COOPERATIVE RESEARCH CENTRE FOR TEMPERATE HARDWOOD FORESTRY

ANNUAL REPORT 1992/93

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

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Cover: "Establishing Eucalypt Plantations". Field tour of Southern Forests conducted by Dr C Beadle, April 1993 (Soil and Stand Management Program)

Left: APPM Pruning Trial

Executive Summary

Professor J Reid
Director

The 1992-1993 year has been one of substantial development for the Cooperative Research Centre for Temperate Hardwood Forestry. Our mission has remained focused on four strategic objectives. These are to:

- develop forest management systems to increase and sustain wood production in hardwood forests in an environmentally sensitive way;
- improve wood quality from hardwood forests to ensure its market suitability for efficient value-added processing;
- establish a national centre of excellence for post-graduate training with emphasis on research in tree genetic improvement and resource protection; and
- develop a national centre for promoting innovation in eucalypt forestry.

The Centre and the new CSIRO/CRC building was officially opened by the Prime Minister, Mr Paul Keating, in August 1992. Full displays of the Centre's activities were on view for the 127 guests which included the Premier of Tasmania, Mr Ray Groom; the Minister for Justice, Senator Michael Tate; the State Minister for Forests, Mr Anthony Rundle; the Shadow State Minister for Forests, Mr David Llewellyn; Mr Duncan Kerr MHR and Senator Paul Calvert.

The Centre has expanded its national role as a centre of forestry excellence and innovation by attracting additional new industry members. APM Forests formally joined the CRC from 1 July 1992 by completion of a Deed of Novation and Bunnings Treefarms formally applied to join the CRC at the Board meeting held in May 1993. This will mean that the plantation sites of our industrial partners will be spread throughout temperate Australia from Western Australia to Tasmania.

The Centre has appointed all except one of its new staff. All appointees are of the highest quality and include scientists recruited nationally, eg Drs Anthony Clarke (Entomologist) and Rabi Misra (Root Scientist) and from overseas, Dr Nuno Borralho (Quantitative Geneticist). They complement the existing strengths of the staff from the CRC parties in the three research programs, Genetic Improvement, Soil and Stand Management and Resource Protection.

We are also fortunate to have recruited an excellent group of post-graduate students from across Australia and overseas. The Centre now has 21 students enrolled in PhD and MSc projects and an additional 8 Honours students. This growth brings the Centre up to its full student target after only two years.

Two symposia were held during the year encompassing all programs within the Centre. One allowed Centre staff to present to our industry partners the aims, objectives and proposed outcomes of the individual projects being undertaken, while the second gave our industry partners the opportunity to outline their strategic objectives and requirements from research and development programs. These symposia provided members of our Industry Research Coordination Committee (IRCC) and Scientific Review Committee (SRC) an opportunity to provide input directly to our research programs and to foster new collaborative projects.

Two successful short courses were also held. One was aimed at private landowners and dealt with the establishment of eucalypt plantations while the second was aimed at researchers from around the country and dealt with strategies for early selection of superior trees to enhance breeding programs.

Major highlights of the research programs for 1992-1993 include:

- Determination of the pattern of genetic diversity in the *Eucalyptus globulus* complex.
- The identification of superior families of *E. globulus* based on two and four year growth data from the 600-family CSIRO *E. globulus* collection.
- Isolation of gibberellins A20, A1 and A29 from cambial tissue of *E. globulus* in collaboration with the CRC for Hardwood Paper and Fibre Science.
- Demonstration of the major impact of inbreeding on the performance of *E. globulus*.
- Finding that copper deficiency may seriously affect plantation growth on highly fertile sites.
- Indications that at some sites fertiliser applied at planting may be wasted and application should be deferred.
- Development of an efficient algorithm to predict annual canopy photosynthetic production from single-leaf, instantaneous light response curves.
- Completion of a study of eucalypt leaf terpenoids and waxes and their relevance to insect feeding and oviposition.
- Quantification of defoliation levels for inclusion in the development of a model of herbivory and tree yield.
- The coreid bug *Amorbus rubiginosus* was cultured under laboratory conditions for the first time.

Management

Participating Bodies

The **Participating Bodies** in the CRC for Temperate Hardwood Forestry are:

- CSIRO Division of Forestry,
- University of Tasmania,
- Associated Pulp and Paper Mills (APPM),
- Australian Newsprint Mills (ANM),
- Forestry Commission, Tasmania.
- Forest Resources,
- Australian Paper Manufacturers (APM)

The Board

The **Board of Management of the CRC** (Figure 1) is comprised of an independent chairman, Mr John Allwright AO, the Director and Deputy Director of the CRC and a representative from each participating body. There have been changes to the Board in recent months, with the addition of one new partner, APM and personnel changes within participating companies. Mr Neil Humphreys replaced Mr Steve Balcombe as the representative for ANM, Mr Ross Waining replaced Mr Des King for Forest Resources and Mr John Cameron is the representative for APM Forests. The Board determines policy guidelines and sets guidelines for the efficient running of the Centre.

Structure

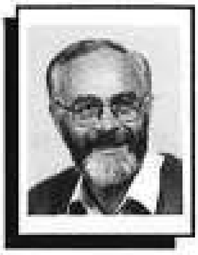
The **Management Structure** of the CRC is headed by the Board and links are depicted in Figure 2. Operation of the four programs is directed through three committees: the Management Committee, the Industrial Research Coordination Committee and the Scientific Review Committee.

The new CSIRO/CRC building,
on campus at the University of Tasmania.

Figure 1 Board of Management of the CRC

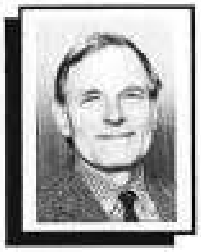
Mr John Allwright, AO
Chairman

Professor Jim Reid
Director

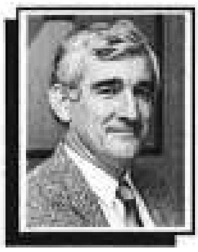


Dr Phil West
Deputy Director

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

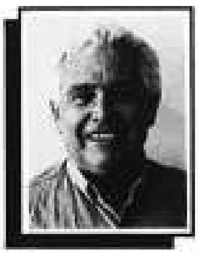


Mr Ken Felton
Commissioner (Management)
Forestry Commission,
Tasmania



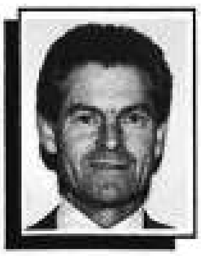
Mr Ian Whyte
Executive Forester,
APPM, Forest Products

Dr Glen Kile
Chief, CSIRO
Division of Forestry



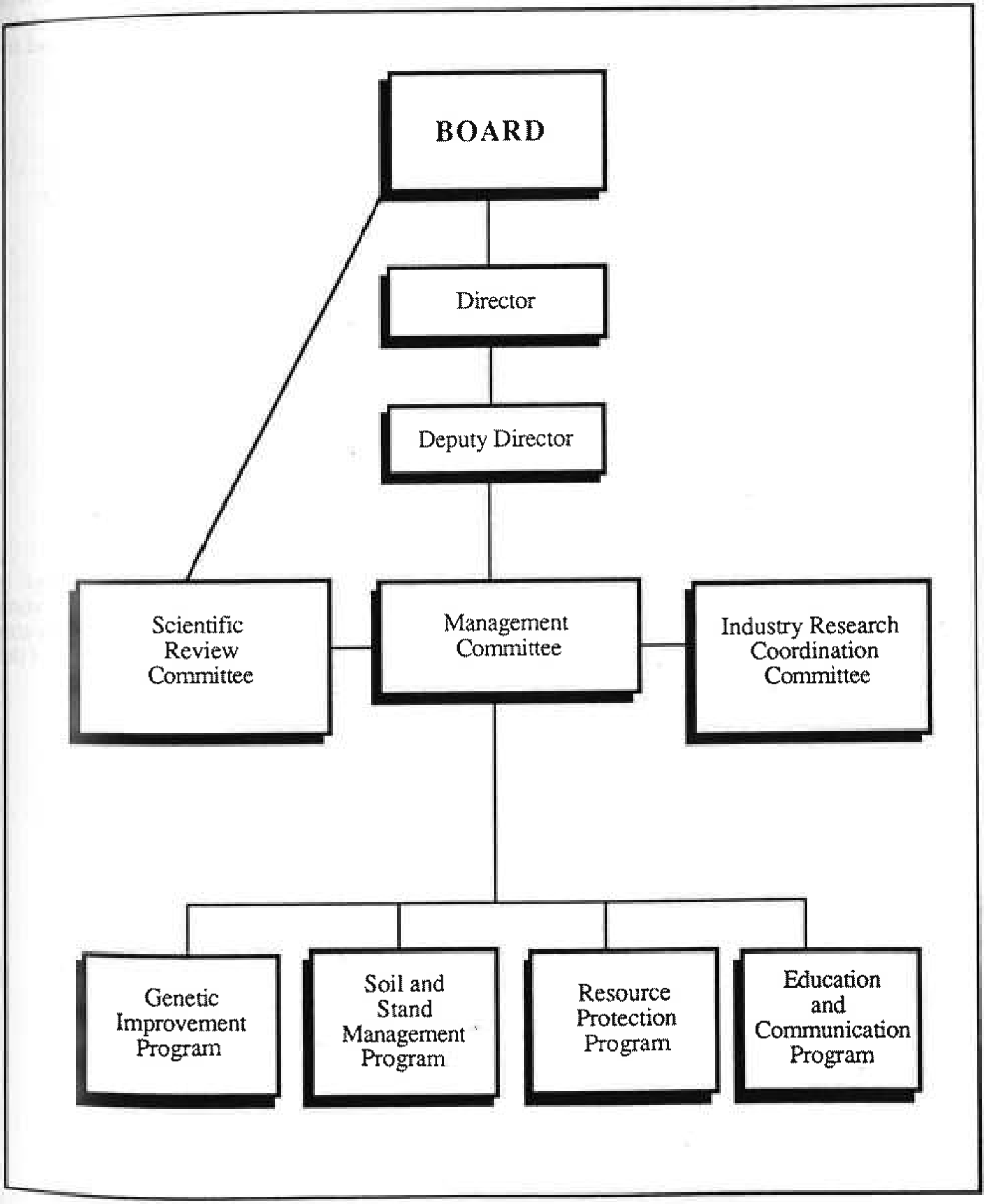
Mr Neil Humphreys
General Manager
ANM, Forest Management

Mr Ross Waining
General Manager
Forest Resources



Mr John Cameron
Development Manager
APM, Forests Pty Ltd

Figure 2 Management Structure of the CRC



Management Committee

The **Management Committee** resolves issues associated with the day to day running of the CRC and is comprised of the Administrative Officer, Program Managers, the Director and the Deputy Director.

Mrs Carol Blake	-	Administrative Officer
Prof Jim Reid	-	Genetic Improvement Program, Director
Dr Phil West	-	Soil and Stand Management Program, Deputy Director
Dr John Madden	-	Resource Protection Program
Dr Neil Davidson	-	Education and Communication Program

Industry Research Coordination Committee

The **Industry Research Coordination Committee** is comprised of Senior Research Scientists from all participating organisations and enables representatives from the Forestry Industry to have a direct input into the direction and scope of the research conducted by the CRC.

Dr Humphrey Elliott	-	Chief, Division of Silvicultural Research and Development, Forestry Commission, Tasmania
Dr David de Little	-	Research Manager, APPM Forest Products
Mr Peter Volker	-	Research Manager, ANM Forest Management
Mr Peter Naughton	-	Research Manager, Forest Resources
Mr Phil Whiteman	-	Research 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

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 and a representative from the CRC for Hardwood Fibre and Paper Science. The Board finalised this Committee in 1992 and it comprises the following personnel:

Dr Garth Nikles	-	Officer in Charge Treebreeding, Queensland Dept of Primary Industries, Forest Service. (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)
Dr Geoffrey Gartside	-	Co-Director, CRC for Hardwood Fibre and Paper Science, Clayton, Victoria.

Strong links have now been established between the CRC for Temperate Hardwood Forestry and the CRC for Hardwood Fibre and Paper Science. The CRC for Hardwood Fibre and Paper Science is developing technologies to allow for rapid screening of samples to gain reliable estimates of parameters for important wood and fibre traits and will rely on advice from the CRC for Temperate Hardwood Forestry in seeking suitable trials for sampling and genetic analysis of the data. To this end Ms C Raymond from the CRC for Temperate Hardwood Forestry is a member of the Program Advisory Committees of the CRC for Hardwood Fibre and Paper Science. Fifty percent of her time is allocated to a project assessing the genetic parameters associated with wood fibre traits. The Director of the CRC for Temperate Hardwood Forestry also sits on their Scientific Review Committee. These links are also supported by the PhD study of Mr Bruce Greaves at the CRC for Temperate Hardwood Forestry which investigates correlations between the properties of wood of different ages within the same tree to ascertain whether early selection for wood properties is possible.

The Genetic Improvement Program of the CRC for Temperate Hardwood Forestry has developed another link with the CRC for Hardwood Fibre and Paper Science in an important cooperative project conducted to investigate the role of gibberellins in fibre production in *E. globulus*. Fibre development is known to change both seasonally and through the height of the trunk and it has been proposed in other species that both gibberellins and auxin play a role in the control of this development. Mr B Ridoutt of the Fibre Resources Program of the CRC for Hardwood Fibre and Paper Science, recently visited our centre and utilised techniques we have developed to identify and quantify key gibberellins and auxin from the cambial zone of *E. globulus* trees. This was the first identification of gibberellins from the cambial zone of any hardwood species, as well as the first identification of gibberellins in *E. globulus*. The Genetic Improvement Program hopes to continue this collaboration and assist in elucidating the role of these phytohormones in the control of fibre development.

A collaborative project between the Genetic Improvement Program and the University of Melbourne, Dr P Ades and A Carnegie is investigating the response of the *Mycosphaerella sp.* leaf spot fungi to *E. nitens* x *globulus* hybrids and pure species. A trial has been visually assessed for leaf damage and a subset of the *E. nitens, E. globulus* and hybrids have been sampled intensively for quantification of damage caused by different species.

Research

Genetic Improvement Program

Program Manager
Professor 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, reliable estimates of relevant genetic parameters must be determined and 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.

Major Achievements of the Program

- The patterns of variation in *Eucalyptus globulus* Labill. complex have been re-assessed and the climatic regimes of the subspecies shown to be markedly different. Two and four year growth data from the 600-family CSIRO collection of *E. globulus* has identified provenances possessing superior families for further selection.

- Genotype by environment interactions for provenances of *E. regnans* and *E. delegatensis* have been determined and recommendations for the choice of material for the future breeding population produced.

- Development of links with the CRC for Hardwood Fibre and Paper Science aim to determine the genetic variation in fibre and paper traits and the hormonal control of fibre properties.

- A protocol for the successful isolation of RNA from eucalypt leaves has been developed and a PCR based approach to determining differences in gene expression has been examined.

- Inter-specific hybrids have been shown to possess higher levels of deleterious abnormalities than outcrossed or inbred controls. Wide intra-specific crosses may well provide the best growth performance and present the optimum approach in breeding.

- A modified system of micro-propagation has been developed which improves shoot growth and rate of production of explants from temperate eucalypts.

- The early 13 hydroxylation pathway was confirmed as the GA biosynthetic pathway in eucalypts and low levels of GAs were shown to coincide with heavy flowering in grafted material.

- The significant impacts of inbreeding on growth up to 43 months were demonstrated for *E. globulus*.

Sub-program 1 *Genetic Resources and Breeding Strategy*

Introduction

Four research projects have been established within this sub-program. These are broadly based to allow several different but potentially important breeding strategies to be examined.

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 restraints imposed by the species. These rates of genetic improvement are controlled by four major factors:

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

Expression of genetic variation will change with tree age and size. The aim of a breeding program is to produce trees with desired characteristics at harvest age. However, it is impractical in terms of the generation interval to wait until harvest age to assess the traits of economic importance. It is thus vital to determine the degree of variation and correlations between the expression of a trait at different ages. Optimum ages for parental and offspring selection may then be identified. The potential for reducing the generation interval by using very early selection is an area of study.

Recently, it has become possible to find genetic markers at the DNA level as well as the protein level. Such markers may allow tree breeders to select for specific traits at an early age and to fingerprint individual genotypes or clones. In addition, the markers allow the genetic diversity within and between populations to be determined to ensure inbreeding effects do not become pronounced and to determine which germplasm should be added to breeding programs.

There is considerable international interest in the use of interspecific hybridisations as a breeding strategy in *Eucalyptus*, yet little of the genetic information to effectively assess or use a hybrid breeding strategy is currently available. Of particular interest is whether hybrid vigour exists and can be exploited in breeding programs. To fully evaluate the benefits and genetic behaviour of interspecific hybrids, adequate pure bred outcrosses are essential (particularly interprovenance crosses) but to date, these have not been incorporated in studies of eucalypt hybrids. Detailed below are reports outlining progress over the last twelve months in these four projects in this sub-program.

Project 1

Project Leader
Dr N Borralho

Breeding Strategies, Genetic Variation and Estimates of Heritabilities and Genetic Correlations

Introduction

To enable development of efficient breeding strategies by commercial growers quantitative information about variation patterns, site by genotype interactions, age to age correlations and the heritabilities of and genetic correlations between economically important traits is crucial.

The aim of this project is thus to:

- assess genetic variation and the magnitude of site x genotype interactions
- develop reliable estimates of variance components, heritability and genetic correlations
- evaluate and develop efficient techniques for increasing the accuracy for predicting breeding values
- evaluate the relative merits of open-pollination, control-pollination and selfing in predicting the breeding values
- determine optimal breeding strategies.

This will be achieved by a co-ordinated program of trial assessment together with collation and analysis of the data. Areas requiring further study will be identified and a co-ordinated program developed to address these areas.

a) Genetic variation and Breeding Strategies for *Eucalyptus globulus*

Quantitative genetic variation and genotype-environment interactions in *E. globulus* are being studied in two projects, one based on the earliest provenance trials of this species (Orme collection), the other on new family collections undertaken by the CSIRO Tree Seed Centre in 1987-88. The later collection is one of the largest ever undertaken (600 families) and will constitute base breeding populations in many countries. Family trials have been established on numerous sites throughout Australia by parties within the CRC.

Reports of *E. bicostata* in the Furneaux Group and in Southern Victoria are thus probably erroneous and result from convergence in capsule morphology.

- The previously described taxon *E. stjohnii* (R T Bak.) R T Bak. is part of the continuum between subspecies *pseudoglobulus* and *bicostata*, but is closer to *pseudoglobulus*.

- Populations phenotypically intermediate between and significantly different from *globulus* and the three-fruited intergrades are highly variable and occur in western Tasmania, on the northern end of Flinders Island, in the Otway Ranges and in west Gippsland.

- An isolated population on Rodondo Island is highly variable and has closest affinities to *pseudoglobulus* despite being within the geographical range of core *globulus*. The population from King Island is intermediate between the Otway phenotype and core *globulus*.

- The climatic regimes of the subspecies are markedly different and most three-fruited and *globulus* intergrade populations have closer climatic affinities to *pseudoglobulus* and *globulus* respectively. Hypotheses relating to the origin of the pattern of variation in *E. globulus* have been published.

- Two and four year growth data from one of the largest trials established from the CSIRO collection (APPM, Massy Greene Drive) has now been analysed and predictions of subprovenance and family performance have been made (Figure 2). Four other trials are currently being assessed for four year growth traits and this data will be used to improve predictions and examine genotype-environment interactions.

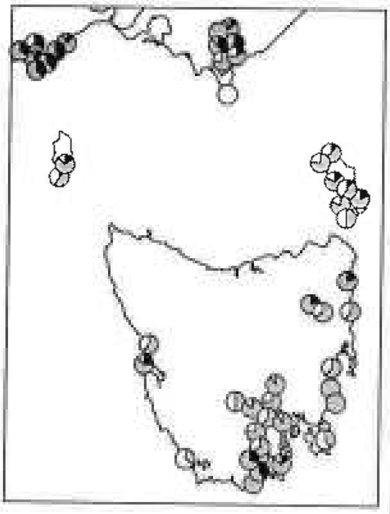


Figure 2 The distribution of top performing families of *Eucalyptus globulus* in APPM's base population trial at Massy Greene. The proportion of families in each subprovince in the top (black) and bottom (white) one hundred on the basis of their estimated conic volume are indicated. It can be seen that the best families are concentrated in the region of the Otway Ranges, south Gippsland and near Geeveston in southern Tasmania.

Goals

- Complete the review of provenance trials of *E. globulus* and its subspecies established in Australia between 1978 and 1986 from the Orme collection (1976).

- Complete the study of genetic variation and site x genotype interactions for growth traits in the 600 family *Eucalyptus globulus* base population trials in Tasmania.

- Collate and analyse data from the international base population trials of *Eucalyptus globulus*.

- Commence assessment of flowering phenology.

- Examine age to age correlations for growth traits using two old trials of *Eucalyptus globulus*.

- Determine the accuracy of mixed model methodology with open-pollinated pedigree structures. This will include a comparison with breeding values predicted from controlled crossing, simulation and an application to selection in a base population of *Eucalyptus globulus*.

- Determine optimal strategies for vegetative propagation in advanced generation breeding programs. Expected gains will be analysed from a range of propagation options.

b) Provenance variation and genotype-environment interactions in *E. regnans* and *E. delegatensis*

Research areas currently covered include:

- patterns of provenance variation for growth, stem form and branch quality;

- potential interactions between genotype performance and planting environment;

- levels of genetic variation, heritabilites and correlations between commercially important traits including growth, stem form, branch quality, flowering traits and insect defoliation;

- potential for use of early selection techniques;

- development of techniques for improving prediction of breeding values and development of breeding strategies.

Outcomes

- Genotype by environment interactions for forty-nine *E. regnans* provenances assessed at ages nine to 13 years and planted across nine sites revealed no clear patterns of provenance performance. Although large provenance differences were found for growth, stem form and branch quality traits at each site the best performing provenances differed from site to site.

- Provenances collected from outlying populations proved generally to be poor performers, possibly due to increased inbreeding in these populations. The local provenance at each site was not amongst the best on growth performance. Three geographic areas (Strzelecki Ranges in Victoria, the north-east of Tasmania and the south-central area of Tasmania) are recommended for use in establishing breeding population for this species.

- For *E. delegatensis* at age 10 years, growth and stem form data from 64 provenances planted across 5 sites have indicated that the provenances collected in Tasmania are distinctly different to those from the mainland, with the Tasmanian provenances performing poorly at all sites, particularly those on the mainland. Local provenances were not found to be optimal for any site.

- Genotype by environment interaction analyses have indicated a strong latitudinal trend in performance, with the optimal provenances for each site being strongly related to the latitude of the planting site. When establishing breeding populations for this species it would be essential to take account of the range of potential planting sites and match this to a specific group of provenances.

Goals

- Development of recommendations on structure of breeding populations for *E. regnans* and *E. delegatensis* and publication of results.

c) Insect Defoliation

Observations of differential defoliation of families of *E. regnans* by the leaf eating beetle *Chrysophtharta bimaculata* has been further investigated using a group of five susceptible and five non-susceptible families which were studied in detail to identify which leaf characteristics influence susceptibility.

The degree of defoliation inflicted by *Chrysophtharta agricola* on an *E. nitens* control pollinated family at APPM was scored in the 1992/93 summer. *Chrysophtharta agricola*, is a leaf eating beetle which feeds on the juvenile foliage of *E. nitens* and *E. globulus*. This contrasts with *C. bimaculata* which feeds on the adult foliage of *E. nitens* but not of *E. globulus*.

Outcomes

- In contrast to results for *E. nitens* and *E. globulus*, leaf oil chemistry was not found to be a major factor in determining susceptibility of *E. regnans* to attack by *Chrysophtharta*. This is probably because *E. regnans* does not contain cineole, a leaf constituent found to be a major deterrent to feeding.

- Total leaf area produced during the growing season was similar for both susceptible and non-susceptible families when all were protected by regular insecticide spraying. However, the proportion of this leaf area which was coloured red was found to be an effective discriminator between susceptible and non-susceptible families. Whether it is the red leaf colour itself which is determining susceptibility or whether it is some associated trait, such as leaf chemistry is not clear.

- Scoring for degree of defoliation inflicted by *C. agricola* in a control pollinated family trial of *E. nitens* owned by APPM this summer has indicated large family differences, with strong provenance effects being apparent.

Goals

- Inform industry of high genotypic effect on defoliation of *E. regnans* by *C. bimaculata* and publication of results.

- Continue scoring *E. nitens* control pollinated family trial to assess whether genotypes susceptible to *C. agricola* are also susceptible to *C. bimaculata*.

Project 2

Project Leader
Ms C Raymond

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-FPS). Research programs within the CRC-FPS are now established with each program having its own Coordinating Committee. Reciprocal linkages have been developed via these Coordinating Committees and the Scientific Review Committee of the CRC-THF.

This project aims to:

- determine suitable trials to sample for wood properties

- assist in the development of non-destructive sampling techniques for wood properties based on an understanding of within tree variation in wood and fibre traits

- assist in evaluating 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 for wood property assessments

- implement these new techniques in genetics and silvicultural trials

- determine the heritabilities of fibre traits and their genetic correlations with growth, tree form and pulping information.

Outcomes

- Suitable field trials have been identified for initial sampling for wood and fibre properties and sampling of an *E. nitens* field trial for an intensive examination of within tree variation in fibre properties has been undertaken.

Goals

- To develop procedures whereby wood properties can effectively be included in breeding strategies.

- To undertake a review of existing literature on genetic variation and heritabilities of wood, fibre and pulping traits in temperate eucalypts.

- To determine whether suitable data sets exist and are available for examining the numbers of trees required for evaluating pulping traits. Estimates of wood and pulping traits from other species suggest that the heritabilities are higher than those for growth traits, suggesting that fewer trees need to be sampled per family.

- Establish a PhD program which will examine changes in wood density and fibre length with age in families of *E. nitens*. By determining these traits in different growth rings within a tree, age-to-age correlations may be estimated and heritabilities and correlations with growth at different ages determined. The project also aims to regrow seedlings of the same families and determine correlations between seedling and later age density and fibre length with the aim of evaluating the potential for using early selection techniques.

Dr Rene Vaillancourt (right) and research student look at protein bands on an electrophoresis gel.

Project 3

Project Leader
Dr A West

Molecular Genetics

Introduction

Work in this project will lead to the development and application of molecular genetic markers for use in breeding programs. Recent advances in molecular biological techniques have enabled the rapid generation of molecular markers, including Restriction Fragment Length Polymorphisms (RFLPs) and Random Amplified Polymorphic DNAs (RAPDs). Use of these is essential for analysis of genetic variation in native and plantation *Eucalyptus* stocks, for the identification of commercially useful traits very early in the breeding cycle and for characterisation of potential inter-specific hybrids (eg Figure 3). The following subprojects have been designed to meet these goals.

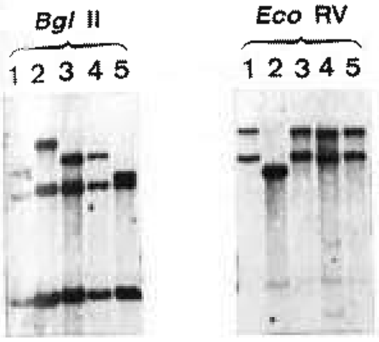


Figure 3. Four species of *Eucalyptus* and one of *Angophora*, a closely related genus, were probed with *Petunia* chloroplast probe *Pst*4 following digestion with restriction endonucleases *Bgl* I I and *Eco*RV. The species are: 1. *Angophora costata;* 2. *Eucalyptus erythrocorys;* 3. *E. cloeziana;* 4. *E. lansdowneana;* and 5. *E. leptophylla*. This Southern blot reveals polymorphism which can be used to examine phylogenetic relationships in *Eucalyptus*.

a) Correlation Between Genetic Distance and Heterosis

The objective of this subproject is to ascertain whether there is correlation between cross success in the F_1 generation (heterosis) and genetic distance (as measured on parents). If a positive correlation is found this may help predict specific combining effects in the F_1.

Outcomes

- DNA has been isolated from 8 out of 8 females and 16 out of 21 males in the CSIRO factorial *E. globulus* crossing trial.
- These DNAs are currently being assayed for RAPD markers.

Goals

- To calculate genetic distance among the CSIRO *E. globulus* parents (using a RAPD data set) and correlate these measurements to the performance of their F_1 hybrids.

b) The application of marker-assisted selection in *Eucalyptus* breeding

Construction of a linkage map in a suitable *Eucalyptus* cross will enable the tagging of specific genetic traits with anonymous genetic markers. This information would be of immense importance to tree breeders since it effectively shortens the time necessary to introduce new traits into plantation stocks. As a model we were planning to use the F_2 from a cross between *E. globulus* and *E. gunnii* and map quantitative traits such as frost resistance and growth rate. These two species differ markedly in their growth rate and frost resistance. However, upon germination the F_2 seems to have a high rate of abnormalities with many plants having extremely slow growth. This problem was not apparent in the F_1. Therefore, once the plants are big enough to sample for DNA extraction, we will check that the molecular markers are inherited in Mendelian fashion before pursuing the construction of a linkage map.

Goals

- Extract DNA from 60 different F_2's and study the inheritance of approximately 50 RAPD markers. If most markers are normal we will proceed with mapping this cross. If markers have abnormal inheritance, we will use crosses between closely related parents.

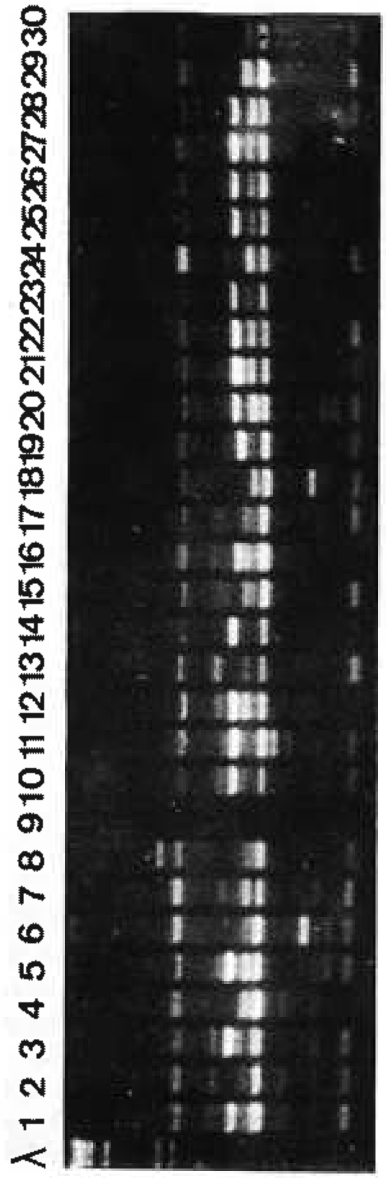


Figure 4. Results of a RAPD analysis of *Eucalyptus* DNA. DNA was isolated from 30 *E. globulus* individuals and amplified by PCR using random sequence primers (RAPD). The products of the reactions are shown following electrophoresis (lanes 1-30, molecular weight markers are shown in the λ lane). Several different genotypes exist, as indicated by the various banding patterns. This information can be used to determine genetic relationship in this group of eucalypts.

c) Genetic Variation in *E. globulus* ssp *globulus* and its relationship to other taxa.

The overall aim of this subproject is to determine the extent of genetic variation in and between local populations of the commercially important *E. globulus* ssp. *globulus* and examine the phylogenetic relationship between *E. globulus* ssp *globulus* and other related taxa. Knowing the genetic relationship among populations of *E. globulus* could be a useful guide to parent selection in breeding programs (Figure 4).

An examination of the genetic variation in *E. globulus* over its full geographical range is underway, using RAPDs, with a view to comparing the results with the recent morphological survey carried out by Jordan *et al* 1993. The chloroplast genomes of a subset of these trees, and 3 related subspecies are also being characterised by RFLP technology, with a view to examining their level of variability and evolutionary relationships.

There is widespread interest in using interspecific crosses as a tree breeding tool. *E. globulus* and *E. nitens*, two commercially important species, are closely related since they belong to the same series (*Viminales*). However, their degree of genetic relationship with one another and to the 43 other species of the series is relatively unknown. This project will study the phylogeny of all taxa within the series *Viminales* using RFLPs and chloroplast specific probes.

Outcomes

- DNA has been isolated from approximately 170 trees of *E. globulus*.
- Tissue samples were collected from 150 trees covering most species in the series *Viminales* were collected.

Goals

- The population study of *E. globulus* will be carried out using genomic markers (RAPDs) and cytoplasmic markers (chloroplast RFLPs).
- The phylogenetic study of series *Viminales* will be pursued using chloroplast RFLPs.

d) The Genetic Control of Phase Changes in *Eucalyptus globulus*

Altering the genes controlling major developmental pathways, such as those which control the transition from the juvenile to the adult growth phase, could provide more productive eucalypts for plantations. This sub-project involves trying to locate some of the genes which are important in the control of phase change in the leaves of *E. globulus*. This particular system has been chosen because there is a dramatic difference in adult and juvenile leaf form in *E. globulus* and because leaves offer the most accessible source of RNA.

To find these genes a new technique is being tested and developed for use in eucalypts. If it can be successfully adapted it will be applicable to many other systems. The technique involves differential PCR fingerprinting of RNA from the *E. globulus* leaves. Subsets of the messenger RNAs contained within the leaves are amplified and displayed on a sequencing gel. The distinctive 'fingerprint' of bands produced by the adult and juvenile leaves will be compared. Any difference in the banding pattern may represent a differentially expressed gene, which could be important in controlling the difference between juvenile and adult leaf form.

Dr Brad Potts (left) and Dr Robert Wiltshire measure flowering in relation to phase change (from juvenile to adult leaves) on *E. risdonii* and *E. tenuiramis*.

Preliminary work to enable the application of this technique to our chosen system is in progress. A protocol for the successful isolation of RNA from eucalypt leaves and capsules has been developed.

Trials of the differential PCR fingerprinting process have shown that banding patterns can be routinely produced.

Goals

- Ensure that the RNA fingerprinting process is reproducible.
- Isolate, clone and sequence a number of differentially expressed genes.

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*. However, while there are reports of hybrid vigour, intraspecific controls are usually absent or insufficient and it is difficult to determine whether genetic gains could be achieved more efficiently, simply by removal of inbreeding and full exploitation of the genetic variation within species.

The aim of the hybrid breeding project is to provide the fundamental genetic and biological information necessary to properly assess and use hybrid breeding strategies with the temperate eucalypt species.

The CRC has brought together one of the largest collections of pedigreed F_1 hybrids of *Eucalyptus*. The project draws on three main genetic resources -

- Miscellaneous F_1 hybrid trials established by APPM and the Department of Plant Science of the University of Tasmania in 1986 and 1988. This material is now reaching an age when we can reliably assess growth performance.
- *E. gunnii* x *gobulus* F_1 and advanced generation hybrids. An incomplete 14 x 8 factorial of F_1 hybrids is available, a subset of which is currently being cloned.
- *E. nitens* x *globulus* F_1 hybrid trials and parental controls (open pollinated material, intra- and interprovenance crosses) established by the CSIRO three years ago on several sites throughout Australia.

E. nitens being artifically pollinated from a cherry picker.

Work undertaken in this project this year is described below.

a) Barriers to interspecific hybridisation

There is some evidence to suggest that cross success and the vigour of F_1 hybrids may decrease with increasing taxonomic distance between the species which could preclude many otherwise desirable F_1 combinations from direct commercial exploitation. This subproject is investigating the barriers to the production of hybrid seed and plants and in particular the relationship between cross-success/heterosis and the genetic/taxonomic distance between parents.

Trials of a wide range of artificial F_1 hybrids have been assessed for height and diameter at ages 3 or 4 and hybrid performance is being reviewed in relation to the taxonomic distance between parents.

Outcomes

- Marked post-mating barriers to the production of *E. gunnii* x *globulus* and *E. nitens* x *globulus* F_1 hybrid seed have been demonstrated (Potts *et al.* 1992).
- F_1 hybrids amongst the closely related species *Eucalyptus globulus*, *E. nitens* and *E. bicostata*, have higher levels of deleterious abnormalities than outcross and inbred controls (Figure 5).

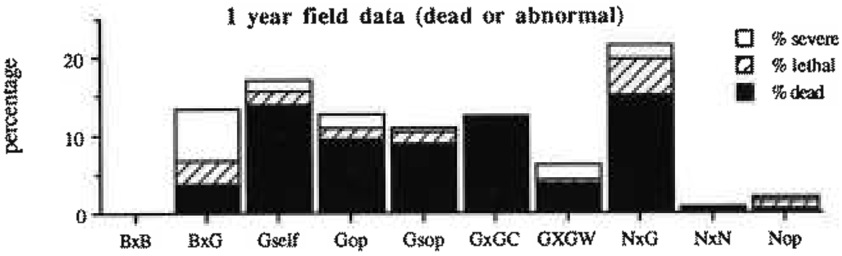


Figure 5 The percentage of deaths and genetic abnormalities in *E. globulus, E. nitens, E. bicostata*, and their interspecific hybrids after one years' field growth. (BxB = *E. bicostata* x *bicostata*; BxG = *E. bicostata* x *globulus*; Gself = self-pollinated *E. globulus* from natural stands; Gop = open pllinated *globulus* from natural stands; Gsop = open-pollinated *E. globulus* from a seed orchard; GxGC = intra-provenance crosses of *E. globulus*; GxGW = inter-provenance crosses of *E. globulus*; NxG = *E. nitens* x *globulus* F_1 hybrids; NxN = intra-provenance crosses of *E. nitens*; Nop = open pollinated *E. nitens* from a seed orchard).

- An optimum level of divergence associated with inter-provenance crossing was apparent for cross success and growth up to two years. Analyses of the two year performance of the cross types on several sites confirmed the stability of the inbreeding effect but showed that the relative performance of parental species and their hybrids was site dependent.

Goals

- Compete analysis of the success of hybridisation between *E. nitens* x *globulus* from pollination to two years plantation growth and publish the conclusions.

- Commence analysis of data from miscellaneous hybrid trials for a broad review of hybrid performance.

b) The inheritance of traits in F_1 and advanced generation hybrids.

Traits currently under investigation using F_1 hybrids include frost, insect pest and desease 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.

To provide suitable character combinations it may be necessary to breed beyond the F_1 generation, yet there is little information on character inheritance, correlations between characters or the extent to which hybrid breakdown occurs in advanced generations.

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.

Advanced generation hybrids of *E. gunnii* x *globulus* are being studied to determine the barriers to hybridisation (hybrid breakdown) and the inheritance of traits in later generations. Of particular emphasis is the potential to which traits such as frost resistance and growth rate can be recombined in crosses between these complementary species and this project will provide the quantitative traits for correlation with Project 3 where Dr R Vaillancourt is investigating selection using molecular markers.

Outcomes

- Hardwood cuttings have been taken by APPM from a virtually complete 4 x 7 factorial of F_1 hybrids along with *E. globulus* and E. *gunnii* outcross controls. Data is now available to study the inheritance of rooting ability and frost resistance.

- Material which successfully cloned is hardening for planting in multi-location trials to examine the relative performance of the hybrids in a range of environments.

Goals

- Establish multi-location clonal trials of *E. gunnii* x *globulus* F_1 hybrids.

- Monitor F_1 hybrid trials to study the inheritance of flowering traits.

- Examine the character inheritance in F_1 and advanced generation progenies of *E. gunnii* x *globulus*.

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?

Genetic parameters for two year growth traits are being estimated for comparisons between intraspecific crosses of varying inbreeding levels and interspecific F_1 hybrids of *E. globulus* and *E. nitens* . The stability of estimates of parameters, breeding values and heterotic effects are being examined amongst cross types and environments.

Outcomes

- Studies based on one years performance have previously indicated that open-pollinated estimates of narrow-sense heritabilities were generally inflated compared to those derived from controlled crossing, suggesting that the use of estimates of heritabilities from open pollinated material may significantly inflate genetic gain estimates.

- The correlation between general combining ability (GCA) and general hybridising ability (GHA) were generally poor for one year growth and frost resistance and did not allow the prediction of hybrid performance on the basis of the performance of the parents in intraspecific crosses. However, the correlation was significant in traits with high individual narrow-sense heritabilities in intraspecific crosses (e.g. leaf shape traits).

Goals

- Comparison of genetic parameters and genetic effects estimated for two year growth from intra- and inter-provenance crosses of *E. globulus* planted on multiple sites using mixed model methology. Specific combining effects will be estimated for the genetic distance study (Project 3a).

- Comparison of intra- and inter-specific (hybrid breeding) parameters and effects as above for hybrids between two *E. globulus* provenances and *E. nitens*. This will include the multi-site analysis of the *E. nitens* half diallel.

d) The response of pests to eucalypt hybrids

Higher insect pest abundance and diversity has been demonstrated on natural hybrids of eucalypts and other species. It is important to extend this work to artificial hybrids in plantations and to differentiate the susceptibility of F_1 and advanced generation hybrids.

The response of fungal and insect pests to eucalypt hybrids are being studied in a PhD project with particular attention to hybrids involving *E. globulus* and *E. nitens*. This project involves the assessment of pest loads (abundance and diversity) in trials and testing genetic susceptibility of F_1 and advanced generation material using field and laboratory feeding studies.

Outcomes

- Initial assessments of chrysomelid damage have been undertaken with *E. nitens* x *ovata* hybrids using visual assessments and traps.

- The response of the *Mycosphaerella* sp. leaf spot fungi to *E. nitens* x *globulus* hybrids and pure species is being studied in a collaborative project with Dr P Ades and A Carnegie from the University of Melbourne. A trial has been visually assessed for leaf damage and a subset of the *E. nitens*, *E. globulus* and hybrids have been sampled intensively for quantification of damage caused by different species.

Goals

- Continue visual assessments of hybrid trials for pest loads and damage.

- Undertake laboratory and *in situ* feeding experiments examining chrysomelid beetle growth and survival on *E. globulus*, *E. nitens* and their hybrid.

- Determine the genetic parameters for *Mycosphaerella* sp. damage and response to hybrids and prepare the results for publication.

Sub-program 2 — *Propagation strategies*

Introduction

Elite genetic material produced in breeding programs must be transferred into operational forestry as soon 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 and to increase seed production. Early flowering would also reduce substantially the generation interval in breeding programs.

A seedling of *E. nitens* may take six years to flower while a grafted ramet from a reproductive by competent ortet may take three to four years. Advances in tree breeding are such that selection of desirable material may occur significantly before flowering. 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 about 25 percent which would provide very significant economic and time savings. In conjunction with this practical aim, an understanding of the physiological base of flowering control and inbreeding in *Eucalyptus* is also being sought.

As superior genetic material becomes available, it will be necessary to propagate it clonally for field evaluation. Micropropagation has the potential to provide high multiplication rates of uniform genotypes for this purpose and, further along the line, for silviculture gains. The technique involves induction of axillary and/or adventitious shoot proliferation on nodal explants followed by rooting shoots. Research in this area will also be applicable in the context of future work on genetic transformation of *Eucalyptus* since this will inevitably involve strategies for the generation of plants from transformed cells.

Two projects have been established in this sub-program, one examining vegetative reproduction through micropropagation and one concentrating on the manipulation of the breeding system to allow more rapid reproduction and to determine the effects of inbreeding.

Project 5

Project leader
Mr V Hartney

(a) Mr Peter Naughton (Forest Resources) holds a grafted *E. globulus*.
(b) Close-up of the graft.

Micropropagation of selected clones

Introduction

The ability to propagate clones of selected forest trees in commercial quantities is of great benefit to plantation forestry as it enables the best genotypes from a breeding program to be grown in plantation sooner than via seedlings.

Clonal propagation also enables selected hybrids (see project 4) and trees with special traits such as adaptation to specific sites, or disease resistance to be grown in commercial plantations.

The aim of this project is to devise methods that will enable clones of temperate eucalypts to be micropropagated for commercial plantations. Current methods of producing clones of these species by stem cutting are unsuitable or unreliable as only a small proportion of selected clones can be propagated in commercial quantities.

Outcomes

- A modified system of micropropagation has been tested on 63 clones representing 18 species within 3 genera (*Eucalyptus, Melaleuca,* and *Acacia).* For all these clones shoot health and the rate of production of explants has improved significantly using this system.

Goals

- Improve the frequency with which clones of temperate eucalypt species produce roots.

- Integrate the modified micropropagation system into standard nursery procedures.

- Evaluate the modified micropropagation system under commercial conditions (once intellectual property considerations have been completed).

- Devise simple and cheap methods of storing clones *in vitro* to overcome the high cost associated with maintenance of clones by regular subculturing.

Project 6

Project Leader
Professor J Reid

Manipulation of Breeding Systems

a) Control of Flowering

The aim of the flowering section of the project is to decrease the time taken to produce a useful seed crop from *E. nitens* and *E. globulus* seedlings and grafts. The current generation time of these species in eastern states may be up to eight years, while the age at which selection of material for further breeding becomes possible continues to fall. The identification of genetic markers using the techniques of molecular biology will further reduce selection age. By combining the advances in early selection technology with mechanisms which reduce the generation time of these species, an effective breeding program could be established.

Early work completed within the CSIRO Division of Forestry has suggested that application of the plant growth retardant paclobutrazol may induce early flowering in non-flowering grafted material and additionally increase the level of reproductive output (flower bud numbers) in trees which have attained reproductive competence. This suggested stimulation of reproductive activity at the phenotypic level is ideal for use in a tree breeding strategy given the absence of impact upon the following generation. This is much more preferable to the alternative of introducing a genetic tendency for early flowering, due to the inevitable introduction of genetic material which will affect other growth traits. Paclobutrazol is thought to be active through reducing the levels of a group of plant hormones known collectively as the gibberellins (GAs). We hope that investigation of levels of these hormones in conjunction with a study of the nature of paclobutrazol transport and catabolism in the plant and in the plant's environment will produce an understanding of the control of bud development, flowering and seed production. This information may then be practically utilised to reduce the generation time of seedlings and eliminate the delay to flowering found in grafted material. An increase in seed production in orchard trees should also be feasible.

Outcomes

- The primary GA biosynthetic pathway in *E. nitens* and *E. globulus* has been confirmed as the early 13-hydroxylation pathway since full scan mass spectra have been obtained for GA_{20} (Figure 6), GA_{29} and GA_{19} and evidence for GA_1 and GA_{53} found by GC-SIM. No evidence for non-13 hydroxylated GAs have been found.

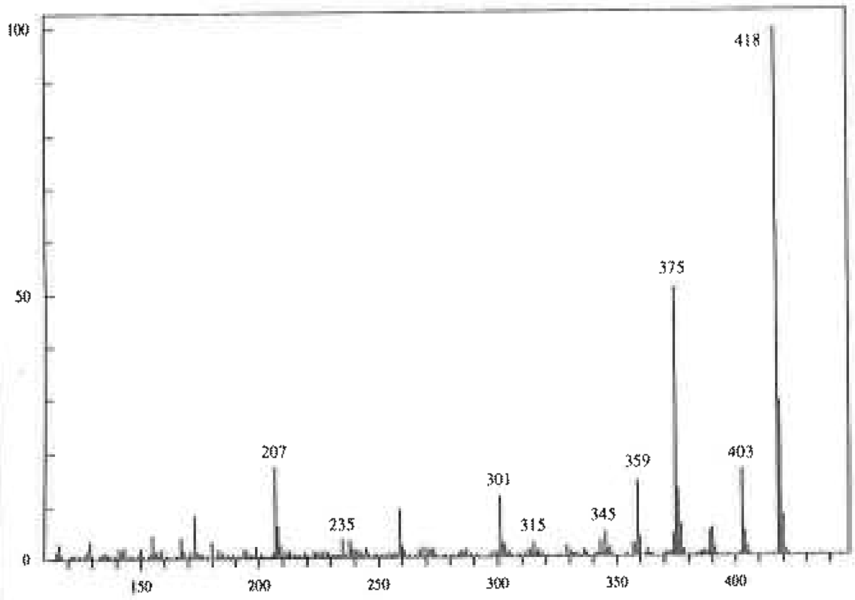


Figure 6 Full scan mass spectrum for GA_{20} - MeTMSi ether, extracted from the cambial zone of *E. globulus*. The molecular ion is the major peak at 418. Other peaks are break down products.

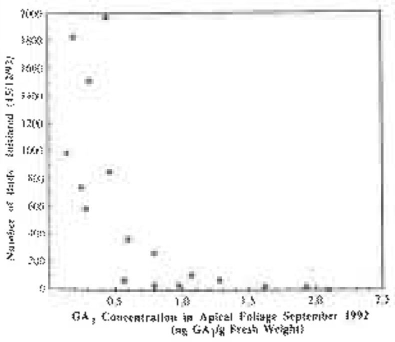


Figure 7 The relationship between GA_1 concentration and flower bud initiation

- The levels of GA_1, GA_{20}, GA_{19}, GA_{53} and GA_{29} have been determined in vegetative tissues of *E. nitens* and *E. globulus*. The levels range from 0.6 to 8.5 $ng.gFW^{-1}$ and are generally similar to those found in other woody perennial species. The levels of GA_1 and its precursor GA_{20} were also monitored in grafted clones treated with paclobutrazol by collar drench and trunk injection. High levels of GA_1 were correlated with low flowering activity (Figure 7).

- The amount of [14C]-paclobutrazol taken up by collar drenching and foliar spraying was compared and found to be similar for approximately nine weeks and to be concentrated in leaf tissue. The patterns of breakdown of paclobutrazol in different plant portions were determined and the half-life has been estimated to be approximately two weeks. Paclobutrazol catabolism in the soil was slow and this probably explains the long lasting effects of soil drenching with paclobutrazol.

- Paclobutrazol was shown to cause precocious flowering in vegetatively juvenile *E. globulus* seedlings. Flower buds were visible after 17 months' growth and fertile open flowers, after 24 months.

- In collaboration with the CRC for Hardwood Fibre and Paper Science (Mr B Ridoutt), the presence of GAs and IAA has been shown in cambial tissue of *E. globulus*. Some GAs are present at higher concentrations than in leaf or bud tissue and the results indicate that their quantification in relation to the differences in fibre differentiation is feasible.

Goals

- Assess the usefulness of paclobutrazol for enhancing eucalypt breeding programs

- Characterisation of the effect of paclobutrazol on the flowering behaviour of *E. globulus* seedlings two years after application.

- Determine the retention of buds and capsules and the seed production from paclobutrazol treated seedlings and check seed and pollen viability.

- Fully assess metabolism of paclobutrazol in plant tissue and extend the study of paclobutrazol breakdown in the soil to assess the effects of different soil types, effects of watering intensity and the effects of ground cover species on turnover rates.

- Determine the effect of paclobutrazol soil drenching on eucalypt fungal associates.

- Determine which of the environmental triggers, water/nutrient stress, cold treatment or photoperiod are most effective in inducing early flowering in *E. globulus*.

- Examine the interaction between environmental triggers and paclobutrazol on GA levels in order to characterise the nature of the floral signal.

- Determine the change in IAA and GA levels in cambial tissue and relate these to fibre length and development in different seasons and at different heights in 6m tall stems of *E. globulus*. This goal is part of collaboration with the CRC for Hardwood Fibre and Paper Science and brings together expertise unique to both Centres.

Promotion of flowering in 18 month old seedlings of *E. globulus* treated with paclobutrazol.

b) Inbreeding

The quantitative and population consequences of inbreeding may influence many stages of tree improvement programs. Inbreeding depression has been recorded for many species and for many traits, although this has not been surveyed in

E. globulus and *E. nitens*. Inbreeding may also change phenotypic variation and correlations.

Since eucalypts have a mixed mating system, open pollinated seed lots may contain a mixture of selfed and out-crossed progeny. If the magnitude of inbreeding depression is large, obtaining seed for plantations from open pollinated seed orchards may compromise otherwise achievable rates of gain. The effect of inbreeding on variation and correlations may, on one hand, lead to improved selection efficiencies due to the increase in genetic variation between and within families or may lead to bias in open pollinated progeny tests if no account is made for inbreeding effects. Inbreeding has traditionally been avoided in the management of breeding populations because of its deleterious effects. However, the possibility of removing deleterious alleles early, achieving higher rates of gain relative to recurrent selection and being able to maintain separate sub-populations with different breeding objectives may offer long term advantages that cannot be realised by programs based on recurrent selection. The role of inbreeding in eucalypt forests will influence the genetic structure of native forests which will in turn have consequences for the introduction into breeding programs of material from the wild. The population genetics of inbreeding in natural forests may also reflect the constraints and opportunities of applied breeding programs.

Outcomes

- The effects of inbreeding on field performance in *E. globulus* over the lifecycle up to 43 months was determined (Hardner 1992). Selfing had a significant effect on mean seed set and field growth at 8, 19 and 43 months but had no effect on germination, survival of germinates 4 months after germination, field survival or date of maturity of progeny. Selfing was found to increase variation between and within families relative to out-crossing.

- Except for selfing, there was no effect of proximity dependent crossing in *E. globulus* on seed set, germination and survival at 6 months after germination. A field trial designed to examine the effects of proximity dependent crossing in *E. globulus* at later ages was planted in southern Tasmania. The work was done by Mr C Hardner as an Honours project.

Goals

- To undertake analysis of later age inbreeding effects in *E. regnans* with particular interest in the effect of inbreeding on mean, variance and correlations of traits, the effect of inbreeding under competition and usefulness of using self families to predict the breeding value of the parent. It is also hoped to undertake crossings to investigate inbreeding effects at different levels of co-ancestry.

- In order to determine the inheritance of self fertility/infertility a mating design will be formulated and crossings undertaken to investigate its control in *E. globulus*.

Soil and Stand Management Program

Program Manager
Dr P West

Introduction

The program aims to provide tools to forest growers to assist them in managing available site and tree resources. This should allow maximum production of the forest products desired with minimum effect on the properties of the site.

To achieve these objectives the program is developing a detailed description of the growth behaviour of eucalypts in plantation forests in relation to environmental factors, especially temperature, the availability of moisture and nutrients and soil physical properties. This will allow the identification of those factors that limit growth at particular sites and, in turn, should lead to silvicultural treatments to ameliorate their effects.

As well as this major task, the program is developing other tools of more immediate use to eucalypt plantation management. These include a simple system to predict site suitability for eucalypt plantations, determination of the optimal soil physical environment for seedling root development to provide guidelines for tillage practice at establishment and empirical determination of growth responses to fertilisers on a wide range of sites.

Major Achievements of this Program

- Determination of single leaf photosynthetic light response curves for *E. nitens*.
- Demonstration that plantations on highly fertile sites may suffer copper deficiency which severely deforms trees.
- Fertiliser applied at planting may be wasted as tree nutrient demand at very young ages may already be met by existing site resources.
- Development of a simple mathematical system to predict whole canopy annual photosynthetic production based on instantaneous single leaf light response curves.
- Development of empirical wood yield prediction models for six commercially important eucalypts.

Project 1

Project Leader
Dr C Beadle

Plantation production and water use

Introduction

This project investigates the photosynthetic and water use characteristics of individual leaves, single trees and the canopies of *Eucalyptus globulus* and *E. nitens*. In particular these variables are being studied as a function of the uptake and distribution of nutrients within the canopy, leaf area index and canopy development, and biomass production in stands managed for pulpwood and sawn timber/veneer.

a) Environmental effects on photosynthesis and water use.

The aim of this study is to identify the principal conditions limiting growth of the major plantation species *E. nitens* and *E. globulus*. Growth, photosynthetic light response and water use are being investigated in response to temperature, water status and N and P supply. Glasshouse studies on clonal material will be compared with results from field fertiliser trials (established under Projects 2 and 3 of this Program) and clonal trials using several *E. nitens* and *E. globulus* accessions (established by Forest Resources at seven widely differing sites in north-east Tasmania).

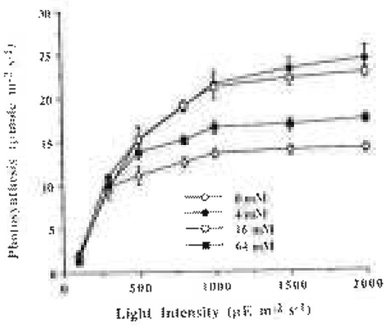


Figure 8. Photosynthetic light response curves for *E. nitens* clones at four external N concentrations; 0, 4, 16 and 64 mM of elemental N.

An investigation of the effect of tissue N concentration on the photosynthetic light response of a single clone of *E. nitens* (provided by APPM Forest Products, Ridgley) was conducted in the glasshouse in sand culture flushed with nutrient solution. There were seven treatments differing in N concentration (0, 4, 8, 16, 32, 64, and 128 mM elemental N) and the photosynthetic light responses were measured for mature leaves. Vertical and horizontal transects within the crowns of the clones were analysed for tissue N concentration, protein concentration and maximum photosynthetic rate. Harvests taken at 3 and 5 months allowed investigation of relative growth rate and resource partitioning into roots stems and leaves.

Outcomes

- Maximum growth rates of *E. nitens* were achieved at 16mM external N concentration which is far in excess of levels previously reported to give optimal growth of *Eucalyptus*. Toxic effects were not evident until concentrations exceeded 64 mM.

- Photosynthesis became 90% light-saturated at about 1000 μE m^{-2} s^{-1} at intermediate N supplies (4 mM to 16 mM) but at lower light intensities when N supply was deficient (0 mM N) and when N was in super-abundance (64 mM N; Figure 8).

(a) Dr Neil Davidson measures rates of photosynthesis in *E. nitens* seedlings. (b) Close-up of the cuvette.

- Maximum photosynthesis (A_{max}) for *E. nitens* was greatest in intermediate N treatments (approximately 20 µmole m^{-2} s^{-1} for 4mM to 16 mM external N) but was reduced in the extreme N treatments (0mM and 64 mM; Figure 8). An increase in A_{max} with increased N concentration (0 to 16 mM N) is consistent with other reports. (see 1991/92 Annual Report for this CRC; Figure 7, p25).

- High rates of photosynthesis were generally associated with high specific leaf weight (high leaf dry weight per unit leaf area). Specific leaf weights were lower under extremes of nutrition (N treatments 0-4 mM and 128 mM).

Goals

- Investigation of the photosynthetic light responses of *E. nitens* and *E. globulus* in N fertiliser trials in the field.

- Establish growth rate, photosynthetic light response and water use of *E nitens*, *E. globulus* and *E. regnans* under other environmental constraints including temperature, phosphorus and water status.

b) Sap flux in individual trees.

Direct measurement of water use by a single tree provides a simple means of comparing the water use and water use efficiency of different genetic material. The heat pulse velocity technique provides a convenient approach to making these measurements. It involves measuring the rate of travel of a heat pulse between two probes inserted into the sap stream of a live tree. Implanting several probes in a tree also allows an estimate of canopy transpiration to be made, given a description of tree to tree variation of sap flux in the stand.

The variation of heat pulse velocity and calculated sap flux at different positions in the sapwood of three-year-old *E. globulus* trees has been investigated. Sap flux was measured at 5 mm intervals across the sapwood on two opposite radii by moving two probe sets simultaneously. A second pair of probe sets, placed at right angles to the first two at fixed positions acted as controls. A ratio of sap flux with position was defined as that given by each moving sensor divided by the average from the static sensors. Also, the behaviour of the four sensors in two probe sets placed at right angles to each other but at different positions within the sapwood was investigated over several days.

Outcomes

- The results show that there is radial variation in sap flux across the sapwood (Figure 9) with lowest fluxes at the centre of the tree.

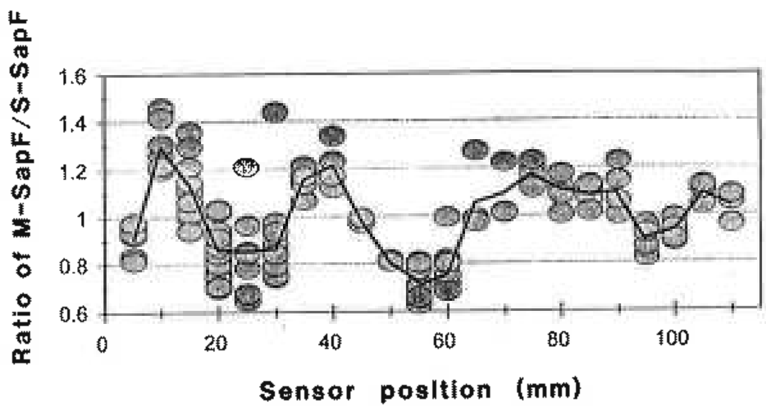


Figure 9 The ratio of sap flux (SapF) of moving (M) to static (S) sensors across sapwood of *E. globulus*. Sensor position was measured from the outer surface of the cambium. Sapwood width was 110 mm.

- There was some indication of repeating patterns of high and low flux perhaps associated with areas of early and late wood.

- Although there was high correlation between sensors (exceeding 85%), sapflow measurements in individual trees will initially require the use of four probe sets to accurately define the flux pattern within the conducting wood. Routine measurements can then be made with fewer probe sets, perhaps two, placed at peak positions in different radii for routine measurements.

Goals

- Calibrate the heat pulse velocity estimate of water loss against that determined using cut tree experiments.

- Estimate canopy transpiration in irrigated stands of *E. globulus* and *E. nitens* for comparison with estimates of evapotranspiration using the neutron moisture meter.

c) Moisture stress tolerance in *E. globulus* and *E. nitens*.

Expansion of the hardwood plantation resource necessitates establishment on sites where growth is limited by available water. This work compares the physiological strategies adopted by *E. globulus* and *E. nitens* in their response to water stress.

(a) A scaffold tower reaching the canopy of a 17 year old *E. nitens* plantation at Surrey Hills (APPM, Forest Products). (b) Mr Mark Hunt, an Honours student with the Centre, measures the water potential of leaves collected from the canopies of *E. nitens* accessed using a scaffold tower.

The stomatal conductance of irrigated and rainfed plots at an experimental plantation east of Hobart has been measured on several days through two stress cycles in the rainfed plots. Pre-dawn water potential and soil water content were recorded often enough to monitor long term trends in water stress. Radiation, temperature, humidity and rainfall are continuously monitored by an automatic weather station.

Monthly measurements of height and diameter are made along with annual harvests of selected trees in each treatment so that changes in leaf area index can be monitored throughout the year from leaf area/sapwood area relationships.

The measurement phase of this work was supported by ACIAR (1990-93) but research is continuing as part of the PhD program of Mr D White within the CRC.

Outcomes

- In the absence of water stress, stomatal conductance increased seasonally to give maximum values in early February and diurnally to give maxima well before midday in both species.
- In the irrigated treatment, mean maximum stomatal conductances were 1.22 and 1.49 cm s^{-1} in *E. globulus* and *E. nitens* respectively and throughout the season remained consistently higher in the former compared to the latter. In the rainfed treatment this was reversed (Figure 10).
- Severe water stress significantly reduced diameter growth and leaf area development. Even in the second year of growth only 40% of the evaporative demand to meet potential growth rates fell as rain.
- The results suggest that *E. nitens* is more conservative in its water use when water stressed than *E. globulus*. Water stress limits growth through a combination of reduced leaf area and stomatal conductance which is more pronounced in *E. nitens* than *E. globulus*.

Goals

- Analyse the effect of repeated cycles of drought on the tissue water relations of *E. globulus* and *E. nitens*.
- Describe the diurnal and seasonal variation in stomatal conductance of juvenile leaves of *E. globulus* and *E. nitens* under irrigated and rainfed conditions.

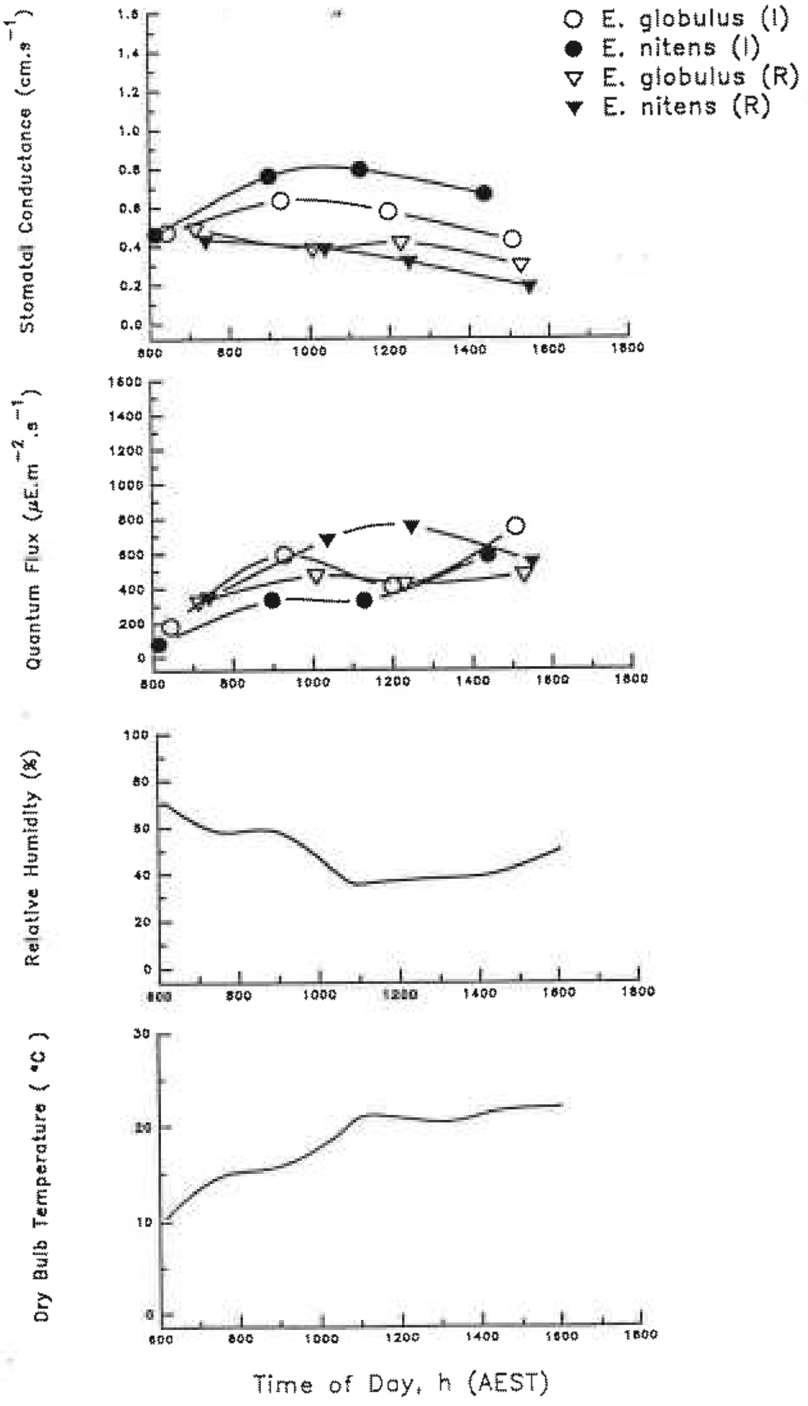


Figure 10 Diurnal change in stomatal conductance in irrigated (I) and rainfed (R) plots of *E. globulus* and *E. nitens* during a single day. The corresponding change in quantum flux, relative humidity and temperature are also plotted.

d) Levels of foliar nutrients in plantation eucalypts under intensive management.

The variation in foliar levels of the macronutrients N, P, K, Ca and Mg was investigated over a two-year period in six species of plantation eucalypts aged between 2 and 4 years of age at four sites receiving high levels of fertiliser. Soil variables were measured prior to and after broadcast application equivalent to 410:180:150 kg per hectare of elemental N:P:K.

Outcomes

- Fifteen months after cessation of fertilisation, significant increases in extractable P and decreases in exchangeable Mg and pH had occurred in the soils at all four sites. No other significant changes in soil chemistry across sites were observed consistent with the concept that the impact of fertiliser is primarily on tree growth and not the soil.

- The largest impact on variation in foliar levels of N and P was due to the different sites at which trees were planted. While levels of N and P increased in the leaves of fertilised trees, it appeared that in spite of short-term increases in the supply of these elements through addition of fertilisers, the ranking of sites was primarily related to pre-existing levels of N and extractable P in the soil.

- The ratio of foliar N:P across sites and sampling occasions varied between 6.1 and 14.6. The lowest foliar levels of N, (<1.52%; Table 1), were found in the fastest growing species, *E. nitens*.

Species	Sep 1985	Mar 1986	Aug 1986	May 1987	Sep 1987
E. globulus	1.25	1.63	1.44	1.74	1.55
E. nitens	1.03	1.38	1.28	1.52	1.40
E. regnans	1.28	1.63	1.55	1.97	1.66

Table 1 Mean foliar N concentrations (%) in the upper canopy across four sites. Note the higher concentrations at the end compared to the beginning of the growing season. *E nitens* was the fastest growing of the three species across all sites and always had the lowest foliar N (and P) concentrations.

- Marked differences between species occurred in foliar levels of K, Ca and Mg in every sampling period. For *E. globulus* K levels, and for *E. globulus* and *E. grandis* Ca levels, were significantly higher and for *E. nitens* Mg was significantly lower than for the other species on each sampling occasion. This resulted in a high ratio of Ca:Mg in all the *Symphyomyrtus* species, >5.2, compared to the *Monocalyptus* species, < 4.9.

For forest managers the results suggest:

- there is some indication that site fertility may be judged by the level of N and extractable P in the soil and

- foliar levels of N and P are related to available levels of these nutrients in the soil but this is not so for the other macronutrients.

Goals

- Describe the seasonal variation in foliar levels of N, P and K in eucalypt plantations.
- Establish the effect of foliar variation in N on net photosynthesis.

e) The establishment of dominance in young stands of eucalypts - implications for pruning and thinning in sawlog plantations.


APPM pruning trial.

When establishing plantations for sawlog production, one option is to plant at high densities, prune the final crop trees early in the rotation and remove other trees by thinning. The optimal stocking for these plantations is yet to be determined. Plantation managers are presently faced with the decision as to which and how many trees they should choose for pruning at three years of age to ensure that there will be the required number of sawn timber and veneer logs available at the end of the rotation.

To assist with this decision, data from a number of young stands of plantation eucalypts are being analysed to determine the degree of change in dominance of individual trees as the plantation ages. This should allow managers to determine with what certainty they can select final crop trees at an early age.

Outcomes

- The changes in the diameter class were studies in four stands of *E. nitens* growing in the Esperance Valley. Between 3 and 5 years of age the proportion of trees which moved into or out of the 30% largest diameter class were 17%, 0%, 33% and 17% in the 4 stands (as proportions of the trees present at 5 years of age). Between ages 4 and 5 years, the corresponding changes were 0%, 0%, 17% and 0%. These relatively small changes suggest that tree position in the dominance hierarchy was well established by 3-4 years of age in these fast growing plantations.
- The distribution of tree height was then investigated in two 9.7 ha blocks of a three-year-old *E. nitens* plantation established at 1220 stems ha^{-1} at Creekton. It was found that these two blocks had 537 and 329 prunable stems, given that a minimum tree height of 6m is required for a pruning to 3m height to be carried out (Table 2).

Block	Height	DBHob	% Prunable
D1	7.08	8.53	44
D2	5.44	5.92	27

Table 2 Mean height (m), DBHob (cm) and % prunable trees in 5 x 30 tree growth plots at age three years (Creekton plantation, *E. nitens*). % prunable trees was based on a minimum height of 6m but excluded trees with multiple leaders, competing limbs and heavy limbs.

- These two sets of results suggested that if 250 final crop stems ha^{-1} are desired in a sawlog plantation, enough of the larger trees in the stand are sufficiently tall at 3 years of age to be selected for pruning to 3m and these will remain the faster-growing trees at the site.

Goals

- The Creekton plantation and others established using different regimes will be used by a post-graduate to be appointed to the Centre and supported by the Forests and Forest Industry Council. The investigation will focus on canopy development of pruned trees following thinning and the maintenance of high rates of growth in sawlog plantations. Of particular interest is the effect of different levels of pruning on subsequent growth and wood quality.

Project 2

Project Leader
Mr R Cromer

Dynamics of Carbon and Nutrients

Introduction

This project aims to investigate the accumulation, allocation and cycling of carbon and nutrients in plantations of *E. nitens* and *E. globulus*, particularly in response to nutrient availability. Specific nutrient deficiencies or toxicities that become evident will also be investigated.

Knowledge of how biomass and nutrients are allocated to various components of trees including leaves, stems and roots, can provide an insight into the mechanisms through which the rate of nutrient supply influences overall rate of growth. Nutrient availability in eucalypt plantations can be manipulated by application of fertilisers, conservation of organic matter between rotations, inoculation of seedlings with suitable ectomycorrhizal fungi and other methods. In this project we will study:

- allocation of biomass and nutrients to above- and below-ground components,

- development of coarse and fine root systems in contrasting fertiliser treatments.

An improved understanding of the mechanisms through which nutrients influence tree growth will enable us to provide industry with recommendations on:

- appropriate fertiliser schedules for hardwood plantations,
- methods to manage slash residues,
- management techniques to sustain or improve site productivity.

a) Allocation and cycling of nutrients

In order to examine the role of nutrients in plantation productivity, the following fertiliser experiments (N plus P) were established with Centre partners during 1992:

- *Southern Tasmania: ANM, West Field.* Soil type is a yellow podzolic on siltstone at an elevation of 430 m with a mean annual rainfall of *ca.* 2000 mm. Planted in October 1992 with *E. nitens* of seed orchard origin raised by APPM. Fertiliser treatments range from nil to 600 kg ha^{-1} N with 300 kg ha^{-1} P applied in a single application two months after planting. One treatment has split application times.
- *North-west Tasmanian: APPM, Middlesex.* Soil type is basalt at an elevation of 620 m with a mean annual rainfall of >2000 mm. Planted in November 1992 with improved seed of *E. nitens*. Nitrogen treatments are the same as for West Field, but P rates were doubled as the soil has a high fixation capacity.
- *North-east Tasmanian: Forest Resources, Nabowla.* Soil type is sandy and silty duplex on siltstone and sandstone (Mathinna Beds) at an elevation of 100-240 m with a mean annual rainfall of *ca* 800 mm. Planted in October 1992 with *E. globulus* of improved seed orchard origin. Fertiliser treatments as for West Field but without a split application.

Outcomes

- The major outcome for 1992/93 has been the establishment of the experiments that will provide sites for intensive research over the next few years.

Goals

- Measurement of above-ground growth in response to added nutrients, the effect of treatments on length of fine roots and the nutrient content of above- and below-ground-components

Figure 11. Two year old *E. nitens*, stripped of their leaves so that branches and stems could be seen. (a) unaffected tree with straight stem and branches (b) severely affected tree with sinuous stem and branches.

- Establishment of two additional experiments in 1993 on sites provided by ANM and Forest Resources where the nitrogen and phosphorus treatments will be applied in factorial combination to allow separation of the effects of these two nutrients.

b) Copper deficiency in *E. nitens*

In Australia, emphasis is currently being placed on the establishment of eucalypt plantations to provide a secure high quality wood resource and to lessen dependence on native forest resources. This has led to an expansion of plantation establishment onto fertile pasture sites.

A fertiliser experiment was established in September 1990 at Gould's Block, Dover, southern Tasmania, on an improved pasture site. Trees were planted in a 5x5 factorial design with application of N at 0, 60, 120, 240 and 480 kg ha^{-1} and P at 0, 30, 60, 120 and 240 kg ha^{-1}. Phosphorus was semi-broadcast as a single dose after planting in September 1990 and nitrogen was applied over a two-year period thereafter.

Outcomes

- At first, most of the trees grew very well (Figure 11a), but after 21 months-of-age, stem malformations were observed in many trees. The degree of malformation increased significantly with increasing levels of applied nitrogen or phosphorus fertiliser and was most severe at the highest levels (Figure 11b).
- Concentrations of Cu in foliage were significantly lower in malformed than unaffected trees (Figure 12) whilst concentrations of other macro- and micro-nutrients were unrelated to the symptoms. Trees with Cu concentrations above 1.4 ppm did not generally exhibit symptoms.

Mr Robin Cromer studies the growth of eucalypts in an aeroponic system where nutrient solution is sprayed onto the roots (Ingastad Growth Units).

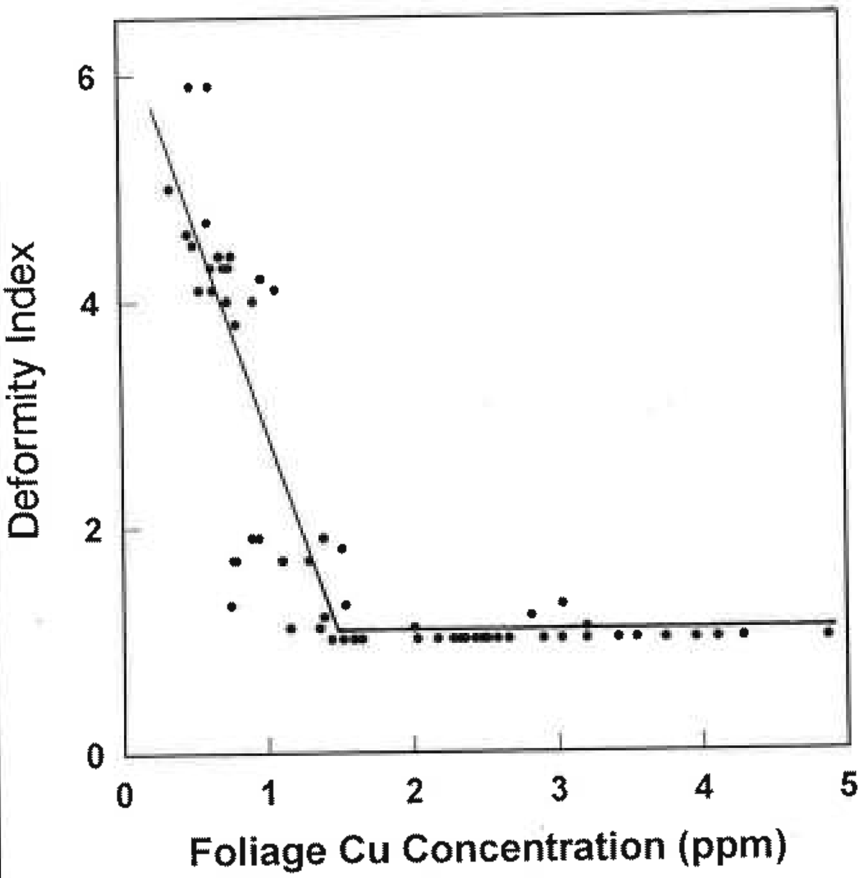


Figure 12 The relationship between deformity index (scale 1-6, increasing with increasing deformity) and Cu concentration in the foliage. The solid line shows the least squares fit to the data of a 'broken-stick' model.

- Applications of Cu, Cu and B, B and a trace element mixture were made (as foliage sprays) in September 1992 (age 2 years) to malformed trees. A significant improvement in whole-tree deformity index was evident by March 1993 in trees that had been sprayed with Cu.

- The observed deformations would substantially reduce the merchantability of affected trees. Managers should avoid excessive use of fertiliser where eucalypts are established on improved pasture sites.

Goals

- A second site has been identified where trees may be exhibiting symptoms of Cu deficiency. If samples of plant material verify this observation, a trial will be established to test ameliorative treatments on one-year-old trees, before symptoms have become apparent.

Project 3

Project Leader
Dr P Smethurst

Dr Phil Smethurst studies soil cores.

Nutrient Supply and Acquisition

Introduction

Research has been initiated to develop techniques for managing the nutrition of temperate eucalypt plantations. The nutrients of primary interest are N and P. Goals of the project are to :-

- determine the rates of N and P supply from native soil resources,
- determine management practices that optimise the availability of these nutrients,
- evaluate the potential of roots to enhance the supply of P in their rhizosphere,
- determine the constraints to mineralisation of N and P,
- describe root development in typical plantations,
- determine the constraints to root growth, and
- quantify the nutrient absorption properties of roots.

a) Soil solution concentrations of nitrogen and phosphorus after fertilisation

This works aims to determine the effects of management practices on soil solution concentrations of N and P. It is these concentrations that determine directly the availability of nutrients to trees.

Fertilisers containing N and P were applied to three plantation sites at various rates within two months of planting. Samples have been collected periodically for the measurement of soil solution concentrations of these nutrients.

Outcomes

- In a gradational yellow podsolic soil in the Florentine Valley, concentrations of ammonium in soil solution (0-10 cm depth, four months after fertilisation) ranged from 0.3 mM without fertiliser to 2.1 mM with 600 kg ha^{-1} of N applied (Table 3).
- Although concentrations of nitrate were higher than those of ammonium and generally decreased with an increasing rate of

N application, differences between treatments in nitrate were not significant.

N Applied ($kg\ ha^{-1}$)	P Applied ($kg\ ha^{-1}$)	NH_4^+ (mM)	NO_3^- (mM)	P (µM)
0	0	0.3	4.7	0.5
75	38	0.5	3.1	0.9
150	75	0.7	2.9	0.9
300	150	1.1	2.7	2.3
600	300	2.1	3.7	4.6
LSD (p = 0.05)	1.0	NS	0.6	

Table 3 Concentration of ammonium, nitrate and phosphorus in soil solution four months after fertilisers were applied to a gradational yellow podsolic soil in the Florentine Valley. N was applied as ammonium sulphate and P as triple super phosphate. samples were collected from 0-10 cm depth and extraction were made using the saturated paste method.

- High nitrate concentrations, and the high mobility of nitrate compared to ammonium, suggests that young trees at this site were taking up N mainly as nitrate. These concentrations of ammonium and nitrate would be adequate to sustain healthy growth of *Eucalyptus* in hydroponic culture. High concentrations of these ions may be the result of increased rates of mineralisation and nitrification after clearfelling and site preparation, and an absence of plants to take up N. However, it is surprising that nitrate concentrations were not increased by N fertilisation.

- The application of P (up to 300 kg P ha^{-1}) did not raise soil solution concentrations of P (Table 3) to the critical concentration of 7 µM suggested in the literature, above which P would not be expected to limit growth.

- Despite the strong effects of fertilisation on concentrations of ammonium N and P in soil solution, early indications are that tree growth during the first 8 months after planting was little affected by these treatments. During this period, the tree seedlings were probably still growing on the N and P reserves brought with them from the nursery. Hence, rates of N and P supply were not the main factors limiting early tree growth on this site.

- From a management point of view, these results suggest that fertiliser need not be applied at establishment at sites of this nature. Application should be delayed until tree demand exceeds the supply, perhaps 1 or 2 years after establishment.

Goals

- Measurement of the Florentine trial and other trials established in cooperation with Project 2 and the industry partners in the Centre will continue and hopefully elucidate the N and P requirements of eucalypt plantations in Tasmania and thereby aid in the refinement of fertiliser prescriptions. As well, future investigations will:-

- Compare methods of sampling soil solution for the measurement of nutrient concentrations.

- Summarise first-year results of the effects of fertiliser applications to various soil types on the concentrations of N and P in soil solution.

Mr Peter Volker (ANM, Forest Management) discusses site preparation techniques for eucalypt plantations in the Florentine Valley.

b) Growth of eucalypts in relation to soil strength and cultivation

Dr R Misra joined the Centre during the year has commenced research to determine the critical mechanical resistance or bulk density of soil above which root growth is restricted. He will also examine above- and below-ground growth in relation to variations in soil physical properties brought about by cultivation practices.

Goals

- Determine the effect of various cultivation treatments of duplex and gradational soils on pine growth 10 years after planting, and, by extrapolation, indicate the potential for long-term effects of cultivation on eucalypt growth.

c) Processes affecting nutrient uptake by plants

There are three students, a Masters student and two Honours students, involved in research projects investigating nutrient uptake by plants and microbes.

Mr T Garnett (MSc candidate) is studying the N absorption properties of eucalypt roots. This work will improve our understanding of how eucalypts acquire N under contrasting environmental conditions. The results will be interpreted in relation to soil solution concentrations and root growth determined by others in the project, with the aim of improving N fertiliser management.

Applied N may be immobilised in the microbial biomass and not become available to trees. Mr M Moroni (AgSci Hons candidate) is studying the potential importance of this in mediating tree growth responses to applied N. Measurements of microbial biomass after fertilisation have commenced on samples from two fertiliser experiments. Variables investigated as potential limitations to microbial growth will be pH, available carbon, N, P and Ca.

Mr I Green (AgSci Hons, candidate) is conducting an experiment to test the hypothesis that uptake of P by *E. globulus* in highly P-fixing soils will be restricted at soil solution concentrations less than 7 μM, a critical value suggested for a diverse range of other species. Results are expected to indicate rates of P application needed to achieve this concentration.

Project 4

Project Leader Dr P Sands

Modelling Plantation Systems

Introduction

The principal task of this project is 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 for purposes including:

- prediction of future wood yields of plantations for yield scheduling,
- optimisation of fertiliser schedules to maximise profitability,
- prediction of impacts on wood yield of environmental change or pest damage,
- prediction of water use at a site to schedule effluent disposal,
- determination of the profitability of silvicultural practices such as thinning or pruning and
- assessment of site suitability for plantations.

a) Model of canopy photosynthetic production

Over periods of time from hours to a day, production by the canopy of an agricultural crop or a forest varies widely in response to environmental variables such as temperature, irradiance and plant water status. Consequently, models of canopy production are frequently quite complex and require extensive input. However, empirical observations suggest annual canopy production is linearly related to radiation intercepted by the canopy. The slope of this relationship, the canopy light utilisation efficiency (ε) appears to be characteristic of the species, modified by factors such as the long-term nutrient or water status of the crop.

This observation suggests calculation of annual production by a forest canopy requires knowledge only of ε and the amount of light intercepted by the canopy. The proposed model of tree growth will calculate annual production in this way. This should simplify substantially the present complexity involved in estimating annual photosynthetic production for a forest canopy.

The single leaf light response curve describes instantaneous photosynthetic rate of a single leaf as a function of amount of radiant energy incident upon the leaf. (See examples of such curves in the report of Project 1a) of this Program). It can be readily measured experimentally in the field or glasshouse, and is characterised by a small number of parameters which change in a definite way as a consequence of changes in environmental factors such as temperature, or changes in leaf nutrient status.

Outcomes

- Theoretical work as part of this project has lead to a simple algorithm for calculating ε given canopy leaf area index and a single-leaf light response curve of typical leaves within the canopy. This algorithm assumes photosynthetic resources are distributed so as to optimise canopy photosynthesis. It also assumes the light-response curve does not vary diurnally and is determined using a measure of mean day-time temperature. However, seasonal variation of solar radiation and temperature are taken in to account. ε is then expressed in terms of the parameters of the light-response curve, so effects of nutrients and temperature on instantaneous photosynthetic rate are taken into account.

Goals

- Development of this model will be completed during 1993-94. Collaboration with other projects in the Program will provide quantitative information on how single-leaf light response curves are affected by nutrient and water status, and by temperature.

b) Tree crown development

An important part of a model of photosynthetic production by forests is a description of canopy structure. This determines how much light the canopy intercepts and, hence, how much photosynthesis may occur. (See discussion on a) above).

Where forest canopies are closed, it is relatively easy to predict light interception. However when canopies are open, during early plantation development or following thinning, it is necessary to predict interception by individual tree crowns. Hence, it is necessary to predict changes with time in those crown properties which determine light interception, namely crown size, leaf weight and leaf area density (leaf area per unit crown volume). At present, no models exist and little published work world-wide addresses the issue of individual tree crown development.

In collaboration with the CSIRO Division of Forestry, work this year examined the dynamics of tree crowns at two experimental sites in *E. regnans* regrowth forest, one site at Buckland, Tasmania and the other at Toolangi, Victoria. At each site a plot was left unthinned and a second plot was randomly thinned to leave a range of stocking densities. The Buckland site is now 16 years old and the Toolangi site 12 years old.

Outcomes

- Figure 13 shows the change in leaf area index (LAI, one sided leaf area per unit ground area) at the two sites. The unthinned plot at Toolangi showed a large decrease in LAI over two years with a much smaller decline in the thinned plot. Large changes in LAI are not unprecedented in forest stands and may result from water stress induced in particular years. The smaller change in the thinned plot may reflect the higher average water availability per tree there. At Buckland there was evidence of some acceleration of LAI development in the thinned stand as the canopy redeveloped following thinning.

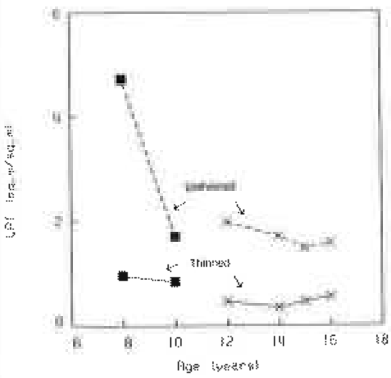


Figure 13 Change of age with leaf area index (LIA) in thinned and unthinned stands of *Eucalyptus regnans* at Buckland, Tasmania (■) and Toolangi, Victoria (X).

Table 4 shows the average rates of change per tree of various crown characteristics. In general, crown volumes increased, whilst leaf weights decreased so that crowns became sparser with time. There did not appear to be any relationships between crown development and tree characteristics or their light environment. This was surprising and discouraging with respect to the possibility of modelling crown development. The slowness of crown redevelopment following thinning in these experiments was surprising.

Measurement	Site	%change per year Unthinned	Thinned
	Buckland		
Crown volume (m^3)		2.7	9.8
Leaf dry weight (kg)		-9.4	0.6
Leaf area density (m^2 m^{-3})		-25.1	-20.0
	Toolangi		
Crown volume (m^3)		-9.9	24.6
Leaf dry weight (kg)		-49.4	-11.8
Leaf area density (m^2 m^{-3})		-47.4	-42.5

Table 4 Mean relative growth rates over 2-3 years for crown characteristics of trees following thinning at Buckland and Toolangi. Relative growth rate of variable X is (1/X)(dX/dt), where t is time (yr)

Goals

- The sites will continue to be monitored to determine what factors are driving crown dynamics and hence to determine prediction models of crown dynamics.

c) Growth efficiency of tree crowns

One aim of the project is to develop models of tree growth in response to management practices such as thinning. Thinning concentrates growth on fewer stems in the stand to increase their average diameter and hence sawlog yields.

Growth efficiency of tree crowns (volume increment per unit leaf area) has been observed to be curvilinear with crown size, with efficiency declining as size increases. Hence, the growth rate of two trees with the same initial diameter will vary with the size of their crowns. Models of tree diameter growth have never taken account of this phenomenon and are often inaccurate predictors, especially in thinned forest where crown sizes may be poorly correlated with tree diameter.

In this work, data from the thinning experiments described in b) were used to estimate growth efficiency of individual trees in the experiment. Efficiency was defined as the rate at which sunlight intercepted by tree crowns is converted to above-ground dry matter. That is efficiency, ε (kg MJ^{-1}), is given by P/r_a, where P is net dry matter production from photosynthesis (kg) and r_a is intercepted light (MJ). We drew on previously published models developed in CSIRO and the Centre to estimate both P and r_a.

Outcomes

- It was found that efficiency was higher in the thinned stands. This is believed to be due to the greater availability of water per tree in the thinned stand, allowing those trees to photosynthesise for a longer period each year. That is, growth response to thinning is a consequence of increased water availability to residual trees.

Goals

- Data from the experiments will be further analysed to develop improved methods of predicting the distribution of diameter growth amongst individual trees in thinned stands.

d) Site suitability for eucalypt plantations

An important part of the assessment of the suitability of a site for eucalypt plantations involves estimation of the wood yields that can be expected from the site. An ideal system for making such estimates would require the measurement of a few, easily obtained, edaphic and climatic characteristics of a site which could then be applied in some simple system to make the desired estimate.

Mr M Laffan of the Tasmanian Forestry Commission has developed such a system. It involves measurement of various site characteristics, namely altitude, rainfall and soil stoniness, depth, organic matter content, total phosphorus, cation exchange capacity and drainage. These factors are applied in a system similar to one developed for assessment of site suitability for agricultural crops by Dr C Hackett of the CSIRO. This involves establishing the relationship between crop yield and each of the measured environmental factors, assuming that none of the other factors limits growth. It is then assumed that yield on any particular site will be determined by whichever of those factors most limits growth at that site. No formal tests of the validity of Mr Laffan's system for eucalypt plantations have yet been conducted.

Goals

- It is intended to obtain data from a number of plantation sites, covering as wide a range as possible of environments in which plantations are likely to be established. These data will be used to determine the precision with which estimates of plantation yields can be made using this system. If this precision is below that which management purposes require (say about 15% of the estimate), work will be undertaken to try to develop the system to increase its precision. At the same time, it is intended to explore other systems presently in use in

Australia to attempt to rationalise these and produce a more widely applicable, single system.

e) Yield of Australian eucalypt forests

The effectiveness of a plantation program is ultimately judged by the gains in productivity that result from it. Tools to assess those gains will have use for policy planning at local and national levels. A baseline for assessing productivity gains is comparison of plantation wood yields with those of native forests. Surprisingly, little has been published to quantify yields of Australian native eucalypt forest.

In collaboration with the CSIRO Division of Forestry, a small amount of work this year completed a project to amalgamate eucalypt wood yield data collected mainly from high quality native forest by major Australian forestry agencies.

Outcomes

- Using these data, stand volume yield prediction models were developed for six commercially important species, *E. regnans*, *E. obliqua*, *E. delegatensis*, *E. pilularis*, *E grandis* and *E. diversicolor*. These models related volume growth to stand age and site index.

- Figure 14 (adjacent page) shows the change with age of stand mean annual increment (stand wood volume growth per unit time elapsed from stand establishment) as predicted by the yield models. Results for each species are shown at each of six site indices with equivalent yields for each species. They indicate that *E. diversicolor* has the most rapid early growth of these species, *E. pilularis* has the slowest and the other species are intermediate between these two. The data from which the models were developed were taken mainly from the areas of natural occurrence of the six species. This means that the species will not necessarily rank similarly in growth rate when grown together at other sites.

Goals

- The results of this work are being published and the subproject is now complete.

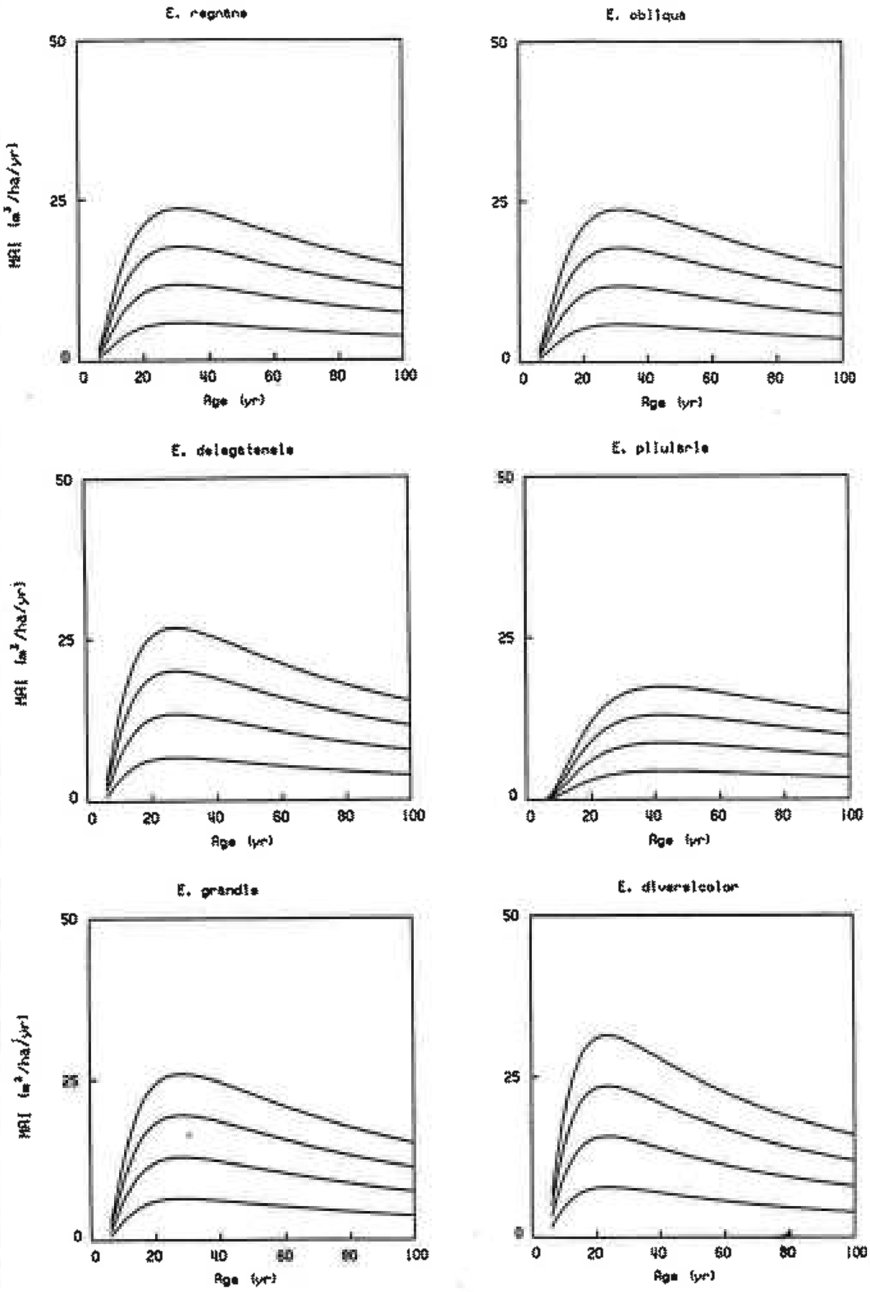
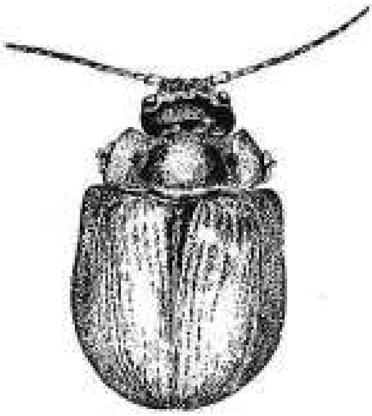


Figure 14 Change with age of mean annual increment (MAI) in stand volume for six eucalypt species. Results are shown for six levels of site productivity, assessed as asymptotic stand volumes of 500 (lowest line), 1000, 1500 and 2000 (uppermost line) m^3 ha^{-1}.

Resource Protection Program

Program Manager
Dr J Madden



Eucalyptus leaf eating beetle *Chrysophthatra bimaculata* (adult, 1cm long). This major insect pest of eucalpyt plantations is the focus of research by CRC entomologists.

Introduction

Projects within the program seek 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.

Major Achievements of the Program

- The effects of *Chrysophtharta bimaculata* browsing on growth of *E. regnans* has been quantified, modelled and incorporated into an operational integrated pest management program.
- An investigation of the chemical composition of the leaves of Tasmanian *Eucalyptus* species has been completed, providing baseline information for the study of herbivore/host plant interactions.
- An intensive beetle monitoring program in the Southern Forests has supplied population phenology data not previously available for southern Tasmania.
- In a study of the two Tasmanian species of coreid bug, advances have been made in understanding the development, oviposition rate and host plant usage.

Project 1

Project Leader
Dr J Madden

Leaf and tree factors affecting eucalypt defoliators

Introduction

The objectives of this project are 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 extractants, leaf physical properties and the reflectance of the canopies of potential host tree species.

Outcomes

- There are indications that it is the proportion of current red leaves within a canopy that discriminates the difference between families in their susceptibility to defoliation.
- In order, cineole, α-pinene and α-terpineol were found to be the most active leaf compounds affecting oviposition and larval survival and development of the leaf-eating chrysomelid beetle *Chrysophtharta bimaculata*. In contrast, *C. agricola*

was not adversely affected by these compounds, but rather by the triterpenoids of leaf surface waxes.

- A phytochemical study of leaf terpenoids and waxes of 29 *Eucalyptus spp* and its relevance to chrysomelid beetle preferences was completed.

- An evaluation of the use of colour traps to detect timing and intensity of chrysomelid attack within plantations was commenced.

Leaf damage in *E. nitens* caused by the larvae of *Chrysophtharta bimaculata*.

Goals

- Determine the incidence of beetle attack and the distribution of eggs in relation to the proportion of coloured leaves between and within trees of species and families within species.

- Relate spectral changes in leaf reflectance to both the pigment change within leaves and shoot growth.

- Quantify the constitutive defensive chemicals of two host tree species and relate their effects on *C. bimaculata* larvae and adult performance and survival through browsing.

- Document the movement and survival of first instar *C. bimaculata* larvae.

- Determine if herbivore-induced defensive reactions are elicited in host leaves/trees following infestation.

- Refine procedures for breaking the reproductive diapause of *C. bimaculata* to permit experimentation throughout the year.

Project 2

Project Leader
Dr H Elliott

Control of insect defoliators

Introduction

Operational trials have been initiated to examine the effects of (a) thinning eucalypt stands and subsequent changes in growth rates and (b) alternate plantings of preferred and less preferred species on subsequent preference and damage by chrysomelid beetles.

A complementary study compared natural defoliation in areas of 5 year old *E. regnans* which had been (i) sprayed regularly with insecticide (ii) sprayed once according to estimated potential risk assessed within an operationally implemented integrated pest management (IPM) strategy and (iii) left unsprayed (control).

Studies of the intensity of defoliation by known populations of *Chrysophtharta bimaculata* placed within gauze cages on *E. nitens* trees at Gould's Block.

Outcomes

- The relationship of *C. bimaculata* larval population size and subsequent damage to *E. nitens* adult foliage was quantified using field cages. Damage occurred in the order of freshly expanded leaves, buds and mature leaves. Initial and final leaf areas were assessed and data analysed for subsequent incorporation in a model of damage impact on tree growth and potential yield.

- Regular spraying of 4 year old plantations of *E. regnans* with α-cypermethrin during growth resulted in larger trees (11.6 cm in diameter) than if spaying occurred once according to IPM recommendations (9.3 cm) or in control plantations (7.7 cm).

- The residual activity of three insecticides on field foliage was assessed. The currently employed material, α-cypermethrin, was found to fully protect foliage from larval attack for more than three weeks (Figure 15). In contrast, cycloprothrin and thiodicarb declined to below 50 per cent effectiveness over one week.

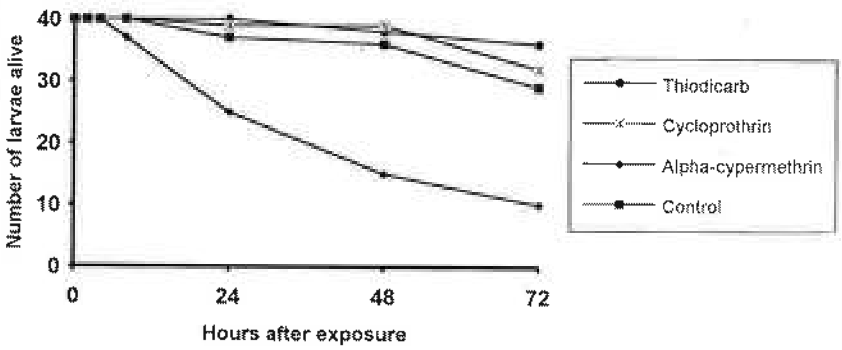


Figure 15 Survival of second instar of *Chrysophtharta bimaculata* on leaves sprayed with 3 insecticides 23 days previously.

- The movement of *C. bimaculata* and its natural enemies within a compartment was monitored by use of coloured sticky traps. Dissection of beetles from each week's collection indicated that trap catches at this time consisted of mature and immature (local) beetles. Invading beetles were found to be infested with mesostigmatid parasitic mites.

Goals

- The impact of browsing by *C. bimaculata* on the growth of *E. nitens* will be evaluated and incorporated into a defoliation model.

- Basic biological studies of *C. bimaculata* will continue and will include studies of adult longevity and dispersal and the effects of temperature on larval development and egg production.

- Factors associated with the *C. bimaculata* Integrated Pest Management Program, such as monitoring and sampling strategies, evaluation of insecticides and investigation of natural enemies will be addressed. This will include determination of the role of host tree and larval frass volatiles on *C. bimaculata* and natural enemy numbers, and an evaluation of application methods, residual toxicity and repellent effects of a range of insecticides.

Project 3

Project Leader
Dr A Clarke

Biology and ecology of Tasmanian coreid bugs

Introduction

This project aims to increase understanding of the taxonomy, biology and life history of two species of coreid bugs which have caused economic damage to plantation eucalypts.

Outcomes

- Successful culture of the coreid bug, *Amorbus rubiginosus* under controlled conditions was achieved for the first time.

- Morphological development of the two species has been intensively examined at different constant temperatures.

- Laboratory methods for mass culturing coreids have been developed.

- Levels of parasitism and identity and incidence of predators have been determined within ongoing population studies.

- The geographical distribution, seasonal phenology and damage status of both species is being established.

Goals

- Clarify the taxonomy of *Amorbus angustior* and *Amorbus rubiginous* .

- Determine the Australian distribution of *Amorbus* spp., with particular reference to the above species, using collections from throughout Australia and seasonal phenology.

- Further examine the developmental biology of *A. angustior* and *Gelonus tasmanicus*. and determine the host tree preference for both species.

Project 4

Project Leader
Professor M Stoddart

Vertebrate browsing

Introduction

Vertebrate browsers can destroy significant numbers of newly planted trees per annum.

The objective of this project is to seek alternative methods to protect seedlings and young trees from damage and destruction in order to obviate the use of environmentally unacceptable materials.

Research in this program has just commenced with the appointment of a PhD student, Ms N Marsh.

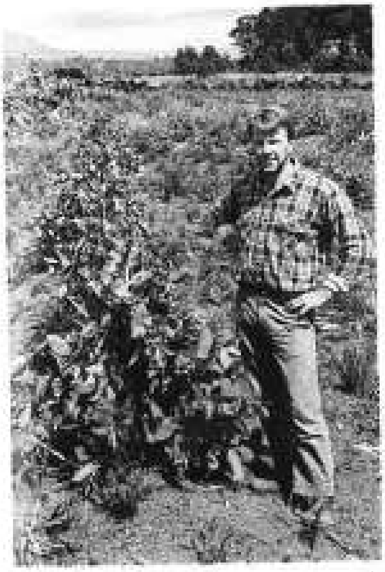
Brushtailed possum (courtesy of the Tasmanian Museum).

Goals

- To ascertain whether browsing species prefer certain species of eucalypts causing more severe damage on some species than others.
- To identify the olfactory, gustatory or visual cues, or a combination of these, which are most important in determining browsing.
- To identify the chemicals that trigger the sensory system and result in either feeding or aversion.

Education and Communication Program

Program Manager
Dr N Davidson



Honours student Mr Tony Hooper in a Forest Resources plantation at Deloraine where he is studying the persistence of inoculated mycorrhizae on the roots of *E. nitens*.

Introduction

In Australia, postgraduate training in production forestry is largely restricted to schools at the University of Melbourne and the Australian National University. These schools have limited capacity for postgraduate training in areas of tree genetics and protection of forests against depredation by insects and vertebrates. The main aims of the Education and Communication Program are to expand postgraduate and postdoctoral research in these fields and to facilitate and enhance interactions within the CRC.

Major Achievements of the Program

- A major expansion of Honours and Postgraduate student numbers from 16 to 28 was achieved in key areas within the three research programs. Two Postdoctoral Fellows were also appointed.
- CRC appointed staff, in addition to those from University departments were involved in teaching in industry workshops, in third and fourth year university classes and in supervision of Honours and Postgraduate students.
- Progress was made towards the development of a CRC ethos and in fostering interactions both within and outside the CRC. Two workshops were held in November 1992 and April 1993, involving all Programs, and weekly research seminars were given by CRC staff and students. As well, the CRC logo was finalised.
- A booklet presenting Research Profiles for all CRC research scientists was completed.
- Two workshops were held during the year which provided members of our Industry Research Coordination Committee (IRCC) and Scientific Review Committee (SRC) an opportunity to provide input directly to our research programs and to foster new collaborative projects.

Honours and Postgraduate Students

In the last 12 months, there has been a substantial increase, from 16 to 28, in the numbers of Honours and Postgraduate students contributing to CRC research. The CRC now has 17 PhD, 3 Masters and 8 Honours students divided amongst the four Programs; 9 in Genetic Improvement, 6 in Resource Protection, 4 in Soil and Stand Management and 9 in Education (Tables 5 and 6).

Table 5(a) Details of research students at the CRC in 1993

Last Name	First Name	Title	Degree	P\F Time	Start	Finish	Funding	CRC Program
BATTAGLIA	Mike	Mr	PhD	Full time	1990	1993	DPI-Forestry	Education
BROOKS	Simon	Mr	BSc(Hons)	Full time	1993	1993	None	Education
CASEY	Steve	Mr	PhD	Full time	1992	1995	APRA-Industry	Education
DUNGEY	Heidi	Ms	PhD	Full time	1992	1995	Univ Res Scholarship & CRC	Genetic Improvement
GARNETT	Trevor	Mr	MSc	Full time	1993	1994	CRC	Soil & Stand Management
GREAVES	Bruce	Mr	PhD	Full time	1993	1996	APRA & CRC	Genetic Improvement
GREEN	Ian	Mr	BAgSci(Hons)	Full time	1993	1993	CRC	Soil & Stand Management
GRIGGS	Judy	Ms	BAgSci(Hons)	Full time	1993	1993	CRC	Resource Protection
HAIFENG	Li	Mr	PhD	Full time	1989	1992	Industry	Resource Protection
HARDNER	Craig	Mr	PhD	Full time	1993	1996	CRC	Genetic Improvement
HASAN	Omar	Mr	PhD	Full time	1990	1993	CRC	Genetic Improvement
HICKEY	John	Mr	MSc	Part time	1991	1994	None, FCT Employee	Education
HOOPER	Tony	Mr	BSc(Hons)	Full time	1993	1993	None	Education
HUNT	Mark	Mr	BAppSci(Hons)	Full time	1993	1993	CRC	Education
LAWRENCE	Naomi	Mrs	PhD	Full time	1993	1996	CRC	Genetic Improvement
MANSON	Andrea	Ms	BSc(Hons)	Full time	1993	1993	CRC	Genetic Improvement
MARSH	Nadia	Ms	PhD	Full time	1993	1996	CRC	Resource Protection
McENTEE	Anne	Ms	PhD	Full time	1992	1995	APRA	Education
MORONI	Martin	Mr	BAgSci(Hons)	Full time	1993	1993	CRC	Soil & Stand Management
NESBITT	Katherine	Ms	PhD	Full time	1992	1995	APRA & CRC	Genetic Improvement
PATTERSON	Kathryn	Ms	PhD	Full time	1993	1996	APRA & CRC	Resource Protection
PRESSER	Jennifer	Ms	BS(Hons)	Full time	1993	1993	CRC	Genetic Improvement
SHOHET	Debbie	Ms	PhD	Full time	1991	1995	APRA & CRC	Resource Protection
STEINBAUER	Martin	Mr	PhD	Full time	1992	1995	CRC	Resource Protection
VOLKER	Peter	Mr	PhD	Part time	1992	1996	None	Genetic Improvement
WHITE	Don	Mr	PhD	Full time	1993	1996	CRC	Soil & Stand Management
WILKINSON	Graham	Mr	MSc	Part time	1990	1994	None, FCT employee	Education
WILLIAMS	Kristen	Ms	PhD	Full time	1991	1994	DPI-Forestry	Education
WILSON	Steve	Mr	PhD	Full time	1993	1996	APRA-Industry (TFRC)	Soil & Stand Management

Table 5(b) Topics and supervisors of CRC research students

Last Name	Topic	Scientific Supervisors
BATTAGLIA	Seed germination and establishment of E. delegatensis	Prof Jim Reid
BROOKS	Resource partitioning in 12 year old seedlings of 6 eucalypt species	Dr Neil Davidson
CASEY	Fire regeneration after logging in dry Eucalypt forest	Dr Robert Hill
DUNGEY	The susceptibility of Eucalypt hybrids to pests	Dr Brad Potts*, Prof Jim Reid
GARNETT	Kinetic uptake parameters of Eucalpyt roots for nitrogen and phosphorous	Dr Phil Smethurst, Dr Neil Davidson*
GREAVES	Age to age correlations in Eucalypts	Ms Carolyn Raymond, Dr Brad Potts*, Dr Nuno Borralho
GREEN	Phosphorous uptake by E. globulus	Dr Phil Smethurst, Dr Bob Menary
GRIGGS	Wood boring insects	Dr John Madden
HAIFENG	Phytochemistry of Eucalyptus spp. and C. bimaculata attack	Dr John Madden
HARDNER	In breeding in eucalypts	Dr Brad Potts*, Dr Nuno Borralho
HASAN	Gibberellins and the control of flowering in E. globulus and E. nitens	Prof Jim Reid
HICKEY	Long-term regeneration in logged mixed forest	Dr Robert Hill*, Dr Mick Brown
HOOPER	Persistance of innoculated mycorrhizae on E. nitens	Dr Neil Davidson*, Dr Nick Malajczuk, Dr Phil Smethurst
HUNT	Micro-environment and water relations of E. nitens and the D. antarctica understorey	Mr Greg Unwin, Dr Chris Beadle, Dr Neil Davidson*
LAWRENCE	Tissue culture of Eucalypts	Mr Vic Hartney, Dr Janet Gorst*
MANSON	Inheritance of traits in F1 and advanced generation hybrids of E. globulus and E. gunnii	Dr Brad Potts*, Dr Rene Vaillancourt
MARSH	Browsing of Eucalypt seedings by possums	Prof Mike Stoddart
McENTEE	Pollination ecology and gene flow	Prof Jim Reid*, Dr Brad Potts
MORONI	Biotic component of soil nitrogen	Dr Phil Smethurst, Dr Martin Lyon*
NESBITT	Molecular markers in E. globulus	Prof Jim Reid*, Dr Adrain West
PATTERSON	The influence of leaf chemistry on grazing of E. nitens leaves by C. bimaculata	Dr John Madden*, Dr Tony Clarke
PRESSER	PCR finger printing of E. globulus RNA to study phase change	Prof Jim Reid
SHOHET	Biological control of C. bimaculata	Dr John Madden*, Dr Humphrey Elliott
STEINBAUER	Sap-sucking insects (Coreid bugs)	Dr John Madden
VOLKER	Estimation of genetic parameters for Eucalypt hybrids	Dr Brad Potts*, Dr Nuno Borralho
WHITE	Water relations of E. nitens and E. globulus under cyclical drought	Dr Chris Beadle, Dr Neil Davidson*
WILKINSON	Genetic variation in E. obliqua	Prof Jim Reid
WILLIAMS	Modelling Eucalyptus distribution	Prof Jim Reid*, Dr Mike Austin, Dr Mick Brown
WILSON	Early growth and survival of eucalypt seedlings	Prof Rob Clarke*, Mr Peter Volker

*** Administrative supervisor**

Table 6 Summary of student enrolments in the CRC

I Undergraduate Students

Degree:	Forest Ecology	First year	5
		Second year	3
		Third year	4
		Fourth year	1
			13

II Postgraduate Students

		Number of Students
Full/Part Time:	Full time	27
	Part time	2
Degree:	BSc Honours	5
	BAgSci Honours	3
	MSc	3
	PhD	17
CRC Program:	Genetics	9
	Soil & Stand Management	4
	Resource Protection	6
	Education	9

Supervisor:	Dr M Austin	1	Dr J Madden*	5
	Dr C Beadle	2	Dr N Malacjzuk	1
	Dr N Borralho	3	Dr R Menary*	1
	Dr M Brown	2	Dr BM Potts	6
	Prof R Clark*	1	Ms C Raymond	1
	Dr A Clarke	1	Prof J B Reid*	8
	Dr N Davidson	5	Dr P Smethurst	4
	Dr H Elliott	1	Prof M Stoddart*	1
	Dr J Gorst*	1	Mr G Unwin*	1
	Mr V Hartney	1	Dr R Vaillancourt	1
	Assoc Prof R S Hill*	2	Mr P Volker	1
	Dr M Lyon*	1	Dr A West*	1

Funding:	CRC (Honours Scholarship)	6
	CRC (PhD/MSc Scholarship)	7
	CRC & Univ Research Scholarship	1
	CRC & APRA	4
	APRA	1
	APRA - Industry	2
	IDP	1
	DPI - Industry Forestry	2
	Non, Employed in forest industry	3
	Non, Self-supporting	2

* University Department Staff

A very successful advertising campaign run in October 1992 attracted 24 applications for PhD programs and 10 for Honours programs. Finally, 7 PhD scholarships were offered (at $18,679), and of these, two (Mr B Greaves and Ms K Patterson) also received an APRA award (Table 5). Three of these students were attracted from interstate, two were scientists in industry or the CSIRO and the remaining two were Honours graduates from the Plant Science Department in Tasmania. Six Honours scholarships were offered; 3 at $5,000 to Honours students undertaking full time research, and 3 at $1,000 to Honours candidates whose research projects in the Faculty of Agriculture contributed approximately 20% of the Honours result.

The Postgraduate Diploma in Science (Forest Processes) was in place during 1993 but did not attract the expected industry interest. An advertising campaign will start in October 1993 to attract students to this course in 1994.

Professor Jim Reid describes vegetation patterns to a third year undergraduate class.

Undergraduate students

The four year Forest Ecology course run by the Plant Science Department has 13 students enrolled for 1993, one of these, Mr S Brooks is in the fourth (Honours) year of this course (see Table 6).

Postdoctoral Fellowships

Three postdoctoral Fellowships were advertised, one in each Research Program. The Postdoctoral position in the Resource Protection Program was accepted by an insect ecologist Dr A Clarke, previously a Tutor at the University of Queensland. Since arriving, Dr Clarke has assumed responsibility as the Project Leader in Project 3 of the Resource Protection Program and is actively involved in the supervision of postgraduate students. The Postdoctoral Fellowship in the Soil and Stand Management Program was accepted by Dr M Battaglia, who has recently completed a PhD in plant ecology at the University of Tasmania. The position in the Genetic Improvement Program remains to be filled.

Teaching

Several of the CRC staff based at the Centre laboratories, at the private companies and the Forestry Commission of Tasmania have been involved with teaching at the CRC.

Five CRC staff members are now contributing to third and fourth year university courses in fields closely 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 and Dr P Smethurst in Soil Nutrition.

(a) At a workshop entitled "Establishing Eucalypt Plantations" Dr Chris Beadle describes the growth responses of 4 eucalypt species planted at several topographic positions near Esperance.
(b) Workshop participants discuss experimental results.

Dr R Vaillancourt gave lectures in Molecular Biology to second year Plant Science students.

Supervision of Postgraduate and Honours students is now well distributed amongst the CRC partner institutions, such that more than half of the student supervision is performed by CRC staff outside University departments (Table 6).

Two short courses were held:
"Tree improvement for future plantations: A role for physiologists?" was a one day workshop and discussion session held on October 12 1992. It was run by Ms C Raymond (Genetic Improvement Program) and Dr P Kriedemann (CSIRO Division of Forestry, Canberra). It produced a lively debate amongst the 12 participants and emphasised potential methods for early selection of eucalypts based on physiological responses.

"Establishing Eucalypt Plantations", held on April 5-6 1993 consisted of a one day workshop with presentations on aspects of silviculture by representatives from each of the Tasmanian forestry companies, followed by a one day field tour to the Southern Forests. The workshop was organised by Dr C Beadle (Soil and Stand Management Program). It attracted 50 participants including students, field workers in the forest industry and farmers with interests in agro-forestry, and was successful in its objective to extend the experience of the Centre staff to the wider forestry community.

Two workshops were held during the year. One allowed Centre staff to present to our industry partners the aims, objectives and proposed outcomes for each project in the three research programs. The second gave our industry partners the opportunity to outline their strategic objectives and requirements from research and development programs. These symposia provided members of our Industry Research Coordination Committee (IRCC) and Scientific Review Committee (SRC) an opportunity to provide input directly to our research programs and to foster new collaborative projects.

Preparations are underway for the CRC to host an international forestry conference, an International Union of Forest Research Organisations Conference entitled "Eucalypt plantations: Improving fibre quality and quantity", to be held from 19-24 February 1995. The chairman of the conference committee is M P Volker from ANM Forest Management.

Mr Peter Volker (ANM, Forest Management) describes the nursery procedures used by ANM.

Ms Nita Ramsden (Forestry Commission, Tasmania) inspects a nursery grown *E. regnans* seedling.

CRC Ethos and Interactions

Interactions within the CRC have been strengthened in the last 12 months and a CRC identity is developing amongst the partners.

Two field days were organised and superbly run by APPM Forest Research in Ridgley (November 1992) and ANM Forest Management in New Norfolk (June 1993) to give CRC staff and students a broad view of their forestry operations. CRC personnel from Hobart visited company field stations and were shown a broad range of forestry operations from preparation and establishment of seedlings, cuttings and tissue cultured plantlets to the preparation of sites for planting, genetics trials, thinning and pruning, harvesting, chipping and the manufacture of paper. People involved in one aspect of the CRC's activities were able to see how their contribution fitted in the full spectrum of forestry operations and were introduced to commercial aspects of plantation forestry.

At a silvicultural workshop "Establishing Eucalypt Plantations", excellent presentations by company experts from APPM, ANM, Forest Resources and the Forestry Commission, Tasmania helped in the understanding of industry needs in the research areas addressed by the Soil and Stand Management Program.

A CRC seminar series has been established with regular presentations from staff from all programs and partners in the CRC.

Closer links are developing between CRC staff and forest scientists from the private companies in all programs, facilitated by strong student interactions.

The Education and Communication Program has also been actively promoting social occasions and sports activities amongst staff members.

Research Profiles

A booklet entitled "Research Profiles of Scientists at the CRC for Temperate Hardwood Forestry" has been produced. For each scientist in the CRC it gives details of academic and employment background, research interests, contribution to CRC projects and recent publications. This booklet is useful firstly as a directory for CRC staff and students seeking advice or interactions with scientists in a particular field and secondly as a description of activities for potential research students.

Goals

- Maintenance of Honours and Postgraduate student numbers at the CRC at approximately 30, which will require a new intake of PhD and Honours students in February 1994. Our hope is the majority of these will be externally funded.

- Continuation of the contribution of CRC staff to teaching activities by involvement in lecturing in third and fourth year university courses, in supervision of students and by holding three workshops for transfer of research results to industry, one run by each of the CRC Programs. The proposed topics are:

    - Ecology and economics of the phytophagous insect *Chrysophtharta bimaculata* (*Eucalyptus* leaf beetle) in eucalypt plantations (Resource Protection Program)

    - Molecular biology for foresters (Genetic Improvement Program) and

    - Stem deformities in rapidly growing eucalypt plantations (Soil and Stand Management Program)

- Continue to develop links and interactions between partners and programs within the CRC, which will include:

    - Holding field days for staff and students of the CRC by each of the Tasmanian forestry companies Forest Resources, APPM, and ANM.

    - Maintaining and updating the booklet produced in 1993 on Research Profiles of staff at the CRC for Temperate Hardwood Forestry.

    - Continuing with the seminar series, social engagements and sporting activities that have been organised for CRC staff.

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 the hormonal control of flowering in *Eucalyptus*, carefully measured doses of paclabutrazol are now being used to promote early flowering in seed orchard trees.

In the Resource Protection Program, strong linkages have now been established with the Forestry Commission and companies. , Through the Integrated Pest Management Program, studies of defoliating leaf beetles by the CRC is continuing to improve pest management systems.

Researchers in the Soil and Stand Management Program have identified Cu deficiency as the cause of a growth deformity in *E. nitens* grown on soils of high nutrient status. The finding has been well publicised and a practice of minimum fertilisation is expected to be adopted by tree farmers on sites of high nutrition, particularly ex-pasture sites.

Partner perspectives

The strong linkage now established between the Resource Protection Program and the original control program conducted by the Forestry Commission and companies for defoliating leaf beetles is continuing to improve pest management systems.

Browsing animals are a major impediment to successful establishment of eucalypt plantations and native forests and the recently initiated CRC project in this area is highly relevant to the Forestry Commission and industry.

The Forestry Commission has been developing a system to predict productivity of eucalypt plantations based on soil and climatic factors. Recently, under the Soil and Stand Management Program, a project to assist in the development of this site selection has been initiated.

Evaluation of eucalypt provenance trials to identify the best genetic material for future plantations is continuing under the Genetic Improvement Program.

- Humphrey Elliott, Forestry Commission, Tasmania

In the 1992 Annual Report I listed several projects from which APPM was hopeful of obtaining information in the short term. The inter- and intra- specific hybrid project is yielding useful information. Trials with fertiliser treatments have been established to look at soil nutrient solution concentrations. A trial has also been established to study the effects of site preparation treatments on soil physical properties. Studies on the effect of flowering promoter, paclobutrazol, have yielded useful information on the persistence of, and best methods of application for this growth regulator.

Studies on natural variation in *Eucalyptus globulus* have yielded useful information on provenance delineation. Useful discussions have also taken place on the design and assessment of experiments to examine inbreeding levels in *E. nitens*. In the Resource Protection Program, a start has been made in a very important area of research with the initiation of a project on mammalian browsing.

- David de Little, APPM Forest Products

Forest Resources sees the positive aspects of collaborative projects being of primary importance. All companies face similar problems in optimising their plantation estate, and the research undertaken should and does reflect the impact of these problems. On-going work in Integrated Pest Management has highlighted the subtleties of leaf defoliators, notably chrysomelids, and hence the difficulty of control. Soil and Stand Management Programs deal directly with nutritional requirements across site variation of *E. globulous* and *E. nitens*. Interim results and recommendations assist in updating our fertilisation regimes. The Genetic Improvement Program is perhaps the more abstract, wherein lies considerable optimism. With our own work augmented by advice, assistance and facilities of the CRC, improved planting stock with more desirable, predictable characteristics is anticipated.

- Peter Naughton, Forest Resources

Coordination and activities between this centre and the CRC for Hardwood Fibre and Paper Science has seen significant progress towards studies of basic fibre properties in relation to pulping. Fertiliser experiments established in late 1992 are already yielding useful information on soil nutrient solutions. A further trial examining effects of soil physical properties on root growth is seen as a major step towards optimisation of site preparation techniques.

Monitoring of chrysomelid insect populations in relation to meteorological conditions was undertaken by the company during last summer. The Resource Protection Program has developed a plan for monitoring population structure and migration patterns which may lead to better control strategies. Significant progress on the important area of mammalian browsing is seen as a priority over the next three years.

- Peter Volker, ANM Forest Management

APM Forests expects considerable synergies to develop under the CRC due to the harnessing of divergent but compatible resources, expertise, skills and cultures. The CRC has made good progress at harnessing:-

- The mission focus, attention to detail, specialist skills, considerable laboratory facilities and commitment to scientific excellence of CSIRO and the Universities.

- The commercial focus, pragmatism, considerable field trials and commitment to continuous improvement of the commercial partners.

APM Forests is pleased with the development and progress of truly cooperative work under all three CRC programs. The following is (an incomplete) list of specific CRC research which is assisting APMF's R&D and plantation programs:-

- Research on genetic variations in *E. globulus* is helping to optimise our breeding strategies for this species.

- Research on early selection for wood and pulp properties will increase the gains we can make in these traits.

- Studies on the genetics of *Mycosphaerella* are assisting with the development of strategies to minimise the impact of this fungal disease.

- The CRC 's tissue culture research is assisting with our strategies to develop systems for vegetative propagation of eucalypts.

- Recently commenced cultivation and nutritional trials are expected to lead to a greater understanding of factors effecting root growth and better methods of site preparation.

- John Cameron, APM Forests Pty Ltd

Staffing and Administration

The appointment of staff continued through the year and the Centre is now almost at its full complement. It took longer than we expected to appoint staff to some key positions, but no compromises were made in selecting the best people.

Dr René Vaillancourt arrived in September 1992 from the USA to take up the position of Molecular Biologist in the Genetic Improvement Program. In November 1992, Dr Rabi Misra arrived to take up the position of Root Scientist within the Soil and Stand Management Program and Dr Anthony Clarke arrived from Queensland in January 1993, to become our Insect Ecologist. Dr Michael Battaglia, a plant ecologist and graduate of the University of Tasmania, was appointed as Postdoctoral Fellow in the Soil and Stand Management Program. Dr Nuno Borralho arrived in June 1993 from Portugal, to take up an appointment as Quantitative Geneticist in the Genetic Improvement Program.

A number of well qualified technical staff were also appointed over the year in all three research programs. They include Susan Headley, Mandy Watson, Linda Dimsey, Paul Tilyard, Andrew Herbert, Stephen Paterson and Sarah Loughhead. In addition, Greg Jordan was appointed as short-term post-doctoral position in the Centre to undertake work on *E. globulus*.

Seven PhD students have taken up APRA and/or CRC Scholarships, within the Resource Protection, Genetics and Soil and Stand Management Programs. (Kathryn Paterson, Naomi Lawrence, Trevor Garnett, Don White, Craig Hardner, Nadia Marsh, Bruce Greaves). Three students received scholarships for their BAgSci honours projects from the CRC with an additional three receiving scholarships to complete BSc(Hons).

Ms Jean Richmond continued with her three quarter time position as secretary to the Director and in February, Mrs Carol Blake was taken on as Administrative Officer in place of Ms Mary Rainbird and Ms Jan Marriner. The final addition to the Administrative team was made in March when Ms Jane Burrell was appointed as Educational Assistant.

There remain a small number of technical positions to fill, along with two Post-doctoral positions within the Genetics Program.

The CRC Extension to the CSIRO Division of Forestry building was completed and staff were occupying their new offices by the time of publication of last years report. The Prime Minister, Mr Paul Keating was invited to officially open the new building on 5th August. He told 127 guests at the opening that it would be hard to imagine a better vista and described the new building as both attractive and functional. It would provide a focus for the development of forestry research in Tasmania. The Chancellor of the University, Sir Guy Green opened the ceremonial proceedings and welcomed the Prime Minister to the University. Dr Glen Kile, Chief of the CSIRO Division of Forestry said the uses and management of Australian Forests had been the subject of much argument in recent years. It should, he said, be a major competitive industry. Dr Kile praised the cooperation of the University in inviting the CSIRO to establish on the University campus. The Chairman of the Board, Mr John Allwright said that it was appropriate that the Prime Minster was in Hobart to open the CRC because the concept for CRC's had come from the Prime Ministers Department, with 50 CRCs now set up across Australia. "There is no cost in research - there is an investment in research and the benefits flow to the community and the nation," he said.

The list of specified personnel in the CRC (Table 7) has changed slightly during the year. Dr N Borralho has been added to the list for the University, Mr K Orme has been replaced by Mr P Naughton as Research Manager for Forest Resources and our new partners APM have appointed Mr J Cameron as their specified CRC representative.

Attachment C near the end of the report provides a full staff list for the Centre.

Table 7 Specified personnel in the CRC.

		Proportion of time in CRC
CSIRO Division of Forestry		
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)
University of Tasmania		
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)
Forestry Commission, Tasmania		
Dr HJ Elliott	Chief, Division of Silvicultural Research and Development	(0.10)
ANM		
Mr PW Volker	Research Scientist	(0.40)
APPM		
Dr DW de Little	Research Manager, Forests	(0.10)
Dr WN Tibbits	Research Scientist	(0.30)
Forest Resources		
Mr P Naughton	Scientist	(0.30)*
APM		
Mr J Cameron	Research Manager	(0.15)

* Actual contribution, not reflected in ATTACHMENT C due to staff turnover.

Publications

Genetic Improvement

Published

Battaglia M and Reid JB (1993) Ontogenetic variation in frost resistance of *Eucalyptus delegatensis* RT Baker. *Aust. J. Bot.* **41**: 137-141.

Battaglia M and Reid JB (1993) The effect of microsite variation on seed germination and seedling survival of *Eucalyptus delegatensis*. *Aust. J. Bot.* **41**, 169-81.

Behringer FJ, Davies PJ and Reid JB (1992). Phytochrome regulation of stem growth and indole-3-acetic acid levels in the *lv* and *Lv* genotypes of *Pisum*. *Photochem. Photobiol.* **56**, 677-84.

Cramp RE and Reid JB (1993). Internode length in *Pisum*. Gene *lkd*. *Plant Growth Regul.* **12,** 141-147.

Hartney VJ and Svensson JGP (1992) The role of micropropagation for Australian tree species. In 'Rapid Propagation of Fast-growing Woody Species' C.A.B. International (Oxon) 7 - 28.

Kang H, Hardner CM, Gullberg U (1992). Lethal equivalents in willows, *Salix viminalis* Silvae Genetica **41,** 110-117.

Potts BM, Volker PW and Dungey HS (1992). Barriers to the production of hybrids in *Eucalyptus*. *In* 'Mass Production Technology for Genetically Improved Fast Growing Forest Tree Species (AFOCEL-IUFRO Symposium; Bordeaux 1992)'. 193-204pp. (Association Foret Cellulose: Nangis - France).

Reid JB and Davies PJ (1992) The genetics and physiology of gibberellin sensitivity mutants in peas In *Progress in Plant Growth Regulation* 1991, (Eds. C Karssen, LC Van Loon and D. Vreugdenhil,) , pp. 214-225. Kluwer, Amsterdam.

Reid JB and Ross JJ (1993) A mutant-based approach to understanding plant growth. *Int. J. of Plant Sci.* **154,** 22-34.

Reid JB, Ross JJ and Swain SM (1992). Internode length in *Pisum*. A new slender mutant with elevated levels of C19 gibberellins. *Planta* **188**, 462-67.

Ross JJ, Murfet IC and Reid JB (1993) The distribution of gibberellins in *Lathyrus odoratus* L. and their role in leaf development.*Plant Physiol.* **102**, 60-8.

Sale MM, Potts BM West AK and Reid JB (1993). Relationships within *Eucalyptus* using chloroplast DNA. Aust. Syst. Bot. **6**, 127-138.

Santes CM, Hedden P, Sponsel VM, Reid JB and Garcia-Martinez JL (1993). Expression of the *le* mutation in young ovaries of *Pisum sativum* and its effect on fruit development. *Plant Physiol.* **101**, 759-64.

Smith VA, Knott CJ, Gaskin P and Reid JB (1992). The distribution of gibberellins in vegetative tissues of *Pisum sativum* L. Biological and biochemical consequences of the *le* mutation I. *Plant Physiol.* **99**, 368-71.

Sponsel VM and Reid JB (1992) The use of an acyclohexanedione retardant, LAB 198999, to determine whether gibberellin A_{20} has biological activity *per se* in dark-grown dwarf (le^{5839}) seedlings of *Pisum sativum*. *Plant Physiol.* **100**, 651-654.

Swain SM, and Reid JB (1992). Internode length in *Pisum*. A new allele at the *Lh* locus. *Physiol. Plant.* **86**, 124-130.

Swain SM and Reid JB (1992). Internode length in *Pisum*. Interaction of genes lh^{i}, *la* and cry^{s} *Pisum Genetics* **24**, 83-85.

Weller JL, Murfet IC and Reid JB (1992). Internode length in *Pisum*. Two further *lv* mutants. *Pisum Genetics* **24**: 86-89.

Weller JL and Reid JB (1993). Photoperiodism and photocontrol of stem elongation in two photomorphogenic mutants of *Pisum sativum L. Planta* **189,** 15-23.

Wiltshire RJE, Potts BM and Reid BM (1992). A paedomorphocline in *Eucalyptus II*: Variation in seedling morphology in the *E. risdonii/tenuiramis* complex. *Aust. J. Bot.* **40**, 789-805

Wiltshire RJE and Reid JB (1993). The pattern of juvenility within *Eucalyptus tenuiramis* Miq. saplings. In Proceedings of a Symposium on Mass Production Technology for Genetically Improved Fast Growing Forest Tree Species (Eds. N. Marien, Cl. Hubert and P. Alazard). (AFOCEL/IUFRO: Bordeaux); pp37-49.

In press

Cauvin B, Potts BM and Najar M *Eucalyptus gunnii:* Estimation des parametres genetiques de resistance au froid et de croissance. *Annales de recherches silvicoles* (AFOCEL: Paris.)

Jordan G, Potts BM, Kirkpatrick JB and Gardiner C. Variation in the *Eucalyptus globulus* complex revisited. *Aust. J. Bot.*

Moncur MW, Rasmussen G and Hasan O, (1993) Effect of paclobutrazol on flower-bud production in *Eucalyptus nitens* (Dean and Maid). *Espalier Seed Orchards.*

Murfet IC and Reid JB (1993). Developmental mutants. In Peas - Genetics, Molecular Biology and Biotechnology (Eds. DR Davies and R Casey). CAB International, Wallingford, UK.

Reid JB and Potts B (1993) Eucalypt biology. In Vegetation of Tasmania (Eds. JB Reid, RS Hill and MJ Brown), Government Printer, Hobart, Tasmania.

Reid JB and Ross JJ (1993). Plant hormones and environmental responses. In *Biology* (Eds. B Knox, P Ladiges and B Evans), McGraw-Hill, Sydney.

Ross JJ, Reid JB and Swain SM (1993) Control of stem elongation by gibberellin A_1. Evidence from genetic studies including the slender mutant *sln*. *Aust. J. Plant Physiol.*

Swain SM, Reid JB and Ross JJ (1993). Seed development in *Pisum*. The *lh^i* allele reduces gibberellin levels in developing seed abortion. *Planta.*

Unrefereed

Grant JE, Moran GF and Moncur MW (1992). Pollination studies and breeding systems in *Acacia mearnsii*. Proceedings: Australian Species for China. ACIAR workshop China, November 1992.

Hardner CM, and Potts BM. Some effects of selfing in *Eucalyptus globulus*. In Research Working Group No 1 of the Australian Forestry Council, Forest Genetics, Proceedings of the Twelfth Meeting, Canberra, February 1993 (Australian Forestry Council, Canberra).

Hasan O, Reid JB and Potts BM (1993). The role of gibberellins in the regulation of flowering and seed production in eucalypts. Report for the Tasmanian Forest Research Council (46pp).

Moncur MW, Hand FC and Ramsden NG (1992). Environmental and cultural effects on flowering and seed production of plantation grown eucalypts, particularly *E nitens* . Progress report for Year 3 to Tasmanian Forestry Council.

Moncur MW and Turner J (1993). Paclobutrazol as a management tool for eucalypts. Proceedings: 12th Research

Group No 1 (Forest Genetics) meeting, Canberra, 15-19 February 1993.

Moncur MW and Turner J (1993). Generation turnover in *Eucalyptus nitens*. CSIRO, Division of Forestry, Annual Report.

Theses

Battaglia, M (1993). Modelling seed germination of *Eucalyptus delegatensis* R.T. Baker to facilitate optimal reafforestation. PhD Thesis (University of Tasmania).

Chalmers, P (1992). Variation in phase change in *Eucalyptus globulus* and its physiological significance. BSc Hons Thesis (Department of Plant Science, University of Tasmania).

Hardner, C (1992). Some effects of inbreeding in *Eucalyptus globulus*. ssp *globulus* BSc Hons Thesis (Department of Plant Science, University of Tasmania).

Soil and Stand Management

Published

Beadle CL (1993). Growth Analysis. In: Photosynthesis and production in a changing environment: a field and laboratory manual (DO Hall et al, eds.) pp.36-46 Chapman and Hall.

Beadle CL, Ludlow MM and Honeysett JL (1993). Water relations. In: Photosynthesis and production in a changing environment: a field and laboratory manual. (DO Hall et al, eds.) pp.113-128 Chapman and Hall.

Davie A, Badcock KA and Beadle CL (1993). 'TISWAT. BAS': A program to calculate simple water-relations parameters from pressure chamber measurements. In: Photosynthesis and production in a changing environment: a field and laboratory manual. (DO Hall et al, eds.) pp.456-462 Chapman and Hall.

Honeysett JL, Beadle CL and Turnbull CRA (1992). Evapotranspiration and growth of two contrasting species of eucalypts under non-limiting and limiting water availability. For. Ecol. Man. **50**, 203-216.

Misra RK and Sands R (1992) A comparison of sap flux and water relations of leaves of various isolated trees with special reference to foundation movement in clay soil. *Plant and Soil* **140**, 269-278.

Misra RK and Sands R (1993) Water extraction by isolated trees and its possible impact on building foundations on clay soils. *Aust. J. Soil Res.* **31**, 25-37.

Roberts MJ, Long SP, Tieszen LL and Beadle CL (1993). Measurement of plant biomass and net primary production of herbaceous vegetation. In: Photosynthesis and production in a changing environment: a field and laboratory manual. (DO Hall et al, eds.) pp1-20. Chapman and Hall.

West PW (1993) Model of above-ground assimilate partitioning and growth of individual trees in even-aged forest monoculture. *J. theor. Biol.* **161.** 369-394.

In Press

Smethurst PJ and Comerford NB (1993) Simulating nutrient uptake by single or competing and contrasting root systems. *Soil Sci. Soc. Am. J.*

Smethurst PJ and Comerford NB. (1994) Potassium and phosphorus uptake by competing pine and grass: observations and model predictions. *Soil Sci. Soc. Am. J.*

Smethurst PJ, Comerford,NB, and Neary DG. (1994) Weed effects on early K and P nutrition, and growth, of slash pine on a Spodosol. *For. Ecol. Manage.*

Smethurst PJ, Comerford NB , and Neary DG. (1994) Predicting the effects of weeds on K and P uptake by young slash pine on a Spodosol. *For. Ecol. Manage.*

Unrefereed Publications

Misra RK and Rose CW (1992) A guide for the use of Erosion-Deposition programs. Division of Environmental Sciences, Griffith University, Brisbane, Queensland, Australia, 55pp.

Theses

Garnett TP (1992). Boron accumulation in two varieties of wheat. BSc Hons Thesis (Department of Plant Science, University of Adelaide).

Smethurst PJ (1992). Application of solute-transport theory to predict uptake of K and P by competing slash pine and grass. PhD Dissertation (Soil Science Department, University of Florida).

Resource Protection

Published

Candy SG, Elliott HJ, Bashford R and Greener A (1992). Modelling the impact of defoliation by the leaf beetle, *Chrysophtharta bimaculata* (Olivier) (Coleoptera: Chrysomelidae) *For. Ecol. Manage.* **54**, 69-89

Elliott HJ, Bashford R, Greener A and Candy SG (1992). Integrated pest management of the Tasmanian Eucalyptus leaf feeding beetle *Chrysophtharta bimaculata* (Olivier) (Coleoptera:Chrysomelidae) *For. Ecol. Manage.* **53**, 29-38.

Mensah RK and Madden JL (1993). Development and application of an integrated pest management program for the psyllid, *Ctenarytaina thysanura* on *Boronia megastigma* in *Tasmania. Entomol. Exp. Appl.* **66**, 59-74.

In Press

Clarke AR (1993). A new species of Scelionidae from Pakistan and its role as a biological control agent. *Bull ent. Res.*

Clarke AR and Walter GH (1993). Biological control and the species status of two host-associated populations of *Trissolcus basalis* (WOLLASTON) (Hymenoptera:Scelionidae) *Aust. J. Ecol.*

Elliott HJ, Bashford R and Greener A (1993) Effects of defoliation by the leaf beetle, *Chrysophtharta bimaculata*, on growth of *Eucalyptus regnans* plantations in Tasmania. *Aust. For.*

Greener A and Candy SG (1993). Effect of the biotic insecticide, *Bacillus thurigiensis* and a synthetic pyrethroid on the survival of predators of the Tasmanian leaf beetle, *Chrysophtharta bimaculata* (Olivier) (Coleoptera:Chrysomelidae). *J. Aust. ent. Soc.*

Education and Communication

Published

Davidson NJ and Pate JS (1992). Water relations of the mistletoe *Amyema fitzgeraldii* and its host *Acacia acuminata*. *J. Exp. Bot.* **43**, 1549-1555.

Galloway R and Davidson NJ (1993). The response of *Atriplex amnicola* to the interactive effects of salinity and hypoxia. *J. Exp. Bot.* **44**, 653-663.

Unrefereed publications

Abdullah M, Akram M Khan WA and Davidson NJ (1993). Selecting halophytic shrubs for the Cholestan Desert In "Productive use of Saline Land" , *ACIAR Proceedings* No **42**, Eds. NJ Davidson and R Galloway, (Australian Centre for International Agricultural Research; Canberra)

Davidson NJ, Galloway R and Lazarescu G (1993). Limits to the productivity of *Atriplex* on salt-affected duplex soils. In "Productive use of Saline Land" , *ACIAR Proceedings* No **42**, Eds. NJ Davidson and R Galloway, (Australian Centre for International Agricultural Research; Canberra)

Galloway R and Davidson NJ (1993). The interactive effects of salt and waterlogging on *Atriplex amnicola*. In "Productive use of Saline Land" , ACIAR Proceedings No. **42**, Eds. NJ Davidson and R Galloway, (Australian Centre for International Agricultural Research; Canberra)

Ismail S, Ahmad R and Davidson NJ (1993). Design and analysis of provenance trials in Pakistan In "Productive use of Saline Land" , *ACIAR Proceedings* No. **42**, Eds. NJ Davidson and R Galloway, (Australian Centre for International Agricultural Research; Canberra).

Lazarescu G and Davidson NJ (1993). Nitrogen concentrations for optimal growth of *Atriplex amnicola*. In "Productive use of Saline Land" , *ACIAR Proceedings* No. **42,** Eds. NJ Davidson and R Galloway, (Australian Centre for International Agricultural Research; Canberra).

Strawbridge M, Davidson NJ and Galloway R (1993). Effect of plant nutrition and environment on the seed quality of *Atriplex amnicola*. In "Productive use of Saline Land" , *ACIAR Proceedings* No. **42**, Eds. NJ Davidson and R Galloway, (Australian Centre for International Agricultural Research; Canberra)

Public Presentations

Genetic Improvement

Conferences/Symposia

Hasan O, Potts BM and Reid JB (1992). Chemical promotion of flower bud initiation in *E. globulus*. In Proceedings of a Symposium on Mass Production Technology for Genetically Improved Fast Growing Forest Tree Species, (Eds. JN Marier, Cl Hubert and P Alazard,) (AFOCEL-IUFRO: Bordeau, France).

Moncur MW and Kleinschmidt GJ (1992). A role for honey bees (*Apis mellifera*) in eucalypt plantations. Proceedings for Mass Production Technology for Genetically Improved Fast Growing Tree Species. AFOCEL-IUFRO Symposium, Bordeaux, France, Vol. 2; 107-115.

Potts BM (1992). Hybridisation and population bottlenecks in *Eucalyptus*: Implications for gene pool conservation. International Symposium on Population Genetics and Gene Conservation of Forest Trees (INRA/IUFRA, Bordeaux, France)

Potts BM and Jordan G (1993). Variation in a base population trial of *Eucalyptus globulus* ssp. *globulus* in Tasmania. In 'Research Working Group No.1 of the Australian Forestry Council, Forest Genetics, Proceedings of Twelfth Meeting, Canberra; February 1993.' (Australian Forestry Council, Canberra).

Hardner CM and Potts BM (1993). Some effects of selfing *Eucalyptus globulus*. In 'Research Working Group No. 1 of the Australian Forestry Council, Forest Genetics, Proceedings of Twelfth Meeting, Canberra; February 1993.' (Australian Forestry Council, Canberra).

Dungey H, Volker PW, Potts BM and Owen J (1993). Interspecific hybridisation between *E nitens* and *E. globulus*: preliminary analysis of early growth and frost resistance. In 'Research Working Group No. 1 of the Australian Forestry Council, Forest Genetics, Proceedings of Twelfth Meeting, Canberra; February 1993.' (Australian Forestry Council, Canberra.)

Reid JB. Control of stem elongation by gibberellin A_1; evidence from genetic studies including the slender mutant *sln*. Robertson Symposium, ANU.

Sale MM, Nesbitt KA and West AK (1993) Identifying DNA markers in *Eucalyptus*. In Proceedings of the 37th

Conference of the Aust. Soc. for Biochem. and Mol. Biol. Vol 25, 185.

Sponsel VM and Reid JB (1992) Further studies on the response of dark and light-grown seedlings of *le* and *le* genotypes of peas to Ga_1 and LA_{20}. *Amer. Soc. Plant Physiol*, 599, 67.

Swain SM, Saito T, Reid JB, and Kamiya Y. Site of action of the *Ls* gene. *Jap Soc. Plant Physiol.*, Plant Cell Physiol. S101.

Soil and Stand Management

Conferences/Symposia

Garnett TP (1992). Water channels: how widespread are they? (Third Adelaide Symposium on Ion Channels, Adelaide, December 1992).

Garnett TP, Tester MA and Nable RO (1992). Boron accumulation in two varieties of wheat. (Australian Society of Plant Physiologists A.G.M., Latrobe University, Melbourne, September 1992).

Misra RK and Rose CW (1992) Sensitivity analysis and applications of the erosion model (GUEST. National Soils Conference, Adelaide, 19-23 April 1992).

West PW (1993) Application of regression analysis to inventory data with measurements on successive occasions. (IUFRO Conference; Copenhagen).

White DA, Beadle, CL Honeysett, JL and Worledge D. The effect of drought stress on height, diameter and leaf area index of *Eucalyptus globulus* Labill and *E. nitens* Maiden. (Chinese Academy of Forestry/ACIAR Projects 8848/9 Workshop, Zhangzhou, China. November 1992).

White DA, Beadle CL, Honeysett JL and Worledge D Seasonal changes in the stomatal conductance of juvenile leaves of *Eucalyptus globulus* Labill. and *E.nitens* Maiden in irrigated and rainfed plantations. (Chinese Academy of Forestry/ACIAR 8848/9 Workshop, Zhangzhou, China. November 1992).

Media Presentations

An item on copper deficiency in *Eucalyptus nitens* was filmed at Goulds Block, Dover, by an ABC crew on 27 January and was shown on ABC TV news on Sunday 31 January.

Resource Protection

Conferences/Symposia

Elliott HJ (1992). Integrated management of the leaf beetle, *Chrysophtharta bimaculata* (Olivier) (Coleoptera:

Chrysomelidae) in eucalypt plantations in Tasmania. Proc. XIX Int. Cong. Entomology. Beijing PRC July 1992:434.

Elliott HJ (1993). Role of eucalypt plantations currently and in the future. (CRC Seminar, July 1992).

Madden JL (1992). Factors affecting host tree selection and feeding behaviour by the eucalypt leaf beetle, *Chrysophtharta bimaculata* (Olivier). (Proc. XIX Int. Cong. Entomology), Beijing PRC July 1992:438.

Madden JL and Mensah RK (1992). Key factor studies of *Ctenarytaina thysanura* on *Boronia megastigma* in Tasmania. (Proc. XIX Int. Cong. Entomology), Beijing PRC July 1992:168.

Education and Communication

Workshops/short courses

The two short courses run during the year were:

i) Tree Improvement for Future Plantations: a role for plant physiologists? A course run by Ms C Raymond (Genetic Improvement Program) and Dr P Kriedemann (CSIRO Division of Forestry).

ii) "Establishing Eucalypt Plantations", held on April 5-6 1993 consisted of a one day course with presentations on aspects of silviculture by representatives from each of the Tasmanian forestry companies, followed by a one day field tour to the Southern Forests. The workshop was organised by Dr C Beadle (Soil and Stand Management Program).

Two workshops were held during the year.

i)The first, held in November 1992 allowed Centre staff to present to our industry partners the aims, objectives and proposed outcomes for each project in the three research programs.

ii) The second, held in April 1993 gave our industry partners the opportunity to outline their strategic objectives and requirements from research and development programs.

Conferences/Symposia

Davidson NJ and Galloway R (1992). The response of *Atriplex amnicola* to the interactive effects of salinity and hypoxia. (Paper presented to the 32nd Annual General Meeting of the Australian Society of Plant Physiologists, La Trobe University, Melbourne, September 1992)

Davidson NJ, Galloway R, Lazarescu, G and Malcolm (1993). Production of *Atriplex forage* from salt-affected duplex soils in Western Australia. (Paper presented at the 1st Southern Temperate Ecosystems conference, Hobart, February 1993)

Grants and Awards to CRC staff

Dr C Beadle $

•ACIAR
Drought studies in *E. globulus* and *E. nitens* 62 513

Dr J Madden

•Forests and Forest Industries Council
C. bimaculata research 67 200

Professor J Reid

•Australian Research Council
Photomorphogenic mutants 21 000

•Australian Research Council
Physiological Genetics/
Hormonal Physiology 91 500

•CSIRO/University of Tasmania
Eucalyptus Flowering 5 200
Prediction of Vegetation 10 000

•Dept of Primary Industry/Forestry Scholarships
Ms Kristen Williams 21 000

Professor M Stoddart

•Tasmanian Forest Research Council
Use of habitat trees by brush possums 24 000

•Australian Research Council
Analysis of odour induced stress in the marsupial sugar glider 73 000

•Australian Research Council
Social dominance in the marsupial sugar glider 13 000

•National Geographic
Habitat requirements and niche parameters of sympatric marsupial carnivores 12 500

Dr P West

•Tasmanian Forest Research Council
Modelling tree stem shape 15 000

Performance Indicators

Genetic Improvement

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

- Reliable estimates of heritablities from both controlled crosses and open pollenated seed have been obtained for certain commercially desirable tree characteristics (e.g. height, volume and diameter) in *E. globulus* and *E. nitens*. This will enable future work on genetic gains, selection age and breeding plans to be developed.

b) Production of F_1 and F_2 seed for field plantings.

- Hybrid seed has been produced and planted in the field. F_2 seed from *E. globulus* x *E. nitens* and *E. globulus* x *E. gunnii* has been produced and seedlings are presently in the glasshouse awaiting transfer to the field.

c) Development of techniques for vegetative propagation of elite material.

- In conjunction with the CSIRO Division of Forestry, an improved system for micropropagation for temperate eucalypts has been developed and we are currently examining the protection of this Intellectual Property.

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

- The GA biosynthetic pathway has been identified as the early 13 hydroxylation pathway and levels of GAs have been related to the intensity of flowering in *E. nitens* grafts. The time for seed production from germination has been reduced substantially for *E. globulus* (to 2.8 years).

e) Techniques for finger-printing eucalypts using DNA markers.

- Molecular markers that would enable finger-printing of eucalypts have been developed and differentiation at the broad taxonomic level has been demonstrated as predicted.

Soil and Stand Management

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

- Single leaf photosynthesis light response curves were established for *E. nitens* at varying levels of N application. These form a basic input to developing models of whole canopy photosynthetic production in relation to variation in environmental variables.

- Work this year suggested that site fertility for eucalypt plantations can be judged from the levels of extractable N and P in soils. These findings have importance in developing a system to assess site suitability for eucalypt plantations based on easily measured environmental variables. It also appears that foliar levels of N and P may reflect levels of these nutrients in soils. This does not appear to apply for other macronutrients (K, Ca and Mg). These results have importance for developing a strategy for the diagnosis of nutrient requirements at any stage of development of a plantation.

- Establishment of eucalypt plantations on previously improved, highly fertile pasture, should ensure maximum growth rates and reduce fertiliser requirements. However, *E. nitens* plantations established under these circumstances and provided with additional N and P fertiliser were found to suffer Cu deficiency which leads to severe stem and branch malformations. These results suggested that fertiliser additions should not be made early in the life of the forest crop, to plantations on improved, ex-pasture sites until the plantation reaches a stage of development where its nutrient demand requires it.

- If fertiliser is applied to plantations at a stage of development when the soil supply of nutrients is already adequate, the fertiliser will be wasted and may be lost from the system. Study of eucalypt plantations established on a gradational yellow podsolic soil, to which N and P fertiliser was applied at the time of establishment, showed no tree growth advantage from the fertiliser at 8 months from planting. The fertiliser substantially increased the concentrations of N and P in the soil solution, but the lack of tree growth response showed that trees already had adequate nutrient available from the resources in the soil at this early stage of plantation development. It appeared that the fertiliser was being wasted and should not be applied until a later age when the nutrient demand of the trees requires it.

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

- Prediction of plantation photosynthetic production is fundamental to growth prediction with process-based models of forest growth. Photosynthesis varies hour by hour as diurnal circumstances change and, in the longer term, as nutrient status or water availability changes over a year. To deal with this, models of photosynthetic production have been highly complex requiring elaborate data and much computer time.

Work in the Centre this year has developed mathematical techniques to predict, much more simply, production over a whole forest canopy for periods as long as a year. The model is based on the instantaneous relationship between photosynthetic production and the irradiance of single leaves. This relationship can be determined experimentally for a species of interest and changes in definable ways as environmental factors such as nutrient or water availability change. The only other inputs are daily weather data, which are routinely available for plantation sites, and the leaf area indent of the plantation. The model then predicts, rapidly and simply, whole canopy photosynthetic production daily, which is easily summed to give annual production, in relation to environmental change.

- Wood yields of mature Australian forests have never been collated in a systematic fashion. These provide a baseline for assessing productivity gains from plantation forests. Work this year developed empirical models of wood yield prediction by high quality, even-aged, monospecific, regrowth eucalypt forests of six commercially important eucalypts.

Resource Protection

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

- Attack of individual trees by chrysomelid beetles is determined by physical and chemical factors. Families of *E. regnans* having high proportions of red leaves in their current foliage sustain greater attack and defoliation than do trees with low proportions. This finding supports, but as yet does not explain the demonstrated preferential response of beetles to traps of different colours. The class of leaf chemicals found to influence the preference of *C. bimaculata* for feeding and oviposition in the adult stage and feeding, development and survival in the laval stage are terpenoids and waxes. Other chrysomelid species differ both qualitatively and quantitatively in their response to these classes of phyto chemicals.

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

- Under field conditions it has been demonstrated that predators of chrysomelids can be aggregated in beetle free areas. Caged cantharid beetles with access to food release aggregation pheromones that result in the attraction of large numbers of conspecifics in a very short time. Conversely spraying trees with sucrose during rain free periods, arrests the movement of coccinelid predators resulting in their accumulation in the treated areas in time. If such treated areas are subsequently attacked then high losses of eggs due to predation are experienced.

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

- It has been confirmed that the extent of defoliation experienced by individual *E. regnans* families is highly repeatable within and between years. Therefore, it may be possible to select families for incorporation into a breeding program on the basis of a single year's exposure to beetle attack.

Education

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

- There are 18 PhD, 3 MSc and 8 Honours students enrolled at the CRC for Temperate Hardwood Forestry. This number now exceeds our target of 25 students in Honours and Postgraduate study.

b) The number of enrolments in special courses.

- The number of students enrolled in the special course "Forest Ecology" has risen slightly to 13 this year. One student, Mr S Brooks, enrolled in the Honours year of this course is studying resource partitioning in eucalypts. The special course "Graduate Diploma in Science with Honours in Forest Processes" did not attract students in its first year and an advertising campaign will be conducted to alert potential interested parties.

c) The quality and number of Post Doctoral Fellows attracted.

- The number of PhD applicants was large. Therefore, it was possible to slect candidates who ranked very highly on the basis of their academic records and research experience. Two Postdoctoral Fellows were appointed in 1992/93. Both Dr A Clarke (an entomologist appointed to the Resource Protection Program) and Mr M Battaglia (a plant ecologist appointed to the Soil and Stand Management Program) both have excellent academic records and list of research publications.

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

- This can be judged by the level of participation by forest industry employees in CRC courses. Mr P Volker (of ANM) and Mr B Greaves (originally with APPM) are currently enrolled in PhD courses. Mr M Hunt is conducting Honours with partial support from Ausfern (a company interested in growing ferns in the understorey of *E. nitens* plantations). Mr M Battaglia, a graduate of the CRC was successful in securing a nationally advertised Postdoctoral Fellowship position.

Communication

a) The degree of adoption of research results by industry.

- As a result of studies of the hormonal control of flowering in Eucalyptus in the Genetic Improvement Program and by the parties, carefully measured doses of paclabutrazol are now being used to promote early flowering in seed orchard trees.

- In the Resource Protection Program, strong linkages have now been established with the Forestry Commission and companies. Through the Integrated Pest Management Program, studies of defoliating leaf beetles by the CRC is continuing to improve pest management systems.

- Researchers in the Soil and Stand Management Program have identified Cu deficiency as the cause of a growth deformity in *E. nitens* grown on soils of high nutrient status. These findings have been well publicised and a practice of minimum fertilisation is expected to be adopted by tree farmers on sites of high nutrition, particularly ex-pasture sites.

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

- A booklet presenting research profiles of staff at the CRC has been completed. This will foster scientific interaction within the CRC because the numbers of staff and students involved make it difficult for new staff members, visitors or students to identify the range of available expertise. It will also foster the further development of links between CRC scientists and the industry partners.

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

- Two workshops were held during the year. The first allowed Centre staff to present to our industry partners the aims, objectives and proposed outcomes for each project in the three research programs. The second gave our industry partners the opportunity to outline their strategic objectives and requirements from research and development programs. These symposia provided members of our Industry Research Coordination Committee (IRCC) and Scientific Review Committee (SRC) an opportunity to provide input directly to our research programs and to foster new collaborative projects.

- Two excellent field days were held where company staff at ANM and APPM described their operations from the nursery and clonal laboratory to field management practices and the processing of fibre at the mill. This allowed CRC staff at Hobart to better understand company operations and interact with company forest practitioners.

- Seminar series which include presentations by CRC staff continue to be held at the CSIRO, Plant Science and Agricultural Science Departments.

d) Organise the first short courses in the second year of the Centre.

Two short courses were held this year. The first was "Tree improvement for the future: a role for plant physiologists". The second was "Establishing Eucalypt plantations". Both were well attended and successfully reached the target audience.

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

Table 1

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

			EXPENDITURE							
PARTNER		Cumulative to date	ACTUAL		PROJECTED					
			1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	GRAND TOTAL
CSIRO DIVISION OF FORESTRY										
	SALARIES	1,142.3	531.4	610.9	623.1	635.7	648.4	661.3	674.7	4,385.5
	CAPITAL									
	OTHER	1,934.3	900.4	1,033.9	1,057.4	1,075.3	1,096.4	1,117.7	1,140.0	7,421.1
	TOTAL	3,076.6	1,431.8	1,644.8	1,680.5	1,711.0	1,744.8	1,779.0	1,814.7	11,806.6
UNIVERSITY OF TASMANIA										
	SALARIES	896.2	488.5	407.7	415.9	424.2	432.7	441.3	450.1	3,060.4
	CAPITAL	40.0	40.0							40.0
	OTHER	1,285.3	648.7	636.6	649.4	662.4	675.6	689.1	702.9	4,664.7
	TOTAL	2,221.5	1,177.2	1,044.3	1,065.3	1,086.6	1,108.3	1,130.4	1,153.0	7,765.1
ANM FOREST MANAGEMENT										
	SALARIES	47.0	21.0	26.0	26.0	27.0	27.0	28.0	28.0	183.0
	CAPITAL									
	OTHER	90.0	28.0	62.0	64.0	67.0	70.0	74.0	76.0	441.0
	TOTAL	137.0	49.0	88.0	90.0	94.0	97.0	102.0	104.0	624.0
APPM										
	SALARIES	123.3	64.0	59.3	69.5	69.5	69.7	77.1	77.1	486.2
	CAPITAL									
	OTHER	210.7	107.0	103.7	109.2	109.2	109.2	109.2	109.2	756.7
	TOTAL	334.0	171.0	163.0	178.7	178.7	178.9	186.3	186.3	1,242.9

Table 1 (continued)

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

PARTNER		Cumulative to date	EXPENDITURE							
			ACTUAL		PROJECTED					
			1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	GRAND TOTAL
FOREST RESOURCES										
	SALARIES	63.7	39.6	24.1	96.8	99.9	102.8	105.9	109.1	578.2
	CAPITAL									
	OTHER	92.7	50.1	42.6	103.2	106.2	109.5	112.9	116.1	640.6
	TOTAL	156.4	89.7	66.7	200.0	206.1	212.3	218.8	225.2	1,218.8
FORESTRY COMMISSION - TASMANIA										
	SALARIES	104.5	47.2	57.3	57.8	58.4	59.3	59.8	60.3	400.1
	CAPITAL									
	OTHER	125.6	61.0	64.6	65.3	66.0	66.7	67.3	68.0	458.9
	TOTAL	230.1	108.2	121.9	123.1	124.4	126.0	127.1	128.3	859.0
APM FORESTS										
	SALARIES	118.1		118.1	118.1	118.1	118.1	118.1	118.1	708.6
	CAPITAL									
	OTHER	81.0		81.0	60.0	60.0	60.0	60.0	60.0	381.0
	TOTAL	199.1		199.1	178.1	178.1	178.1	178.1	178.1	1,089.6
TOTAL IN-KIND CONTRIBUTIONS										
	SALARIES	2,495.1	1,191.7	1,303.4	1,407.2	1,432.8	1,458.0	1,491.5	1,517.4	9,802.0
	CAPITAL	40.0	40.0							40.0
	OTHER	3,819.6	1,795.2	2,024.4	2,108.5	2,146.1	2,187.4	2,230.2	2,272.2	14,764.0
GRAND TOTAL IN-KIND		6,354.7	3,026.9	3,327.8	3,515.7	3,578.9	3,645.4	3,721.7	3,789.6	24,606.0

Table 2

CASH CONTRIBUTIONS ($000's)

	Cumulative to date	EXPENDITURE: ACTUAL 1991/92	ACTUAL 1992/93	PROJECTED 1993/94	PROJECTED 1994/95	PROJECTED 1995/96	PROJECTED 1996/97	PROJECTED 1997/98	GRAND TOTAL
PARTNERS									
A CSIRO Division of Forestry									
B University of Tasmania	500.0	500.0							500.0
C Forestry Commission Tasmania									
D APPM									
E ANM	20.0		20.0	20.0	20.0	20.0	20.0	20.0	120.0
F Forest Resources									
G APM Forests									
TOTAL CASH FROM PARTICIPANTS	520.0	500.0	20.0	20.0	20.0	20.0	20.0	20.0	620.0
INTEREST	79.1	10.5	68.6	43.8	29.8	22.7	13.4	7.4	196.2
FUNDING FROM THE CRC GRANT	2,397.1	948.6	1,448.5	1,698.4	1,698.4	1,698.4	1,698.4	1,556.9	10,747.6
TOTAL CRC CASH CONTRIBUTION	2,996.2	1,459.1	1,537.1	1,762.2	1,748.2	1,741.1	1,731.8	1,584.3	11,563.8
Cash carried over from previous year			1,163.4	876.1	595.2	453.4	267.8	149.1	
Less unspent balance		1,163.4	876.1	595.2	453.4	267.8	149.1	0.0	
TOTAL CASH EXPENDITURE	2,120.1	295.7	1,824.4	2,043.1	1,890.0	1,926.7	1,850.5	1,733.4	11,563.8
ALLOCATION OF CASH EXPENDITURE BETWEEN HEADS OF EXPENDITURE									
SALARIES	754.9	118.8	636.1	1,149.1	1,217.6	1,252.2	1,183.6	1,115.6	6,673.0
CAPITAL	500.0		500.0						500.0
OTHER	865.2	176.9	688.3	894.0	672.4	674.5	666.9	617.8	4,390.8

Table 3

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

EXPENDITURE

ALL PROGRAMS

	Cumulative to date	ACTUAL		PROJECTED					
		1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	GRAND TOTAL
GRAND TOTAL (IN-KIND)	6,354.7	3,026.9	3,327.8	3,515.7	3,578.9	3,645.4	3,721.7	3,789.6	24,606.0
GRAND TOTAL (CASH EXPENDITURE)	2,120.1	295.7	1,824.4	2,043.1	1,890.0	1,926.7	1,850.5	1,733.4	11,563.8
TOTAL RESOURCES APPLIED TO ACTIVIES OF CENTRE	8,474.8	3,322.6	5,152.2	5,558.8	5,468.9	5,572.1	5,572.2	5,523.0	36,169.8

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

TOTAL SALARIES (CASH AND IN-KIND)	3,250.0	1,310.5	1,939.5	2,556.3	2,650.4	2,710.2	2,675.1	2,633.0	16,475.0
TOTAL CAPITAL (CASH AND IN-KIND)	540.0	40.0	500.0						540.0
TOTAL OTHER (CASH AND IN-KIND)	4,684.8	1,972.1	2,712.7	3,002.5	2,818.5	2,861.9	2,897.1	2,890.0	19,154.8

Table 4

Allocation of resources between catagories of activities (1992/93)

PROGRAM	RESOURCE USAGE			
	Cash $000's	In-kind $000's	Staff Contributed	Staff funded by CRC
Research	1559.1	2938.9	10.9	8.5
Education	212.8	336.9	1.0	0.5
Commercialisation/ tech Transfer	0.0	0.0	0.0	0.0
Administration	52.5	52.0	0.4	0.0
TOTAL	1824.4	3327.8	12.3	9.0

AUDITORS REPORT

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Price Waterhouse

INDEPENDENT AUDIT REPORT
TO THE MEMBERS OF THE CO-OPERATIVE
RESEARCH CENTRES COMMITTEE REPRESENTING
THE COMMONWEALTH IN RESPECT OF

CO-OPERATIVE RESEARCH CENTRE FOR TEMPERATE HARDWOOD FORESTRY

Scope

We have audited the attached financial information set out in tables 1 to 4 for the year ended 30 June 1993. The Directors of the Co-operative 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 consistent with the financial reporting requirements of the Commonwealth Agreement dated 10 September 1991 and is appropriate to meet the needs of the members of the Co-operative Research Centres Committee. We have conducted an independent audit of the financial information pursuant to Clause 14(f) of the Commonwealth Agreement in order to express an opinion to the members of the Co-operative Research Centre Committee on its preparation and presentation and to report on the matters identified below in relation to the sources and applications of the Co-operative 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 Co-operative 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 Co-operative 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 amount and other disclosures in the financial information. These procedures have been undertaken to provide reasonable assurance that the Co-operative 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 only 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)]

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 Co-operative Research Centre for Temperate Hardwood Forestry funding for the year ended 30 June 1993 and the Co-operative Research Centre for Temperate Hardwood Forestry has complied with the requirements of Clauses 4, 5(1), 5(2), 5(3), 9(1), 9(5) and 12(2) of the Commonwealth Agreement.

Price Waterhouse
Price Waterhouse
Chartered Accountants

Steven A Hernyk
Partner

Hobart
18 August 1993

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

CRC FOR TEMPERATE HARDWOOD FORESTRY

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

ANM FOREST MANAGEMENT

Name	Designation	Program	% time CRC	Cumulative to date	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
SALARIES												
VOLKER, P	Scientist	Genet	40									
HETHERINGTON, S	Scientist	Genet	20									
HETHERINGTON, S	Scientist	SSM	10									
	Total Salary			38.0	17.0	21.0	21.0	22.0	22.0	23.0	23.0	149.0
	Direct On-Costs	*% of total Salary*										
	Payroll tax											
	Superannuation											
	Workers Compensation											
	Leave Loading											
	Long Service Leave											
	Other											
	Total On-Costs	23		9.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	34.0
	Total Salaries & On-Costs			47.0	21.0	26.0	26.0	27.0	27.0	28.0	28.0	183.0
CAPITAL												
Cash contribution						20.0	20.0	20.0	20.0	20.0	20.0	120.0
	Total Capital			20.0		20.0	20.0	20.0	20.0	20.0	20.0	120.0
OTHER		*% of Total Salaries & On -Costs*										
	Office Support				11.0	9.0	9.0	10.0	10.0	11.0	11.0	71.0
	Experiments (land rent)				10.0	25.0	26.0	27.0	28.0	30.0	31.0	177.0
	Trial maintenance				0.0	22.0	23.0	24.0	25.0	26.0	27.0	147.0
	Vehicle Costs				7.0	6.0	6.0	6.0	7.0	7.0	7.0	46.0
	Total Other			90.0	28.0	62.0	64.0	67.0	70.0	74.0	76.0	441.0
TOTAL IN-KIND CONTRIBUTION				157.0	49.0	108.0	110.0	114.0	117.0	122.0	124.0	744.0

APM FORESTS

SALARIES

Name	Designation	Program	% time CRC	Cumulative to date	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
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									
	Total Salary			51.3		51.3	51.3	51.3	51.3	51.3	51.3	307.8

Direct On-Costs	*% of total Salary*	Cumulative to date	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
Payroll tax										
Superannuation										
Workers Compensation										
Leave Loading										
Long Service Leave										
Other										
Total On-Costs		66.8		66.8	66.8	66.8	66.8	66.8	66.8	400.8
Total Salaries & On-Costs		118.1		118.1	118.1	118.1	118.1	118.1	118.1	708.6

CAPITAL

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

Page 2 APM

OTHER	*% of Total Salaries & On -Costs*	Cumulative to date	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
Head office overheads										
Office Support										
Office Hire										
Operational										
Total Other		81.0		81.0	60.0	60.0	60.0	60.0	60.0	381.0
TOTAL IN-KIND CONTRIBUTION		199.1		199.1	178.1	178.1	178.1	178.1	178.1	1,089.6

CRC FOR TEMPERATE HARDWOOD FORESTRY

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

APPM FOREST PRODUCTS

SALARIES Name	Designation	Program	% time CRC	Cumulative to date	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
DE LITTLE, D	Scientist	Res Prot	10									
TIBBITS, W	Scientist	Genet	30									
RASMUSSEN, G	Scientist	Genet	40									
HOLZ, G	Scientist	SSM	10									
RAVENWOOD, I	Technician	Genet	25									
JOYCE, K	Technician	Genet	25									
RICE, J	Technician	Genet	25									
BOWER, D	Technician	Genet	25									
	Total Salary			111.7	58.0	53.7	63.0	63.0	63.1	69.8	69.8	440.4
		% of total Salary										
	Direct On-Costs											
	Payroll tax											
	Superannuation											
	Workers Compensation											
	Leave Loading											
	Long Service Leave											
	Other (Training)											
	Total On-Costs			11.6	6.0	5.6	6.5	6.5	6.6	7.3	7.3	45.8
	Total Salaries & On-Costs			123.3	64.0	59.3	69.5	69.5	69.7	77.1	77.1	486.2
CAPITAL												
	Total Capital											
OTHER		*% of Total Salaries & On-Costs*										
	Head Office Overheads			43.1	21.0	22.1	22.1	22.1	22.1	22.1	22.1	153.6
	Office Support			24.4	18.0	6.4	6.4	6.4	6.4	6.4	6.4	56.4
	Office Hire			35.6	20.0	15.6	21.1	21.1	21.1	21.1	21.1	141.1
	Operational			59.6		59.6	59.6	59.6	59.6	59.6	59.6	357.6
	Experiments			8.0	8.0							8.0
	Purchase of NAPEFP & support PhD student			40.0	40.0							40.0
	Total Other			210.7	107.0	103.7	109.2	109.2	109.2	109.2	109.2	756.7
	TOTAL IN-KIND CONTRIBUTION			334.0	171.0	163.0	178.7	178.7	178.9	186.3	186.3	1,242.9

CRC FOR TEMPERATE HARDWOOD FORESTRY

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

FOREST RESOURCES

SALARIES Name	Designation	Program	% time CRC	Cumulative to date	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
NAUGHTON, P	Scientist	SSM	1									
BADKIN, P	Technician	SSM	10									
BADKIN, P	Technician	Genet	4									
GORDON, V	Scientist	Genet	35									
HETHERINGTON, S	Scientist	Genet	6									
FRENCH, S	Technician	Genet	10									
NAUGHTON, P	Scientist	Educ	4									
HETHERINGTON, S	Scientist	Educ	1									
GORDON, V	Scientist	Educ	1									
	Total Salary			50.1	31.1	19.0	76.0	78.3	80.7	83.1	85.5	453.7
	Direct On-Costs	*% of total Salary*										
	Payroll tax	7		3.5	2.2	1.3	5.3	5.5	5.6	5.8	5.9	31.6
	Superannuation	5.5		2.7	1.7	1.0	4.1	4.3	4.5	4.6	4.7	24.9
	Workers Compensation	5		2.5	1.6	0.9	3.8	3.9	4.0	4.1	4.4	22.7
	Annual Leave	8		4.0	2.5	1.5	6.0	6.3	6.4	6.7	6.8	36.2
	Long Service Leave	2		1.0	0.6	0.4	1.6	1.6	1.6	1.6	1.8	9.2
	Other											
	Total On-Costs			13.6	8.5	5.1	20.8	21.6	22.1	22.8	23.6	124.6
	Total Salaries & On-Costs			63.7	39.6	24.1	96.8	99.9	102.8	105.9	109.1	578.3
CAPITAL												
	Total Capital											
OTHER		*% of Total Salaries & On -Costs*										
	Head Office Overheads			8.7	4.8	3.9	11.6	12.0	12.3	12.7	13.2	70.5
	Office Support)											
	Office Hire)			42.6	19.1	23.5	46.8	48.0	49.6	51.1	52.5	290.6
	Laboratory Rent)											
	Experiments			41.5	26.3	15.2	44.8	46.2	47.6	49.1	50.4	279.6
	Total Other			92.7	50.1	42.6	103.2	106.2	109.5	112.9	116.1	640.6
	TOTAL IN-KIND CONTRIBUTION			156.5	89.8	66.7	200.0	206.1	212.3	218.8	225.2	1,218.9

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

FORESTRY COMMISSION 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
ELLIOTT, H	Chief, Division of Silviculture	Prot	15									
GREENER, A	Research Forester	Prot	50									
PARSONS, S	Research Forester	Prot	50									
BASHFORD, R	Technician	Prot	10									
BAKER, S	Technician	Prot	50									
RAMSDEN, N.	Technician	Prot	50									
KUBE, P	Research Forester	Genet	20									
	Total Salary			87.1	39.6	47.5	48.0	48.4	49.0	49.4	49.9	331.8
	Direct On-Costs	*% of total Salary*										
	Payroll tax	7			2.8	3.3	3.3	3.4	3.4	3.5	3.5	23.2
	Superannuation	5			1.2	2.4	2.4	2.4	2.5	2.5	2.5	15.9
	Workers Compensation	4.5			1.8	2.1	2.1	2.1	2.3	2.3	2.3	15.0
	Leave Loading	1.2			0.6	0.6	0.6	0.6	0.6	0.6	0.6	4.2
	Long Service Leave	3.1			1.2	1.4	1.4	1.5	1.5	1.5	1.5	10.0
	Other											
	Total On-Costs			17.3	7.5	9.8	9.8	10.0	10.3	10.4	10.4	68.2
	Total Salaries & On-Costs			104.5	47.2	57.3	57.8	58.4	59.3	59.8	60.3	400.1
CAPITAL												
	Total Capital											

Page 2 Forestry Commission

OTHER	% of Total Salaries & On -Costs	Cumulative to date	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
* Head Office overheads	34.5		14.8	16.4	16.5	16.8	16.9	17.0	17.2	115.6
* Office Support	22.5		9.7	10.7	10.8	10.9	11.1	11.2	11.3	75.7
* Office Hire	18		7.7	8.6	8.7	8.7	8.8	8.9	9.0	60.4
Operational	61		28.8	28.9	29.3	29.6	29.9	30.2	30.5	207.2
* **Not applied to technical salaries**										
Total Other		125.6	61.0	64.6	65.3	66.0	66.7	67.3	68.0	458.9
TOTAL IN-KIND CONTRIBUTION		230.0	108.1	121.9	123.1	124.4	126.0	127.1	128.3	858.9

CRC FOR TEMPERATE HARDWOOD FORESTRY

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	1994/95	1995/96	1996/97	1997/98	TOTAL
BEADLE, C	Scientist	SSM	70									
BOXALL, B	Technician	SSM	30									
CROMER, R	Scientist	SSM	40									
DENTON, B	Technician	SSM	20									
LASALA, A	Technician	SSM	50									
MUMMERY, D	Scientist	SSM	30									
OTTENSCHLAEGER, M	Technician	SSM	100									
SANDS, P	Scientist	SSM	100									
TURNBULL, C	Scientist	SSM	70									
WEST, P	Scientist	SSM	80									
WILTSHIRE, D	Scientist	SSM	50									
HAND, F	Technician	Genet	100									
HARTNEY, V	Scientist	Genet	70									
MONCUR, M	Scientist	Genet	20									
OWEN, J	Scientist	Genet	40									
RAYMOND, C	Scientist	Genet	100									
SVENSON, M	Technician	Genet	70									
	Total Salary			905.4	421.2	484.2	493.9	503.7	513.7	524.1	534.6	3,475.4
	Direct On-Costs	*% of total Salary*										
	Superannuation	16.7			70.3	80.8	82.4	84.1	85.8	87.6	89.3	580.3
	Productivity Benefit	3			12.6	14.5	14.8	15.1	15.4	15.6	16.0	104.0
	Long Service Leave	2.5			10.5	12.1	12.3	12.6	12.9	13.1	13.4	86.9
	Leave Loading	1.5			6.3	7.2	7.4	7.6	7.7	7.8	8.0	52.0
	Comcare	2.5			10.5	12.1	12.3	12.6	12.9	13.1	13.4	86.9
	Total On-Costs			236.9	110.2	126.7	129.2	132.0	134.7	137.2	140.1	910.1
	Total Salaries & On-Costs			1,142.3	531.4	610.9	623.1	635.7	648.4	661.3	674.7	4,385.5

CAPITAL

	% of Total Salaries & On -Costs	Cumulative to date	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
Total Capital										
OTHER										
Divisional Administration/Support	96		510.3	586.4	598.1	610.2	622.6	634.9	647.7	4,210.2
Institute Overheads	9		47.8	55.0	56.1	57.2	58.3	59.5	60.7	394.6
Corporate Overheads	24		127.6	146.5	149.6	152.6	155.6	158.7	161.9	1,052.5
Amortised Capital Costs	37		196.7	226.0	230.6	235.3	239.9	244.6	249.7	1,622.8
Direct Operating Allocation		38.0	18.0	20.0	23.0	20.0	20.0	20.0	20.0	141.0
Total Other		1,934.3	900.4	1,033.9	1,057.4	1,075.3	1,096.4	1,117.7	1,140.0	7,421.1
TOTAL IN-KIND CONTRIBUTION		3,076.6	1,431.8	1,644.8	1,680.5	1,711.0	1,744.8	1,779.0	1,814.7	11,806.6

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
REID, J	Scientist	Genet	50									
DUNGEY, H	Student	Genet	100									
CHALMERS, P	Student	Genet	50									
WILLIAMS, M	Technician	Genet	50									
NESBITT, K	Student	Genet	50									
GORST, J	Scientist	Genet	10									
HASAN, O	Student	Genet	70									
BOBBI, P	Technician	Genet	60									
CASEY, S	Student	Genet	100									
HARDNER, C	Student	Genet	50									
MENARY, B	Scientist	Genet	10									
HAIG, G	Technician	Genet	10									
THOMSON, B	Technician	Genet	10									
WEST, A	Scientist	Genet	20									
PRESSER, J	Student	Genet	50									
SALE, M	Student	Genet	100									
GREAVES, B	Student	Genet	50									
MADDEN, J	Scientist	Prot	30									
LI, H	Student	Prot	80									
MARSH, N	Student	Prot	100									
STEINBAUER, M	Student	Prot	100									
PATTERSON, K	Student	Prot	100									
STODDART, M	Scientist	Prot	20									
HILL, B	Scientist	Educ	20									
BATTAGLIA, M	Student	Educ	100									
WILLIAMS, K	Student	Educ	100									
BEATTIE, J	Scientist	Educ	10									
WILTSHIRE, R	Student	Educ	30									
UNWIN, G	Scientist	Educ	10									
McENTEE, A	Student	Educ	50									
CLARKE, R	Student	Educ	10									
WILSON, S	Student	Educ	50									
HUNT, M	Student	SSM	50									
HOOPER, A	Student	SSM	50									
GREEN, I	Student	SSM	50									

		Program	% time CRC	Cumulative to date	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
GRIGGS, J	Student	SSM	50									
MORONI, M	Student	SSM	50									
BROOKES, S	Student	SSM	50									
	Total Salary			594.6	324.1	270.5	275.9	281.4	287.1	292.8	298.7	2,030.5
	Direct On-Costs	*% of total Salary*										
	Payroll tax	7			22.7	18.9	19.3	19.7	20.1	20.5	20.9	141.9
	Superannuation	17			55.1	46.0	46.9	47.9	48.8	49.8	50.8	345.3
	Workers Compensation	1			3.2	2.7	2.8	2.8	2.9	2.9	3.0	20.3
	Leave Loading	1.4			4.5	3.8	3.9	4.0	4.0	4.1	4.2	28.5
	Long Service Leave	3.17			10.3	8.6	8.8	8.9	9.1	9.3	9.5	64.5
	Outside Studies	21.15			68.5	57.2	58.3	59.5	60.7	61.9	63.2	429.4
	Total On-Costs			301.6	164.4	137.2	139.9	142.7	145.6	148.5	151.5	1,029.9
	Total Salaries & On-Costs			896.2	488.5	407.7	415.9	424.2	432.7	441.3	450.1	3,060.3
CAPITAL												
	Modifications to Plant Science Building				40.0							40.0
	Total Capital			40.0	40.0							40.0
OTHER		*% of Total Salaries & On -Costs*										
	Academic Services	25			122.1	101.9	103.9	106.0	108.1	110.3	112.5	764.9
	General Univ Services	41			200.3	167.2	170.5	174.0	177.4	181.0	184.6	1,255.0
	Dept Office Support	10			48.8	40.8	41.6	42.4	43.3	44.2	45.0	306.2
	Laboratory Rent & Equip	32			156.3	130.5	133.1	135.8	138.5	141.3	144.1	979.5
	Office Space	8			39.1	32.6	33.3	33.9	34.6	35.3	36.0	244.7
	Central Science Laboratory					80.0	81.6	83.2	84.9	86.6	88.3	504.6
	Management Agency				82.0	83.6	85.3	87.0	88.8	90.5	92.3	609.6
	Total Other			1,285.3	648.7	636.6	649.4	662.4	675.6	689.1	702.9	4,664.7
TOTAL IN-KIND CONTRIBUTION				2,221.5	1,177.2	1,044.3	1,065.2	1,086.5	1,108.3	1,130.4	1,153.0	7,765.0

ATTACHMENT C

CENTRE STAFF

ATTACHMENT C

RESEARCH STAFF RESOURCES (1992/93)

	Employer	Main activity	Total % time	% spent on Research Program Gen	SSM	Prot	Total on Research	% spent on Educucation	% Spent on Commercialisation Program	% spent on CRC Administration
ANM										
VOLKER, P		R	40	40			40			
HETHERINGTON, S		R	30	20	10		30			
Total			70	60	10	0	70	0	0	0
APM										
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	0	0	0
APPM										
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	0	0	0
Forest Resources										
NAUGHTON, P		R	5		1		1	4		
GORDON, V		R	36	35			35	1		
HETHERINGTON, S		R	7	6			6	1		
Total			48	41	1	0	42	6	0	0
Forestry Commission										
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	0	115	135	0	0	0

	Employer	Main activity	Total % time	% spent on Research Program *Gen*	*SSM*	*Prot*	Total on Research	% spent on Education	% Spent on Commercialisation Program	% spent on CRC 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			
WEST, P		R	80		60		60			20
HARTNEY, V		R	70	70			70			
MONCUR, M		R	20	20			20			
OWEN, J		R	40	40			40			
RAYMOND, C		R	100	100			100			
Total			620	230	370	0	600	0	0	20

	Employer	Main activity	Total % time	% spent on Research Program *Gen*	*SSM*	*Prot*	Total on Research	% spent on Education	% Spent on Commercialisation Program	% spent on CRC Administration
University of Tasmania										
REID, J		R	50	20			20	10		20
GORST, J		R	10	10			10			
MENARY, B		R	10	10			10			
WEST, A		R	10	10			10			
MADDEN, J		R	30			30	30			
STODDART, M		R	20			20	20			
HILL, B		R	20				0	20		
BEATTIE, J		R	10				0	10		
BOBBI, R		R	60	60			60			
WILTSHIRE, R		R	30				0	30		
UNWIN, G		R	10				0	10		
CLARKE, R		R	10				0	10		
Total			270	110	0	50	160	90	0	20

CRC funded	Employer	Main activity	Total % time	% spent on Research Program Gen	SSM	Prot	Total on Research	% spent on Education	% Spent on Commercialisation Program	% spent on CRC Administration
CLARKE, A	Uni Tas	R	100			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			
BATTAGLIA, M	Uni Tas	R	100		100		100			
OSLER, G	Uni Tas	R	100		100		100			
POTTS, B	Uni Tas	R	100	100			100			
BORRALHO, N	Uni Tas	R	100	100			100			
Total			900	300	450	100	850	50	0	0

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

	Total equiv. person years	Person years spent on Research program Gen	SSM	Prot	Total on Research	Person years spent on Education Program	Person years spent on Commercialisation Program	Person years spent on CRC Administration
Total Contributed	13.4	6.0	4.2	1.8	12.0	1.0	0.0	0.4
Total funded by CRC	9.0	3.0	4.5	1.0	8.5	0.5	0.0	0.0
Grand total	22.4	9.0	8.7	2.8	20.5	1.5	0.0	0.4
Proportion of total professional (%) staff resources in each activity	100.0	40.2	38.8	12.5	91.5	6.7	0.0	1.8

SUPPORT STAFF

Contributed	
Organisation	Number of staff (person years)
ANM	0.0
APM	0.4
APPM	1.0
Forest Resources	0.2
Forestry Commission	1.1
CSIRO	3.7
University of Tasmania	1.3
Total	7.7

CRC Funded (by employing organisation)	
Organisation	Number of staff (person years)
CSIRO	0.8
University of Tasmania	10.6
Total	11.4

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