Boral Forest Resources plantations in north-eastern Tasmania.

- Peter Naughton,

ANM Forest Management

The CRC has made a significant contribution to the establishment of a national eucalypt breeding cooperative within the Southern Tree Breeding Association Inc. This has brought together CRC members in another form of cooperation outside the CRC and strengthened linkages between the CRC and the eucalypt plantation industry in general. This past year has been frustrating in the sense that it has been difficult to recruit scientists and students to certain projects. This further demonstrated the need for high quality training in forestry related disciplines to service our industry. All programs are making significant progress in various areas of research and these are beginning to have an impact on operational aspects of ANM's silvicultural practices.

- Peter Volker

APM Forests Pty Ltd

To remain internationally competitive Australia's forest products industry needs to focus on reducing costs at each stage of the value adding. Improving wood quality is vital in reducing harvesting, transport and processing costs. APM Forests welcomes the CRC's initiative to strengthen research on the impact of breeding, silviculture and harvest age on wood

properties for solid wood products and pulp and paper (the latter through closer ties with the CRC for Hardwood Fibre and Paper Science). Cooperative Research and Development in pre-competitive areas is important, given the scale of Australia's industry.

Many CRC projects have already resulted in considerable assistance to APM Forests, including:

- analysis of the CSIRO *E. globulus* collection with the Southern Tree Breeding Association, which indicates breeders will maximise their gain through exchanging breeding values and genetic material under cooperative arrangements,
- indirect selection for basic density using a pilodyn, which promises more genetic gain at a lower cost,
- analysis of an existing CSIRO/AMPF self pollination trial which has yielded challenging results with implications for the future use of open-pollinated trials for breeding, and
- research on *Mycosphaerella*, vegetative propagation, site preparation and nutrition, which is expected to provide future benefits.

- John Cameron,



Staffing and Administration

By July 1993, the appointment of staff to the CRC for Temperate Hardwood Forestry was almost complete and most of the subsequent changes in staffing represent staff turnover.

Dr Omar Hasan, a recent PhD graduate of the University of Tasmania, was a new appointment to the position of postdoctoral fellow on the Genetic Improvement Program investigating hormonal control of flowering and wood properties in *E. globulus*.

Mrs Shelley Caswell was appointed to the position of Administrative Officer (half time) to replace Mrs Carol Blake (0.8 time). Mr Andrew MacDonald and Mr Tim Eldridge respectively replaced Mr Paul Tilyard and Ms Mandy Watson as technicians in the Genetic Improvement Program. Mr Mark Van den Berg was a new appointment as technician in the Resource Protection Program.

New students starting with the CRC this year include ten PhD students (James Bulinski, Steve Candy, Bradley Howlett, Alastair Hunt, Mark Hunt, Zoltan Lukacs, Libby Pinkard, Paulina Teixeira, Sarah Wall and Tim Wardlaw), two Masters students (Catherine Reid and Xianming Wei) and four Honours students (Paul Chambers, Joanne Dingle, Mark Jackson and Steven Ogbourne).

Two important changes have occurred to the Management of the CRC. Firstly, the Office of the Chief Scientist has appointed a Visitor to the CRC. He is Professor Harold Woolhouse, Dean, Faculty of Agriculture, University of Adelaide. He will provide advice on the strategic directions for the Centre.

Secondly, we have recruited an eminent Australian, Mr John Kerin, as the new Chairman of the Board of the CRC. He replaces our inaugural Chairman, Mr John Allwright AO, following his untimely death. Mr Kerin is a former Treasurer and Minister of Agriculture in the Australian Government. He has a broad knowledge of the problems facing primary industries across this country and provides a national focus for the Centre.

The specified personnel list for the CRC (Table 6) remains unchanged from 1992/93 and a full staff list for the Centre is presented in Attachment C at the end of this report.

Table 6 Specified personnel in the CRC.

<u>CSIRO Division of Forestry</u>		<i>Proportion of time in CRC</i>
Dr PW West	Deputy Director (Program Manager, Soil and Stand Management)	(0.80)
Dr CL Beadle	Senior Research Scientist	(0.70)
Mr RN Cromer	Principal Research Scientist	(0.40)
Mr VJ Hartney	Senior Experimental Scientist	(0.70)
Ms CA Raymond	Research Scientist	(1.00)
Dr PJ Sands	Principal Research Scientist	(1.00)
Dr P Smethurst	Research Scientist	(1.00)
<u>University of Tasmania</u>		
Prof JB Reid	Director (Program Manager, Genetic Improvement)	(0.50)
Dr NJ Davidson	Lecturer (Program Manager, Education and Communication)	(1.00)
Dr JL Madden	Reader (Program Manager, Resource Protection)	(0.30)
Dr BM Potts	Lecturer	(1.00)
Prof DM Stoddart	Professor of Zoology	(0.20)
Dr A West	Senior Lecturer	(0.10)
Dr N Borralho	Lecturer	(1.00)
<u>Forestry Commission, Tasmania</u>		
Dr HJ Elliott	Chief, Division of Silvicultural Research and Development	(0.10)
<u>ANM</u>		
Mr PW Volker	Research Scientist	(0.40)
<u>APPM</u>		
Dr DW de Little	Research Manager, Forests	(0.10)
Dr WN Tibbits	Research Scientist	(0.30)
<u>Forest Resources</u>		
Mr P Naughton	Scientist	(0.30)
<u>APM</u>		
Mr J Cameron	Research Manager	(0.15)

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Misra, R K (1994) Critical penetrometer resistance for root growth in soils. Paper accepted for oral presentation at the 13th ISTRO conference, Aalborg, Denmark, July 22-29, 1994.

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White, D A, Honeysett, J, Worledge, D and Beadle, C L. (1994) Effects of water stress on the growth of *E. globulus* and *E. nitens* in plantations. (Faces of farm forestry. Aust. Forest Growers Conf. Launceston, May 1994).

Resource Protection

Conferences, seminars

Clarke, A R (1993) "The CRC for Temperate Hardwood Forestry and research into insects attacking plantation forests". Seminar presented to the CRC for Tropical Pest Management, Brisbane, July, 1993.

Clarke, A R, Madden, J, Steinbauer, M J and Patterson, K (1993) Resource Protection within the CRC for Temperate Hardwood Forestry. *Program and Abstracts, Australian Entomological Society 24th Scientific Conference and AGM, Cairns, 3rd-8th July, 1993*. Poster Abstract, p96

Madden, J L (1993) Options for control of forest pests. *Program and Abstracts, Australian Entomological Society 24th Scientific Conference and AGM, Cairns, 3rd-8th July, 1993*. Poster Abstract, p77.

Education and Communication

Workshops

"Quantitative genetics applied to tree breeding", held from 24-26 November 1993, run by Dr Nuno Borralho from the Genetic Improvement Program. The presentations were:-

Dr G Hodge	Introduction and theory of the use of BLP and BLUP in forestry
Ms C Raymond	Genotype by environment interactions
Dr B M Potts	Biological constraints to accurate parameter estimation and prediction of breeding values
Ms H Dungey	Genetic parameters for <i>Mycosphaerella</i> spp. damage on <i>E. nitens</i> <i>E. globulus</i> and their F ₁ hybrids
Dr N Borralho	The theory and use of BLUPs
Mr C Hardner	Inbreeding effects

Open days

"Open day at the Lewisham plantation", held on 18 March 1994, run by Dr Chris Beadle from the Soil and Stand Management Program.

Displays

Displays at CSIRO's second Double Helix Club day at the Marine Laboratories in Hobart, April 1994.

Display at Elizabeth College, November 1993.

Symposia

A symposium was held on 23 May, 1994 to inform CRC staff, company representatives and the Board of the major research developments. The presentations were:

Dr N Borralho	Improving the efficiency of breeding programs
Dr H Elliott	Controlling leaf beetles
Dr B M Potts	Breeding from <i>Eucalyptus globulus</i> .
Dr P Smethurst	Plantation nutrient supply
Dr P West	Mechanisms of thinning response
Mr D White	Physiological responses to drought



Grants and Awards to CRC staff

Genetic Improvement

Dr Nuno Borralho

Australian Postgraduate Research Award (Industry) for a PhD research project on "Selection procedures in tree breeding to maximise profitability in Australian forestry and pulp industry production systems"

Soil and Stand Management

Dr Chris Beadle

DITAC Bilateral Science and Technology Program

Visit to Australia by Dr Peter Dye \$3,500

Forests and Forest Industry Council

Pruning research and postgraduate scholarship \$26,000

ANM Forest Management

Irrigated plantations for pulpwood production \$24,500

Mr Trevor Garnett

Macquarie University, Milthorpe Memorial Award

Nitrogen uptake by roots of *E. nitens* with compaction-induced differences in morphology. \$750

Resource Protection

Dr John Madden

C. bimauculata research and PhD scholarships

Forests and Forest Industry Council \$68,871

Performance Indicators

At the end of its first three years the CRC has made excellent progress in achieving the performance indicators specified in the Commonwealth Agreement. This includes the generic indicators such as the number of international publications in refereed journals (67 in 1994) and the participation of visiting scientists of international repute in our Visiting Scientist Scheme. We achieved those indicators associated with the establishment of the Centre and building the Management structure easily within the specified periods. Outlined below are achievements against the indicators for the specified programs.

Genetic Improvement

Five specific indicators were set for this Program and four have already been achieved or exceeded during our first three years.

a) Production of reliable estimates of heritabilities and correlations between characters

- This indicator has been fulfilled since heritabilities for commercially important characters such as growth, frost resistance, insect susceptibility, *Mycosphaerella* damage, flowering time, etc have been determined in *E. globulus*, *E. nitens* and *E. regnans*. These parameters have been determined from controlled crosses as well as from open pollinated progeny where increased reliability has been developed by the inclusion of natural stand characteristics. The most extensive determination has been done with the CSIRO *E. globulus* collection whose progeny were grown over many sites across four states. Selection strategies and likely genetic gains have been determined in conjunction with the STBA.

b) Production of F₁ and F₂ hybrid seed for field plantings

- F₁ hybrid seed has been produced and planted in the field for many crosses.
- F₂ plants from *E. globulus* x *E. gunnii* are now 18 months old and an extensive F₂ crossing program for *E. globulus* x *E. nitens* has been completed.

c) Development of techniques for vegetative propagation of elite material

- An improved micropropagation procedure for elite material has been developed in conjunction with CSIRO, Division of Forestry. This has reduced the costs involved in micropropagation considerably. Field plantings have not been made, although discussions are underway with our industry partners on this matter. Due to the difficulty of propagating temperate eucalypts we are examining how propagation ability can be most cost effectively integrated into breeding strategies.

d) Reduction of generation time and determination of gibberellin (GA) biosynthetic pathway

- The GA biosynthetic pathway has been identified and the generation interval for *E. globulus* reduced to 2.8 years. This technique is now being routinely used in commercial breeding programs. Further refinement of this technique is being carried out.

e) Techniques for finger-printing eucalypts using DNA markers

- This goal has been achieved by the use of RAPD markers. Further, a linkage map has been developed for *E. globulus* x

Soil and Stand Management

E. gunnii and QLT's have been identified for branching and frost resistance, well in advance of project outcomes.

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

- A modelling system has been developed to predict photosynthetic production in relation to site environmental facts which may be used as part of a system site suitability for plantation establishment.
- The concentrations of N and P in soil solution may be used as indicators of site fertility.
- *E. globulus* is better adapted as a plantation species than *E. nitens* on sites where water availability is the major factor limiting productivity.
- Failure to control understorey development following thinning of regrowth eucalypt forest may substantially reduce the tree growth response to thinning.

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

- Effects of nutrient availability and acclimation of leaves to air temperature have been included in the model of canopy photosynthetic production to improve its accuracy.
- A canonical S-system model was developed to describe biomass yield of forests and shown to have application as part of process based models where parts of the system are poorly understood.

Resource Protection

a) Determination of the factors that predispose trees to attack by defoliating insects and mammals

- Field experiments assessing survival and growth of *C. bimaculata* 1st instar larvae, indicate that survival of such larvae is not the dominant factor influencing host-tree resistance.
- A range of plant and leaf characters, such as height, leaf toughness, oil composition and N, P, K levels, were demonstrated not to differ significantly across nine *E. regnans* families previously ranked for their resistance to *C. bimaculata*.

- Monitoring of leaf colour and oviposition suggests that leaf colour is a correlate, but is not a prime determinate of oviposition preference by adult *C. bimaculata*.

b) The development of biological control techniques to minimise damage caused by *C. bimaculata*

- The coccinellid *Cleobora mellyi* (ladybird) is the major predator of *C. bimaculata*. Studies of population dynamics suggest ladybird populations can be manipulated to reduce the numbers of *C. bimaculata*.
- Egg parasitoids of *C. bimaculata* are naturally present in low numbers but preliminary investigations suggest that if released in large numbers they may be effective as an inundative control agent.
- Aspects of the phenology, movement, local abundance, and oviposition of *C. bimaculata* have been studied and we now have a much better understanding of ecology of the species for which we are developing biological strategies.

c) Assessment of the feasibility of breeding insect tolerant genotypes of *Eucalyptus* species.

- The degree of defoliation suffered by selected families of *E. regnans* has now been demonstrated to be repeatable not only across years, but also across sites and therefore can be included in selection indices.
- Studies have shown high heritability of insect damage in *E. regnans* and *E. nitens*, indicating the potential for selecting insect resistant genotypes.

Education

a) The number of postgraduate students trained in the areas specified

- There are 24 PhD, 4 MSc and 4 Honours students enrolled at the CRC for Temperate Hardwood Forestry. This number exceeds our target of 25 students in Honours and Postgraduate study.

b) The number of enrolments in special courses

- There are 12 students enrolled in the special "Forest Ecology" course this year. This year we had our first enrolment in the "Graduate Diploma with Honours in Forest Processes" course, Ms Joanne Dingle. She is studying the interactive effects of salinity and waterlogging on the growth of 6 families of *E. globulus*.

c) The quality and numbers of postdoctoral fellows attracted

- There are now five postdoctoral fellows working with the CRC, or soon to be appointed to the CRC.
- In the Resource Protection Program, Dr Tony Clarke has played a key role, leading research in project 2 and 4 on the control of insect defoliators and the biology of other insect pests of *Eucalyptus*. A new post doctoral fellow/research fellow will be appointed in vertebrate browsing.
- In the Genetic Improvement Program, Dr Omar Hasan is identifying and quantifying gibberellins, auxins and abscisic acid in the cambial tissue of *E. globulus* with the aim of determining their effect on wood properties. A new postdoctoral fellow in vegetative propagation will start in late August on a project investigating somatic embryogenesis.
- In Soil and Stand Management, Dr Mike Battaglia has been investigating the effect of temperature acclimation and chilling injury on the photosynthesis of *E. nitens* and *E. globulus* (Project 1). Dr Battaglia was successful in securing a three year ARC fellowship at the University of Tasmania starting in July 1994 and in this capacity will continue research on forest ecology and interact with Dr Neil Davidson and Professor Jim Reid from the CRC.

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

- A PhD student with the CRC, Mr B Greaves has recently been employed in a senior management position with APM Forests. Two of our Honours graduates from 1993, Ms Andrea Manson and Mr Simon Brooks are now employed at Forestry Tasmania. Two scientists at Forestry Tasmania, Mr T Wardlaw (Forest pathologist) and Mr S Candy (Statistician) have recently enrolled in PhD courses at the CRC. A senior manager at ANM Forest Management, Mr Peter Volker is enrolled in a PhD course at the CRC. A postdoctoral fellow working with the CRC, Dr Battaglia has taken up a three year ARC fellowship in which he will study the development of mixed stands in native forests.

Communication

a) The degree of adoption of research results by industry

In the last 12 months, 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.

- Researchers in the Genetic Improvement Program have quantified the reduction in growth due to inbreeding for *E. globulus*. The impact of inbreeding on breeding strategy can now be modelled and incorporated into company practice. Also, as a result of studies of hormonal control of flowering in *Eucalyptus*, carefully measured doses of paclobutrazol are now being used to promote early flowering in seed orchard trees.
- Bruce Greaves has shown that the use of pilodyn measurements will allow estimates of basic density to be included in breeding programs in a cost effective way. These measurements are now being made in breeding populations so that they can be included in selection indices. Theoretical studies have shown that this will provide greater cost saving for pulp production than using only indices involving growth rate.
- The CRC for Temperate Hardwood Forestry, in collaboration with the Southern Tree Breeders Association (Southern Australia), is completing a national genetic evaluation of *Eucalyptus globulus* ssp *globulus* which will provide tree breeders with the first direct comparison of breeding values for growth of around 50,000 trees. The analysis includes more than 500 open pollinated families from 15 sites in Australia, grown from seed collected across the whole natural range of subspecies. The results are expected to be the basis for a national selection and breeding program for the species.
- The Resource Protection Program, in close collaboration with Forestry Tasmania, is continuing to develop the Integrated Pest Management Program which is used by Forestry Tasmania and forestry companies to control outbreaks of defoliating insects in their plantations.
- In 1992/93 the Soil and Stand Management Program identified Cu deficiencies as the cause of growth deformities in *E. nitens* plantations on sites previously receiving high rates of N and P (eg ex-pasture sites). Subsequent research has shown this deficiency to affect a small but significant number of plantation sites and companies have now employed a policy of minimum fertilisation on ex-pasture sites.

b) The quality and relevance of technical publications targetted to user groups

- During the last year scientists and students working for the CRC have produced 41 refereed publications and 26 unrefereed publications which includes 11 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 and their existence is

highlighted in quarterly research summaries and in the future will also be highlighted in the CRC newsletter, "Overstorey".

- A booklet entitled "Research Profiles of scientists at the CRC for Temperate Hardwood Forestry", produced in the last reporting period, was distributed this year and is helping to establish links between CRC scientists on the University campus and those in industry.

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

- A very successful workshop on "Quantitative genetics applied to tree breeding" which attracted participants from throughout Australia was run from 24-26 November 1993 in Hobart by the Genetic Improvement Program. This had to be limited to invited delegates because of demand.
- An open day was held at a plantation of *E. nitens* and *E. globulus* genotypes at Lewisham on 18 March 1994. Results of studies conducted on water relations and photosynthesis were described by the researchers involved. The open day was organised by the Soil and Stand Management Program and attracted 50 participants.
- A symposium was held on 23 May, 1994 to inform CRC staff, company representatives and the Board of the major research developments.
- A three day course on 'Reproductive Biology of *Eucalyptus* and application to breeding' was presented by Dr Brad Potts at the Universidad Austral de Chile. It was organised by the Cooperative de Mejoramiento Genetico Forestal, Universidad Austral de Chile, Facultad de Ciencias Forestales, Valdivia, Chile.



BUDGET

Tables:

- 1) In-kind contributions from partners
- 2) Cash contributions and expenditure
- 3) Summary of resources applied to activities of centre
- 4) Allocation of resources between categories of activities

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

TABLE 1

EXPENDITURE

PARTNER	Cumulative to date Actual	ACTUAL			PROJECTED			GRAND TOTAL	
		1991/92	1992/93	1993/94 Actual	1993/94 Budget	1994/95	1995/96		1996/97
CSIRO DIVISION OF FORESTRY									
SALARIES	1,755.9	531.4	610.9	613.6	544.8	625.7	638.1	651.1	664.2
CAPITAL									
OTHER	2,976.8	900.4	1,033.9	1,042.5	907.2	1,058.6	1,080.3	1,100.7	1,122.7
TOTAL	4,732.7	1,431.8	1,644.8	1,656.1	1,452.0	1,684.3	1,718.4	1,751.8	1,786.9
UNIVERSITY OF TASMANIA									
SALARIES	1,226.8	488.5	407.7	330.6	758.1	337.2	344.0	350.8	357.9
CAPITAL	40.0	40.0							40.0
OTHER	1,838.8	648.7	636.6	553.5	672.4	564.6	575.9	587.4	599.1
TOTAL	3,105.6	1,177.2	1,044.3	884.1	1,430.5	901.8	919.9	938.2	957.0
ANM FOREST MANAGEMENT									
SALARIES	85.0	21.0	26.0	38.0	26.0	34.0	35.0	36.0	37.0
CAPITAL									
OTHER	188.0	28.0	62.0	98.0	104.0	121.0	125.0	130.0	132.0
TOTAL	273.0	49.0	88.0	136.0	130.0	155.0	160.0	166.0	169.0
NORTH FORESTS									
SALARIES	193.9	64.0	59.3	70.6	64.0	69.5	69.7	77.1	77.1
CAPITAL									
OTHER	336.1	107.0	103.7	125.4	182.0	125.4	125.4	125.4	125.4
TOTAL	530.0	171.0	163.0	196.0	246.0	194.9	195.1	202.5	202.5

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

TABLE 1 CONT

EXPENDITURE

PARTNER	ACTUAL			PROJECTED					GRAND TOTAL
	1991/92	1992/93	1993/94 Actual	1993/94 Budget	1994/95	1995/96	1996/97	1997/98	
FOREST RESOURCES	Cumulative to date								
	Actual	Budget							
	88.7	153.0							211.5
SALARIES	39.6	24.1	25.0	51.0	30.7	30.7	30.7	30.7	
CAPITAL									
OTHER	50.1	42.6	26.7	112.0	51.1	51.1	51.1	51.1	323.8
TOTAL	89.7	66.7	51.7	163.0	81.8	81.8	81.8	81.8	535.3
FORESTRY TASMANIA	Cumulative to date								
	Actual	Budget							
	173.5	84.0							459.0
SALARIES	47.2	57.3	69.0	28.0	70.4	71.1	71.7	72.3	
CAPITAL									
OTHER	61.0	64.6	78.1	69.0	80.2	81.0	81.9	82.7	529.5
TOTAL	108.2	121.9	147.1	97.0	150.6	152.1	153.6	155.0	988.5
APM FORESTS	Cumulative to date								
	Actual	Budget							
	236.7	236.0							711.1
SALARIES		118.1	118.6	118.0	118.6	118.6	118.6	118.6	
CAPITAL									
OTHER		81.0	60.6	60.0	60.6	60.6	60.6	60.6	384.0
TOTAL		199.1	179.2	178.0	179.2	179.2	179.2	179.2	1,095.1
TOTAL IN-KIND CONTRIBUTIONS	Cumulative to date								
	Actual	Budget							
	3,760.5	4,463.4							9,047.6
SALARIES	1,191.7	1,303.4	1,265.4	1,589.9	1,286.1	1,307.2	1,336.0	1,357.8	40.0
CAPITAL	40.0								
OTHER	1,795.2	2,024.4	1,984.8	2,106.6	2,061.5	2,099.3	2,137.1	2,173.6	14,275.9
TOTAL	3,026.9	3,327.8	3,250.2	3,696.5	3,347.6	3,406.5	3,473.1	3,531.4	23,363.5

CASH CONTRIBUTIONS (\$000's)

TABLE 2

PARTNERS	ACTUAL				PROJECTED				GRAND TOTAL
	1991/92	1992/93	1993/94 Actual	1993/94 Budget	1994/95	1995/96	1996/97	1997/98	
A CSIRO Division of Forestry									
B University of Tasmania	500.0								500.0
C Forestry Tasmania									
D North Forests									
E ANM Forest Management		20.0	20.0		25.0	20.0	20.0	20.0	125.0
F Forest Resources									
G GPM Forests									
TOTAL CASH FROM PARTICIPANTS	500.0	20.0	20.0	20.0	25.0	20.0	20.0	20.0	625.0
INTEREST	10.5	68.6	25.0		48.3	36.2	14.2	2.0	204.8
OTHER EXTERNAL FUNDS			1.8						1.8
FUNDING FROM THE CRC GRANT	948.6	1,448.5	1,723.5	1,600.0	1,745.7	1,756.0	1,772.1	1,635.4	11,029.8
TOTAL CRC CASH CONTRIBUTION	1,459.1	1,537.1	1,770.3	1,600.0	1,819.0	1,812.2	1,806.3	1,657.4	11,861.4
Cash carried over from previous year		1,163.4	876.1		961.0	695.1	262.3	28.4	
Less unspent balance	1,163.4	876.1	961.0		695.1	262.3	28.4	0.0	
TOTAL CASH EXPENDITURE	295.7	1,824.4	1,685.4	1,600.0	2,084.9	2,245.0	2,040.2	1,685.8	11,861.4
ALLOCATION OF CASH EXPENDITURE BETWEEN HEADS OF EXPENDITURE									
SALARIES	118.8	636.1	1,079.6	1,247.0	1,427.3	1,509.8	1,385.0	1,140.7	7,297.3
CAPITAL		500.0	62.0						562.0
OTHER	176.9	688.3	543.8	353.0	657.6	735.2	655.2	545.1	4,002.1

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

TABLE 3

EXPENDITURE

ALL PROGRAMS	EXPENDITURE										GRAND TOTAL
	ACTUAL					PROJECTED					
	1991/92	1992/93	1993/94	1993/94	1993/94	1994/95	1995/96	1996/97	1997/98		
GRAND TOTAL (IN-KIND)	Cumulative to date				Budget						
	Actual	9,604.9	10,795.2	3,250.2	3,696.5	3,347.6	3,406.5	3,473.1	3,531.4		23,363.5
GRAND TOTAL (CASH EXPENDITURE)		3,805.5	3,760.0	1,685.4	1,600.0	2,084.9	2,245.0	2,040.2	1,685.8		11,861.4
	TOTAL RESOURCES APPLIED TO ACTIVITIES OF CENTRE	13,410.4	14,555.2	4,935.6	5,296.5	5,432.5	5,651.5	5,513.3	5,217.2		35,224.9

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

TOTAL SALARIES (CASH AND IN-KIND)	1,310.5	1,939.5	2,345.0	2,836.9	2,713.5	2,817.0	2,721.0	2,498.5		16,345.0
TOTAL CAPITAL (CASH AND IN-KIND)	40.0	500.0	62.0							602.0
TOTAL OTHER (CASH AND IN-KIND)	1,972.1	2,712.7	2,528.6	2,459.6	2,719.0	2,834.5	2,792.3	2,718.7		18,277.9

TABLE 4

Allocation of resources between categories of activities (1993/94)

PROGRAM	RESOURCE USAGE			
	Cash \$000's	In-kind \$000's	Staff Contributed	Staff funded by CRC
Research	1,496.1	3,214.2	12.4	9.1
Education	66.7	8.0	0.2	0.5
Commercialisation/ tech Transfer				
Administration	122.6	28.0	0.4	
TOTAL	1,685.4	3,250.2	13.0	9.6

AUDITORS REPORT

Price Waterhouse



**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 3 of the Annual Report for the year ended 30 June 1994 as required by clause 14(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.



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

1. The Researcher's Contributions were made in accordance with the Budget as specified in the Agreement and their value has equalled or exceeded the amount of the Grant [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 5(2)

The Researcher's allocations of the budgetary resources between Heads of Expenditure has been higher than the allocation in the Budget by \$100,000 or 20%(whichever is the greater amount) without prior approval by the Committee. Other expenditure of \$544,000 was higher than the Budget of \$353,000.



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 1994 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.

A handwritten signature in cursive script, appearing to read 'Price Waterhouse'.

Price Waterhouse
Chartered Accountants

Hobart
26 August 1994

A handwritten signature in cursive script, appearing to read 'Steven A Hernyk'.

Steven A Hernyk
Partner

CRC TEMPERATE AND HARDWOOD FORESTRY

Notes to and forming part of the accounts

Summary of significant accounting policies

All funds under the Co-operative Research Centre's control are administered through the University of Tasmania 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.

(d) Employee entitlements

Provision has not been made for pro-rata entitlements to annual and long service leave.

PARTNER CONTRIBUTIONS

Cumulative to date 1991/92 1992/93 1993/94 1993/94 1994/95 1995/96 1996/97 1997/98 TOTAL

OTHER

% of Total Salaries
& On -Costs

	Cumulative to date	1991/92	1992/93	1993/94	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
	Actual	Actual	Budget	Actual	Budget					
* Head Office overheads		14.8	16.4	19.6		19.9	20.2	20.4	20.6	111.3
* Office Support		9.7	10.7	13.1		13.4	13.6	13.7	13.9	88.1
* Office Hire		7.7	8.6	10.4		10.6	10.7	10.8	10.9	69.7
Operational		28.8	28.9	35.0		36.3	36.5	37.0	37.3	239.8
* Not applied to technical salaries										
Total Other	203.7	61.0	64.6	78.1	69.0	80.2	81.0	81.9	82.7	529.5
TOTAL IN-KIND CONTRIBUTION	377.2	108.1	121.9	147.1	97.0	150.6	152.1	153.6	155.0	988.4

CRC FOR TEMPERATE HARDWOOD FORESTRY

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

SALARIES

FOREST RESOURCES

Name	Designation	Program	% time CRC	Cumulative to date		1991/92	1992/93	1993/94 Actual	1993/94 Budget	1994/95	1995/96	1996/97	1997/98	TOTAL
				Actual	Budget									
NAUGHTON, P	Scientist	SSM	20											
NAUGHTON, P	Scientist	Genet	10											
BADKIN, P	Technician	Genet	5											
GORDON, V	Scientist	Genet	20											
FRENCH, S	Technician	Genet	5											
QU, M	Technician	Genet	5											
NAUGHTON, P	Scientist	RPP	5											
NAUGHTON, P	Scientist	Educ	2											
Total Salary				69.8	120.4	31.1	19.0	19.7	40.2	24.1	24.1	24.1	24.1	166.2

% of total Salary

Direct On-Costs	4.9	2.2	1.3	1.4	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	11.7
Payroll tax	3.7	1.7	1.0	1.0	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	8.5
Superannuation	3.5	1.6	0.9	1.0	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	8.3
Workers Compensation	5.6	2.5	1.5	1.6	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	13.6
Leave Loading	1.3	0.6	0.4	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	3.3
Long Service Leave														
Other														
Total On-Costs	18.9	32.6	8.5	5.1	5.3	10.8	6.6	6.6	6.6	6.6	6.6	6.6	6.6	45.3
Total Salaries & On-Costs	88.7	153.0	39.6	24.1	25.0	51.0	30.7	30.7	30.7	30.7	30.7	30.7	30.7	211.5

CAPITAL

Total Capital														
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OTHER

% of Total Salaries & On-Costs

Head Office Overheads	11.7	4.8	3.9	3.0	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	26.1
Office Support	54.7	19.1	23.5	12.1	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	113.9
Office Hire														
Laboratory Rent Experiments	53.1	26.3	15.2	11.6	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	183.9
Total Other	119.4	536.0	50.1	42.6	26.7	112.0	51.1	51.1	51.1	51.1	51.1	51.1	51.1	323.8
TOTAL IN-KIND CONTRIBUTION	208.1	489.0	89.7	66.7	51.7	163.0	81.8	81.8	81.8	81.8	81.8	81.8	81.8	535.4

CRC FOR TEMPERATE HARDWOOD FORESTRY
Itemised List of In-Kind Contributions (\$'000's)

UNIVERSITY OF TASMANIA

SALARIES Name	Designation	Program	% time CRC	Cumulative to date		1991/92		1992/93		1993/94		1994/95		1995/96		1996/97		1997/98		TOTAL	
				Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget						
REID, J	Scientist	Genet	50																		
DUNGEY, H	Student	Genet	100																		
GORST, J	Scientist	Genet	10																		
BOBEL, P	Technician	Genet	40																		
HARDNER, C	Student	Genet	100																		
HAIG, G	Technician	Genet	20																		
THOMSON, B	Technician	Genet	10																		
MENARY, R	Scientist	Genet	10																		
WEST, A	Scientist	Genet	5																		
JORDON, G	Scientist	Genet	50																		
MADDEN, J	Scientist	Prot	30																		
STODDART, M	Scientist	Prot	20																		
UNWIN, G	Scientist	Educ	20																		
WILTSHIRE, R	Scientist	SSM	20																		
CLARKE, R	Scientist	SSM	10																		
Total Salary				763.5	1,405.1			324.1	270.5	168.9	503.0	172.3	175.7	179.2	182.8	1,473.6					

Direct On-Costs

	% of total Salary
Payroll tax	7
Superannuation	17
Workers Compensation	1
Leave Loading	1.4
Long Service Leave	3.17
Outside Study-Academics	21.15
HECS/Student contribns	
Total On-Costs	

Total Salaries & On-Costs

53.4	22.7	18.9	11.8	12.0	12.3	12.5	12.8	103.0
129.8	55.1	46.0	28.7	29.3	29.9	30.5	31.1	250.5
7.6	3.2	2.7	1.7	1.7	1.8	1.8	1.8	14.8
10.7	4.5	3.8	2.4	2.4	2.5	2.5	2.6	20.8
24.3	10.3	8.6	5.4	5.5	5.6	5.7	5.8	47.0
153.7	68.5	57.2	28.0	28.6	29.1	29.7	30.3	271.5
83.7			83.7	85.4	87.1	88.8	90.6	435.6
463.3	164.4	137.2	161.7	255.1	168.2	171.6	175.0	1,143.1
1,226.8	488.5	407.7	330.6	758.1	344.0	350.8	357.9	2,616.7

CAPITAL

40.0	40.0							
40.0	40.0							40.0
								40.0

OTHER	% of Total Salaries & On-Costs	Cumulative to date		1991/92	1992/93	1993/94	1993/94	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
		Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget
Academic Services	25	306.6		122.1	101.9	82.6		84.3	85.9	87.7	89.4	653.9	
General Univ Services	41	503.0		200.3	167.2	135.5		138.2	141.0	143.8	146.7	1,072.6	
Dept Office Support	10	122.6		48.8	40.8	33.0		33.7	34.3	35.0	35.7	261.4	
Laboratory Rent	32	392.6		156.3	130.5	105.8		107.9	110.1	112.3	114.5	837.4	
Office Space	8	98.1		39.1	32.6	26.4		26.9	27.5	28.0	28.6	209.1	
Central Science Laboratory		163.2		0.0	80.0	83.2		84.9	86.6	88.3	90.1	513.0	
Management Agency		252.6		82.0	83.6	87.0		88.7	90.5	92.3	94.2	618.4	
Total Other		1,838.8	2,029.8	648.7	636.6	553.5	672.4	564.6	575.9	587.4	599.1	4,165.7	
TOTAL IN-KIND CONTRIBUTION		3,105.6	4,187.6	1,177.2	1,044.3	884.1	1,430.5	901.8	919.9	938.2	957.0	6,822.4	

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

CSIRO DIVISION OF FORESTRY

SALARIES

Name	Designation	Program % time	CRC	Cumulative to date		1991/92		1992/93		1993/94		1993/94		1994/95		1995/96		1996/97		1997/98		TOTAL
				Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget			
BEADLE, Dr. C	Scientist		70																			
CROMER, Mr R	Scientist		40																			
LASALA, Ms A	Technician		50																			
MUMMERY, Mr D	Scientist		30																			
OTTENSCHLAEGER, Ms M	Technician		100																			
SANDS, Dr. P	Scientist		100																			
TURNBULL, Mr. C	Scientist		70																			
WEST, Dr P	Scientist		80																			
WILTSHIRE, Mr D	Technician		40																			
DENTON, Mr B	Technician		20																			
HAND, Mr F	Technician		100																			
HARTNEY, Mr V	Scientist		70																			
MONCUR, Mr M	Scientist		20																			
OWEN, Mr J	Scientist		40																			
RAYMOND, Ms C	Scientist		100																			
SVENSSON, Mr J	Technician		70																			
Total Salary				1,397.8	1,302.9	421.2	484.2	492.4	442.9	502.2	512.3	522.5	533.0	3,910.7								

Direct On-Costs	% of total Salary	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Superannuation	16.7	70.3	80.8	82.1	83.8	85.6	87.2	89.0	578.8														
Productivity Benefit	3	12.6	14.5	14.8	15.0	15.0	15.7	16.0	103.6														
Workers Compensation	0.9			4.5	4.6	4.6	4.8	4.8	23.3														
Long Service Leave	2.5	10.5	12.1	12.4	12.6	12.9	13.1	13.4	87.0														
Leave Loading	1.5	6.3	7.2	7.4	7.5	7.7	7.8	8.0	51.9														
Other		10.5	12.1	0.0	0.0	0.0	0.0	0.0	22.6														
Total On-Costs		110.2	126.7	121.2	123.5	125.8	128.6	131.2	867.2														

Total Salaries & On-Costs	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Salaries & On-Costs	1,755.9	1,602.6	531.4	610.9	613.6	544.8	625.7	638.1	651.1	664.2	4,335.0										

Cumulative to date 1991/92 1992/93 1993/94 1993/94 1993/94 1994/95 1995/96 1996/97 1997/98 TOTAL

Actual Budget Actual Budget

CAPITAL

Total Capital

OTHER

% of Total Salaries
& On -Costs

Divisional Administration/Support	96	1,685.7		510.3	586.4	589.0	600.7	612.8	625.0	637.6	4,161.8
Institute Overheads	9	158.1		47.8	55.0	55.3	56.3	57.9	58.6	59.8	390.7
Corporate Overheads	24	421.4		127.6	146.5	147.3	150.1	153.3	156.2	159.5	1,040.5
Amortised Capital Costs	37	649.7		196.7	226.0	227.0	231.5	236.3	240.9	245.8	1,604.2
Direct Operating		61.9		18.0	20.0	23.9	20.0	20.0	20.0	20.0	141.9

Total Other

2,976.8	2,741.0	900.4	1,033.9	1,042.5	907.2	1,058.6	1,080.3	1,100.7	1,122.7	7,339.1
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TOTAL IN-KIND CONTRIBUTION

4,732.7	4,343.6	1,431.8	1,644.8	1,656.1	1,452.0	1,684.3	1,718.4	1,751.8	1,786.9	11,674.1
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CRC FOR TEMPERATE HARDWOOD FORESTRY
Itemised List of In-Kind Contributions (\$'000's)

APM FORESTS

SALARIES

Name	Designation	Program	CRC	% time Cumulative to date		1991/92	1992/93	1993/94	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
				Actual	Budget									
CAMERON, J	Scientist	Genet	5											
WHITEMAN, P	Scientist	Genet	20											
KRYGSMAN, M	Scientist	Genet	40											
APPLETON, R	Technician	Genet	15											
PYE, C	Technician	Genet	20											
CAMERON, J	Scientist	SSM	5											
WHITEMAN, P	Scientist	SSM	10											
KRYGSMAN, M	Scientist	SSM	20											
APPLETON, R	Technician	SSM	5											
CAMERON, J	Scientist	Prot	5											
WHITEMAN, P	Scientist	Prot	5											

103.1	102.6	51.3	51.8	51.3	51.8	51.8	51.8	51.8	51.8	51.8	51.8	51.8	51.8	310.3
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Direct On-Costs % of total Salary

Payroll tax														
Superannuation														
Workers Compensation														
Leave Loading														
Long Service Leave														
Other														

133.6	133.4	66.8	66.8	66.7	66.8	66.8	66.8	66.8	66.8	66.8	66.8	66.8	66.8	400.8
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236.7	236.0	118.1	118.6	118.0	118.6	118.6	118.6	118.6	118.6	118.6	118.6	118.6	118.6	711.1
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CAPITAL

Total Capital

OTHER	% of Total Salaries & On-Costs		Cumulative to date		1991/92	1992/93	1993/94	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL	
	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget
Head office overheads														
Office Support														
Office Hire														
Operational														
Total Other	141.6	120.0	81.0	60.6	60.0	60.6	60.6	60.6	60.6	60.6	60.6	60.6	384.0	
TOTAL IN-KIND CONTRIBUTION	378.3	356.0	199.1	179.2	178.0	179.2	179.2	179.2	179.2	179.2	179.2	179.2	1,095.1	

CRC FOR TEMPERATE HARDWOOD FORESTRY
Itemised List of In-Kind Contributions (\$'000's)

ANM FOREST MANAGEMENT

SALARIES Name	Designation	Program	% time	Cumulative to date		1991/92	1992/93	1993/94	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
				CRC	% time									
VOLKER, P	Scientist	Genet	40											
HETHERINGTON, S	Scientist	RPP	5											
HETHERINGTON, S	Scientist	SSM	15											
Total Salary				67.0	78.0	17.0	21.0	29.0	26.0	29.0	30.0	31.0	32.0	189.0
Direct On-Costs														
			% of total salary											
Payroll tax														
Superannuation														
Workers Compensation														
Leave Loading														
Long Service Leave														
Other														
Total On-Costs			30.9	18.0		4.0	5.0	9.0	26.0	5.0	5.0	5.0	5.0	38.0
Total Salaries & On-Costs				85.0	78.0	21.0	26.0	38.0	26.0	34.0	35.0	36.0	37.0	227.0
CAPITAL														
TOTAL CAPITAL														
OTHER														
Office Support				30.0		11.0	9.0	10.0		10.0	10.0	12.0	11.0	73.0
Experiments (land rent)				63.0		10.0	25.0	28.0		30.0	32.0	33.0	34.0	192.0
Trial Maintenance				75.0		0.0	22.0	53.0		54.0	56.0	58.0	59.0	302.0
Vehicle Costs				20.0		7.0	6.0	7.0		7.0	7.0	7.0	8.0	49.0
Cash Contribution				40.0						20.0	20.0	20.0	20.0	80.0
Total Other				188.0	312.0	28.0	62.0	98.0	104.0	121.0	125.0	130.0	132.0	696.0
TOTAL IN-KIND CONTRIBUTION				273.0	390.0	49.0	88.0	136.0	130.0	155.0	160.0	166.0	169.0	923.0

530.0 738.0

171.0 163.0 196.0

246.0 194.9

195.1 202.5

202.5 202.5

1,325.0

ATTACHMENT C

CENTRE STAFF

ATTACHMENT C

RESEARCH STAFF RESOURCES (1993/94)

ANIM	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				
VOLKER, P		R	40	40			40			
HETHERINGTON, S		R	20	0	15	5	20			
Total			60	40	15	5	60			

APM	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				
CAMERON, J		R	15	5	5	5	15			
WHITEMAN, P		R	35	20	10	5	35			
KRYGSMAN, M		R	60	40	20		60			
Total			110	65	35	10	110			

North Forests	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				
DE LITTLE, D		R	10			10	10			
TIBBITS, W		R	30	30			30			
RASMUSSEN, G		R	40	40			40			
HOLZ, G		R	10		10		10			
Total			90	70	10	10	90			

Forest Resources	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				
NAUGHTON, P		R	37	10	20	5	35	2		
GORDON, V		R	20	20			20			
Total			57	30	20	5	55	2		

Forestry Tasmania	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				
ELLIOTT, H		R	15			15	15			
GREENER, A		R	50			50	50			
PARSONS, S		R	50			50	50			
KUBE, P		R	20	20			20			
Total			135	20		115	135			

Employer	Main activity	Total % time	% spent on Research Program			Total on Research	% Spent on			
			Gen	SSM	Prof		Commercialisation Program	Education	Administration	
CSIRO, Forestry										
BEADLE, C	R	70		70		70				
CROMER, R	R	40		40		40				
MUMMERY, D	R	30		30		30				
SANDS, P	R	100		100		100				
TURNBULL, C	R	70		70		70				20
WEST, P	R	80		60		60				
HARTNEY, V	R	70	70			70				
MONCUR, M	R	20	20			20				
OWEN, J	R	40	40			40				
RAYMOND, C	R	100	100			100				20
Total		620	230	370		600				20

University of Tasmania									
Employer	Main activity	Total % time	Gen	SSM	Prof	Total on Research	% spent on Education	% Spent on Commercialisation Program	% spent on Administration
REID, J	R	50	30			30			20
GORST, J	R	10	10			10			
MENARY, B	R	10	10			10			
WEST, A	R	5	5			5			
MADDEN, J	R	30			30	30			
STODDART, M	R	20			20	20			
JORDON, J	R	50	50			50			
WILTSHIRE, R	R	20		20		20			
UNWIN, G	R	20				0	20		
CLAPKE, R	R	10		10		10			
Total		225	105	30	50	185	20		20

CRC funded

	Employer	Main activity	Total % time	% spent on			Total on Research	% Spent on	
				Research Program				Commercialisation Program	% spent on Administration
				Gen	SSM	Prot			
CLARKE, A	Uni Tas	R	100			100			
VAILLANCOURT, R	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			
HASAN,O	Uni Tas	R	100		100	100			
POTTS, B	Uni Tas	R	100		100	100			
BORRALHO, N	Uni Tas	R	100		100	100			
OSLER, G	Uni Tas	R	80		80	80			
BATTAGLIA, M	Uni Tas	R	80		80	80			
Total			960	400	410	100	910	50	

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
	Research program						
	Gen	SSM	Prot				
13.0	5.6	4.8	2.0	12.4	0.2		0.4
9.6	4.0	4.1	1.0	9.1	0.5		
22.6	9.6	8.9	3.0	21.5	0.7		0.4
100.0	42.5	39.4	13.2	95.1	3.1		1.8

Total Contributed

Total funded by CRC

Grand total

Proportion of total professional (%) staff resources in each activity

SUPPORT STAFF

Contributed	
Organisation	Number of staff (person years)
ANM	0.0
APM	0.4
North Forests	1.0
Forest Resources	0.2
Forestry Tasmania	1.1
CSIRO	3.8
University of Tasmania	0.7
Total	7.2

CRC Funded (by employing organisation)	
Organisation	Number of staff (person years)
CSIRO	0.8
University of Tasmania	10.5
Total	11.3



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