DEPLOYMENT OF ELITE EUCALYPT GENETIC MATERIAL IN SOUTHERN AFRICA

SILVIA PONGRACIC

1997 GOTTSTEIN FELLOWSHIP REPORT

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JOSEPH WILLIAM GOTTSTEIN MEMORIAL TRUST FUND

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund is *"to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust's major forms of activity are,

1. Fellowships - each year applications are invited from eligible candidates to submit a study programme in an area considered to be of benefit to the Australian forestry and forest industries. Study tours undertaken by Fellows have usually been to overseas countries but several have been within Australia. Fellows are obliged to submit reports on completion of their programme. These are then distributed to industry if appropriate.

2. Seminars - the information gained by Fellows is often best disseminated by seminars as well as through the written reports.

3. Wood Science Courses - at approximately two yearly intervals the Trust organises a week-long intensive course in wood science for executives and consultants in the Australian forest industries.

4. Study Tours - industry group study tours are arranged periodically and have been well supported.

Further information may be obtained by writing to,

The Secretary,
J.W. Gottstein Memorial Trust Fund,
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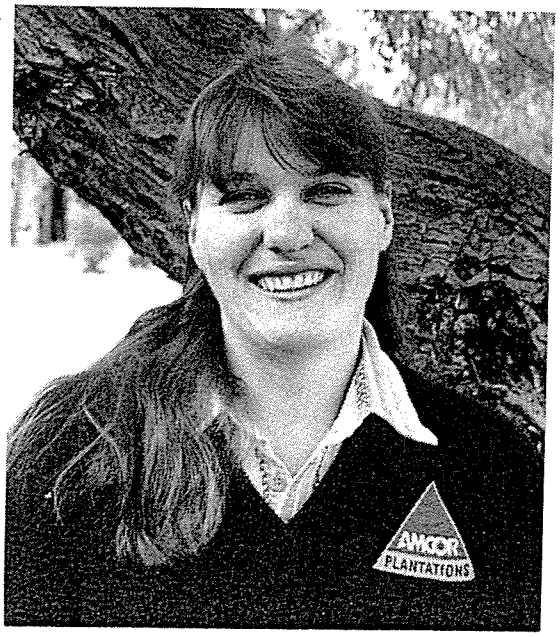
Clayton, Victoria, 3169 Australia

At the time that **Silvia Pongracic** received her Gottstein Fellowship she was a Research and Development Forester with Australian Paper Plantations Pty Ltd in Morwell, Victoria. Her Fellowship aims were to investigate and recommend efficient procedures for the selection and deployment of elite eucalypts genetic material into Australian plantations to improve growth and wood quality. During her tour she visited several private and government forestry organisations in South Africa and Zimbabwe and attended a IUFRO Conference. She has made several recommendations relating to the establishment of eucalypt plantations under Australian conditions in her report.



More recently Silvia has accepted a new position as Resource Research and Development Manager with the Forest and Wood Products Research and Development Corporation (FWPRDC) in Queensland.

Deployment of Elite Eucalypt Genetic Material in Southern Africa

1997 Gottstein Trust Report

Silvia Pongracic

Ten year old *E. grandis* logging coupe, South Africa

Deployment of Elite Genetic Material in Southern Africa

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I would like to acknowledge the support of the Joseph William Gottstein Memorial Trust Fund in making this study tour possible. The support of Australian Paper Plantations, in particular Phil Whiteman and Bill Briggs, is also gratefully acknowledged. Bill Keating as secretary to the Gottstein Trust Fund facilitated all dealings in an extremely efficient and timely manner. Drs Tony Michell and Chris Harwood made valuable comments on the report which were appreciated.

Executive Summary

Southern Africa has a history of establishing eucalypt plantations predominantly for pulp and paper but also for sawn timber production. The climate in Southern Africa favours the growth of sub tropical eucalypt species such as *Eucalyptus grandis* which appreciate the warm climate and summer rainfall achieved in the wetter areas of South Africa and Zimbabwe. Both private and government forestry organisations have had a focus on genetically improving eucalypt plantations, both for volume growth and wood properties, and also for drought tolerance and disease resistance.

Organisations in southern Africa have approached the issue of improving the genetic quality of their plantations by both selecting preferred clones from pure species and adopting a hybridisation approach between eucalypt species exhibiting favourable traits. *E. grandis* grows extremely well in high rainfall areas, but requires some drought tolerance when planted in drier zones, as is now occurring due to lack of suitable land. Disease issues are also a major focus for maintaining and improving the productivity of eucalypt plantations. Clonal forestry, from 3rd and 4th generation selections, is the preferred approach of many organisations as it is believed that matching clones to sites can improve productivity by 30% over selecting generally good performers. Clonal forestry is possible in Southern Africa as *E. grandis* and its clones can form roots readily and are relatively easily propagated.

Australia's focus for eucalypt breeding is predominantly on *E. globulus* and *E. nitens* and is still working on 1st and 2nd generation selections. Neither of these two species form roots readily and they are difficult to propagate vegetatively. The potential to hybridise with a species which roots readily, such as *E. grandis*, may provide a solution to recalcitrant rooting and provide options for undertaking clonal forestry rather than family forestry as is now being practiced. Plantation development in northern NSW and southern Queensland is focussing on many of the species and potential hybrids currently being evaluated in southern Africa. Future adoption of eucalypt improvement from southern Africa is likely to benefit plantation productivity in these areas.

1. Introduction

Australia is the original source of the large number of eucalypt species planted in highly productive plantations throughout the world. Despite this Australia is not the world leader in breeding and genetics of the majority of eucalypt species. This is largely because access to the native forest resource for both sawntimber and pulp wood had negated the need for large plantation areas of eucalypts to be established. Without large areas of single eucalypt species being grown for maximum wood and fibre production the impetus to develop a highly targeted breeding program has not developed.

With the increasing pressure on native forests from both the environmental and tourism fronts access to native forest for commercial timber production is becoming more controversial and therefore more difficult. The high costs of running an effective breeding program, which ensures the maintenance of sufficient genetic variety in addition to superior deployment genotypes, has resulted in fragmented breeding programs run independently by various organisations within Australia. Since 1994 Australia has had a cooperative breeding program for *Eucalyptus globulus* and *E. nitens* facilitated through the Southern Tree Breeding Association. This cooperative approach addresses the need for sufficient genetic variety in addition to targeting the most highly productive genotypes.

The Southern Tree Breeding Association has an impressive history in breeding programs through its *Pinus radiata* program which has been running since 1990 when it was initiated through the co-operation of CSIRO and various research organisations and plantation growers in southern Australia. The *P. radiata* breeding program is more advanced and focussed as large areas of this single species have been planted throughout southern Australia since the 1950s. Third generation deployment stock is currently being used as mother plants in Australian Paper Plantations pine nursery.

With an increased focus, from government, community and plantation growers, on the establishment of hardwood plantations, it is imperative that elite genotypes be deployed in these plantations in the shortest possible time to maximise growth and maintain competitiveness in both the domestic and world markets. The federal government's 2020 vision for a trebling of Australia's plantation area is indicative of the importance placed on the supply of timber from well managed and highly productive hardwood plantations. Access to worlds best practice in eucalypt breeding necessitates looking outside Australia to investigate more advanced eucalypt breeding programs.

2. Why Breed?

Why is there such focus on breeding and improving performance through genetic manipulation? There are basically three ways of improving the productivity of any plantation stand.

- Firstly establish the plantation on an optimum site - high rainfall, high temperature, high incident radiation. Unfortunately most plantation growers do not have the luxury of only establishing good sites, and traditionally forestry has inherited the marginal agricultural land that "is not good enough for farming, but good enough for trees".
- Secondly through getting the silviculture correct - site preparation, optimum spacing, weed control, fertiliser application, further weed control. Thinning may or may not be required depending on the product.
- Thirdly through improving the inherent capacity of the trees themselves. This is achieved naturally through natural selection or can be sped up by breeding programs which select the best individuals for the desired end products.

Once the plantation site is determined, and the correct "recipe" for growing the trees on the site developed, the only method remaining for improving plantation performance is through manipulation of natural genetic variation within the species, or in more focussed cases, the manipulation of genes themselves to produce a desired response.

The approach of any breeding program, whether it is for cattle, wheat or plantation timber species is similar, however there are a few attributes of plantation timber species

which make their breeding programs unique. Initially measurements are taken on a section of the species population and selections from that population for superior performance in various traits are made. These selections are then crossed (interbred) and the offspring should exhibit the superior traits for which their parents were selected. This process is repeated to further improve various traits. This method may result in throwbacks, where occasionally the offspring do not exhibit the sum of the parents' superiority, or where selecting for one trait has a detrimental effect on another trait. This approach relies on exploiting the natural variation in the traits selected for, and also on the heritability of that trait, where heritability is the proportion of the total variability of that trait which may be accounted for by genetic factors. This quantitative genetics approach relies only on exploiting the natural variation within a species.

Other genetic approaches involves the production of transgenic plants, where actual genes have been manipulated. This relies on the correct gene for the trait being identified, a method of successfully transferring that gene, or blocking it off, in the target plant, the capacity for the manipulated plant to grow and the ethical dilemmas surrounding the deployment of genetically manipulated material.

Once desired individuals have been produced or identified, they must be mass produced, or bulked up by various means. Methods can range from grafting, microcutting production, tissue culture or less intensively through open pollinated seed orchards, where the superiority of the mother plants is ensured, and the paternal input will come from similarly superior, but unknown, stock. From there the individuals can be used in breeding programs or deployed into the plantation proper.

In tree breeding the intergenerational time can be as long as 10 years. Offspring (progeny) trials are measured at age 6 for various traits. Selection at a younger age is uncertain as the characteristics selected for may not hold true through to rotation age. Then manipulation through open or controlled pollinations for breeding and deployment populations may take up to 4 years, before the next series of progeny trials may be established. This long time interval reflects the forestry rotation age and if it could be shortened, could lead to significant savings in plantation forestry by deploying superior stock earlier.

3. Australian Timber Plantation Breeding Interests

Before investigating the progress in tree breeding in southern Africa I felt it important to obtain an overview of the interests of forestry/plantation organisations in tree breeding in Australia. To this end I circulated a questionnaire in March 1997 to Australian forestry organisations to gauge interest in various species. The survey was developed in conjunction with Peter Gore (Eucalypt Program Manager, STBA) and a copy of the questionnaire may be found in Appendix 1. The information gained is summarised in Table 1 which also includes information gained from a survey undertaken by Liz Barbour, (WA CALM) in 1997.

Table 1 provides the areas planted to the dominant eucalypt species. Plantation area statistics were not available for SFNSW and WA CALM nor were new consortiums, such as Green Triangle Plantations Company and ITC included. The dominant planted eucalypt species for the data available were *E. globulus* and *E. nitens* with 71, 204 ha and 53, 275 ha respectively. Breeding programs for both of these species are conducted by the STBA, of which many of the replying organisations are members. The species with the next largest area under plantation was *E. regnans*, with 17, 365 ha, but no plantation organisation was pursuing an active breeding program for this species. Queensland DPI is pursuing breeding of 6 eucalypt species on a smaller scale, and SFNSW has an active *E. pilularis* and *E. dunnii* program.

The selection focus for all eucalypt species was volume growth with wood density being quoted by most organisations as being important. Pulp yield and sawlog quality were viewed as other important attributes in breeding. Sawntimber and kraft pulp production were the dominant purpose of eucalypt plantations, with ANM aiming at thermo-mechanical pulp production. The majority of plantations were being established with improved seed and most organisations were establishing their their own seeds orchards to supply this need. Research interests of plantation organisations focussed on vegetative propagation methods (cuttings and tissue culture) with some interest in the development of hybrids between species.

Table 1: Summary of eucalypt breeding programs by Australian forestry/plantation organisations

Species	Owner	Plantation area (ha)	1997 area (ha)	Plantation purpose	Source of genetic stock(%)		STBA member	Breeding program	Developing own seed orchards	Currently purchase outside seed	Selection of eucalypt stock
					native stand	seed orchard					
E. globulus	AP Plantation	6,213	1,100	kraft pulp	-	100	yes	no	yes	no	volume, form, wood density, pulp yield
	Boral Timber	2,000	-	kraft pulp	-	100	no	no	yes	no	volume, wood density
	Bunnings TF*	52,850	4,500	kraft pulp	98	2	yes	yes	yes	yes	volume, wood density, drought tolerance
	ForTas	800	-	multi-purpose	-	-	yes		yes	yes	volume, wood density, sawlog quality
	North FP	4,400	1,200	kraft pulp	-	100	yes	yes	yes	no	volume, wood density and pulp yield
	PISA	4,667	1,600	pulp, sawntimber	97	3	yes		yes	yes	volume, wood density, pulp yield
	VPC	274	250	sawntimber	-	100	no		yes	yes	volume growth
	WACALM	80,000	15,000	woodchips	?	?	no	yes	?	?	?
E.nitens	ANM	1,049	50	TMP	-	100	yes	no	no	yes	volume growth
	AP Plantation	791	200	kraft pulp	-	100	yes	no	yes	no	volume, form, wood density, pulp yield
	Boral Timber	12,000	900	kraft pulp	-	100	no	no	yes	no	volume, wood density
	ForTas	6,700	500	multi-purpose	-	100	yes	no	yes	yes	volume, wood density, sawlog quality
	North FP	32,600	4,800	kraft pulp	-	100	no	yes	yes	no	volume, wood density and pulp yield
	VPC	135	250	sawntimber	20	80	no	no	yes	yes	volume growth
	WA CALM	?	?	?	?	?	no	yes	?	?	?
E. regnans	ANM	2,915	-	TMP	-	-	-	-	-	-	-
	AP Plantation	5,420	-	kraft pulp	-	-	-	-	-	-	-
	VPC	7,500	-	sawntimber	-	-	-	-	-	-	-
E. pilularis	DPI Qld	50	10	sawntimber	100	-	-	-	-	-	-
	SFNSW	?	?	sawntimber	?	?	-	?	?	?	volume, sawlog quality
E. maculata	DPI Qld	100	10	sawntimber	100	-	-	-	-	-	?
E. grandis	DPI Qld	100	10	sawntimber	50	50	-	-	-	-	volume, sawlog quality
E. pellita	DPI Qld	50	40	sawntimber		100	-	-	-	-	volume, sawlog quality
E. cloezlana	DPI Qld	100	50	sawntimber	50	50	-	-	-	-	volume, sawlog quality
E. argophloia	DPI Qld	?	?	sawntimber	100	-	-	-	-	-	volume, sawlog quality
E. dunnii	SFNSW	?	?	sawntimber	100	-	-	-	-	-	volume, sawlog quality
E. camaldulensis	WA CALM	?	?	?	?	?	-	-	-	-	?

* 27, 200 ha self owned, 25, 650 ha as farm share agreements

Table 2: Summary of eucalypt breeding programs by non land owner organisations

Organisation	Species	Purpose of plantation	Selection	Research Interests
CFTT (Vic)	*E. saligna*	sawntimber, pulp potential, landscape rehabilitation	volume growth, wood density	hybrid crosses, tissue culture
	E. camaldulensis	sawntimber, pulp potential, landscape rehabilitation	volume growth, wood density	hybrid crosses, tissue culture
	E. grandis	sawntimber, pulp potential, landscape rehabilitation	volume growth, wood density	hybrid crosses, tissue culture
	E. globulus	sawntimber, pulp potential, landscape rehabilitation	volume growth, wood density	hybrid crosses, tissue culture
CRC - SPF	*E. globulus*	kraft pulp	volume growth, wood density, survival	hybrid crosses, tissue culture, clonal forestry, cuttings technology
	E. nitens	kraft pulp	volume growth, wood density, survival	hybrid crosses, tissue culture, clonal forestry, cuttings technology
	E. grandis	kraft pulp	volume growth, wood density, survival	hybrid crosses, tissue culture, clonal forestry, cuttings technology
FORBIO	*E. globulus*	kraft pulp	volume growth, wood density, pulp yield	clonal forestry, tissue culture, cuttings technology, hybrids
	E. grandis	kraft pulp	volume growth, wood density, pulp yield	clonal forestry, tissue culture, cuttings technology, hybrids

The contribution of research organisations to eucalypt breeding are shown in Table 2. These research organisations are collaborating with private industry through various co-operatives to develop superior genotypes for deployment for a variety of reasons. The targeted species were again *E. globulus* and *E. nitens* with a relatively large focus on *E. grandis*, which is only planted in small areas in Queensland.

The outcome of this survey confirmed that *E. globulus* and *E. nitens* were the two species of most overall importance to Australian plantation/forestry organisations and that vegetative propagation and hybridisation were the key areas of research interest. These subjects became the focus for the study tour of southern Africa which involved visiting forestry organisations in both Zimbabwe and South Africa.

4. Zimbabwe

4.1 Forestry in Zimbabwe

Zimbabwe is a landlocked country in southern Africa of approximately 39 million ha bordered by Zambia, Namibia, Botswana, South Africa and Mozambique. Approximately 2.5% or 975 000 ha is forested, of which 800 000 ha is native forest and 175 000 ha (18% of forested area) is under exotic plantations. Softwood plantations comprise 79% (138 000 ha) of the plantation estate with the dominant species being *Pinus patula*, *P. taeda* and *P. elliottii,* the majority of which is state owned and managed by the Forestry Commission. 37, 000 ha are planted to exotic hardwoods of which the main species are *E. grandis*, with some *E. camaldulensis*, *E. tereticornis*, *E. microcorys* and *E. cloeziana*. The minor eucalypt species are largely used for dryland afforestation rather than pure commercial plantations. In addition there is a significant area planted to *Acacia mearnsii* which is owned by the Wattle Company which was established in the 1950s for tannin extraction from wattle bark.

The first eucalypts were planted in Zimbabwe in 1892 near Mutare for amenity purposes, with the first pine plantations being established in 1903. The first eucalypt

plantations were established in 1922 in central Zimbabwe from seed brought in from South Africa. A forestry department within the Department of Agriculture was established in 1920 which took over management of the state owned plantations with the Forestry Commission being formed in 1954 when the first exotic tree breeding programs were initiated.

The main plantation estates in Zimbabwe are in the eastern highlands near the Mozambique border where high rainfall and a mild climate is optimum for softwood plantations. Hardwood plantations are found both in the eastern highlands and in central Zimbabwe, south of Harare, where there is lower rainfall and a hot climate. Average mean annual increment (MAI) for eucalypts, pine and wattle is 20, 17 and 9 m^3/ha/yr respectively, with the native woodlands having an MAI of 0.5 m^3/ha/yr. Typical eucalypt silviculture involves stocking of 1350-1550 stems per hectare and an 8-9 year rotation for light poles and 10-12 years for transmission poles with no pruning. Products from commercial plantations include sawntimber, veneer and plywood (22 year old pine with 3 thinnings), mining timbers, treated poles, particle and fibre board, pulp and paper products, wattle extract and charcoal.

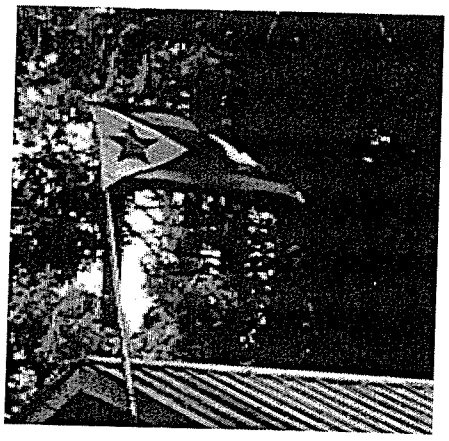

Figure 1: Zimbabwean Flag above Forestry Research Institute, Harare

The timber industry in Zimbabwe is dominated by 3 organisations that produce 80% of the nation's timber: Forestry Commission 40%, Border Timbers 22% and Wattle Timber 24%. Generally producers grow and process their own timber with the Forestry Commission opening a state of the art sawmill in 1996 at Chimanimani in the eastern highlands which will take 130 000 m^3 round timber input and produce 55 000 m^3 of sawntimber. Some pulplogs are produced and transported to South Africa. The forest industry generates $1.2 billion Zim dollars or 3% of Zimbabwe's GDP. The forestry sector has been

growing steadily since 1990 with 33% of sales being in export markets - namely South Africa, Botswana and the U.K. Three forests are currently undergoing assessment for environmental sensitivity by the Forest Stewardship Council and two companies are implementing ISO 14000 Environmental Management Systems.

The Zimbabwe Forest Commission has separate Commercial Forestry and Research Divisions (in addition to various other divisions - social forestry, agroforestry). The Research Division has programs in tree breeding, silviculture, matching species to sites and forest protection. There are 3 forest research stations in Zimbabwe, 2 in eastern highlands (John Meikle and Muguzo) which are focussed on commercial forest research with the third being located near Bulawayo (Chesa) which is a dryland forest research station. One of the objectives of the Forest Research Division is "to produce seed of high genetic quality". Tree breeding programs exist for *E. grandis*, *E. tereticornis* and *E. camaldulensis* as well as the main pine species (*P. patula*, *P. elliottii* and *P. taeda*), and alternative species are being screened for both commercial and social forestry. The Forest Research Division supports private industry through silvicultural research and by providing improved germplasm to the industry.

4.2 Tree Breeding in Zimbabwe

Timber tree breeding began in Zimbabwe in the late 1950's soon after the Forestry Commission was formed. It was recognised at that time that genetic improvement of planting stock would improve plantation yield. Because of the cheap cost of labour in Zimbabwe many of the standard silvicultural practices could afford to be done manually and improving mechanisation of many activities would not result in cost savings to plantation development. At the initiation of the tree breeding program Zimbabwe also established the Tree Seed Centre which commercialises improved germplasm, the profits of which are used to fund forest research. Forty percent of the research budget is funded through seed sales, both domestically within Zimbabwe and externally to South Africa and other African countries and wider afield to USA and European countries.

Plus trees were initially selected in 1958 from the local plantations, and a breeding population determined for each eucalypt species. A classic breeding strategy was adopted with parallel progeny tests and grafted clonal seed orchards. By the 1980's the third generation of eucalypt stock was being evaluated with new material being imported and incorporated into the program and the classic breeding approach had become too big and unwieldly to deal with the large number of families involved. In 1981 a decision to move to a multiple population breeding strategy (MPBS) resulted in fifty three sub populations for 9 species of eucalypts being established. This approach resulted in the testing and seed production facilities being combined in breeding seedling orchard (bso). Each population had only one bso established at a single site, resulting in an inability to determine genetic by environment interaction and to compare the performance of families in different sub populations. However the bso approach was efficient in terms of infusing new material into the breeding populations. In 1994 the drawbacks to the bso approach resulted in another modification to the breeding program with the introduction of a composite breeding seedling orchard (cbso) which resulted in structured populations incorporating breeding, selection and seed production at a single site.

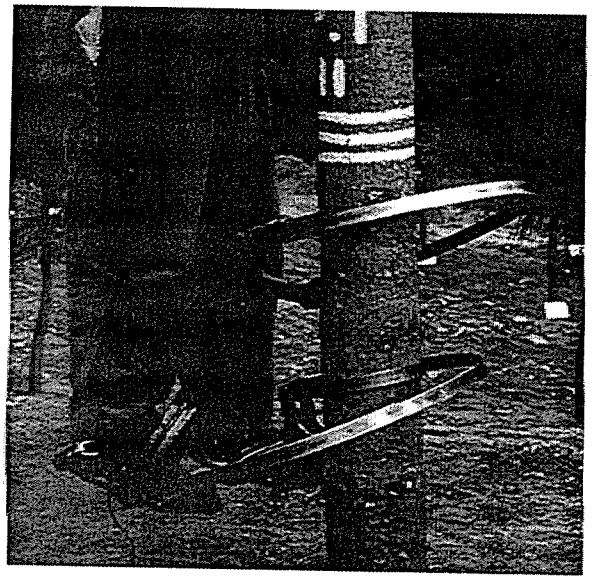

Figure 2: Tree climbing "bicycle" used to access the plus tree canopies

Breeding objectives, which define the traits which are being optimised, were defined as survival, volume, branching, stem straightness and density. Individual candidate plus trees were selected on their superior phenotypic (visible or measurable) characteristics and these were maintained in the breeding program. Trees were also selected for their general combining ability meaning that the trees selected have a capacity to cross with many partners to produce offspring with improved characteristics. Less emphasis was placed on specific combining ability, backcross breeding or reciprocal selection.

Selected individuals are bulked up using various vegetative propagation techniques with stem cuttings being the most successful for pine species and sub tropical eucalypts such as *E. grandis* or *E. camaldulensis* and some hybrid clones. Hybrid clones have not been a large focus of the Zimbabwean breeding program as pure species have been suitably productive and the market has been too small. However with the advent of extending plantations to marginal areas where the pure species are not as economic due to drought stress, hybrids of eucalypts will become a larger focus in the eucalypt breeding programs.

The Forest Research Centre has developed an internationally recognised Tree Seed Centre which follows international standards for seed testing to ensure maximum quality. The Seed Centre is closely linked to the tree breeding, silviculture, forest protection, mapping and inventory sections of the forestry research program as advice is also given from the Seed Centre on the most appropriate species depending on the area to be planted and the purpose for planting. Zimbabwean forestry is closely linked with social forestry as approximately 35% of Zimbabwe is actually in communal lands which support subsistence villages which require firewood and cash wood crops (poles/posts). Breeding programs with local species are now being initiated in order to perpetuate multiple use from village plantations.

The eucalypt breeding program is entering its fourth generation of selections. Major breeding programs exist for *E. grandis* and *E. camaldulensis* with the best families in the high elevation, high rainfall area growing at 2cm/day in height (approximately 7m per year). Two breeding populations have been developed for *E. grandis*, one a high

elevation, high rainfall population and the other a low elevation low rainfall population. New genetic stock is injected into the breeding program from purchase from other institutions, with CSIRO (Australia) providing much of the eucalypt seed. Approximately 314 kg of eucalypt seed was harvested from various eucalypt seed orchards during the 1995/96 collection.

Figure 3: Dryland eucalypt screening

Figure 4: Unique to southern Africa - baboon damage in canopy of pine plantation

4.3 Implications for Australian Eucalypt Breeding

Zimbabwe is in its fourth generation of eucalypt selections for improved survival, volume growth, reduced branching, increased stem straightness and improved wood density. This is in contrast to Australia's approximately second generation programs for *E. globulus* and *E. nitens*. The sub tropical eucalypt species have been particularly successful in Zimbabwe due to high summer rainfall. The sub tropical eucalypts also have the capacity to be bulked up via cuttings propagation ensuring the rapid deployment and multiplication of particular clones in both the breeding program and deployment populations. The main species of interest to Australian cold temperate

plantations (*E. globulus* and *E. nitens*) do not easily form roots from stem cuttings and alternative methods need to be developed for bulking up of elite germplasm.

5. South Africa

The South African section of the study tour involved attending an international forestry research conference for 5 days and then visiting various forestry related industries and organisations around South Africa. The South African forestry industry is dominated by pulp, paper and board manufacture producing 2, 300, 000 metric tons of pulp and 2, 047, 000 metric tons of paper and board with 755, 000 metric tons of printing paper produced, 1, 147, 000 metric tons of packaging paper and 145, 000 metric tons of tissue paper produced in 1995. There is also a smaller, but significant sawmilling industry which provides structural timber for construction and mining purposes. Private industry is dominated by large companies SAPPI, MONDI and SAFCOL with Hans Merensky Holdings/Northern Timbers and SAFCOL involved in sawntimber production. Research and breeding programs are maintained in house to a large extent with CSIR and the Institute for Commercial Forest Research (ICFR) also running programs for the main planted species (*E. grandis*), hybrids (*E. grandis* x *E. urophylla*, *E. camaldulensis*, *E. saligna, E. tereticornis, E. nitens*) and also for the cold tolerant eucalypts (*E. nitens, E. macarthurii, E. dunnii*).

5.1 IUFRO Conference: Environmental Constraints to Forest Function

Two subject groups (Whole Plant Physiology and Canopy Processes) of the International Union of Forestry Research Organisations (IUFRO) met in Mpumalanga Province in South Africa from May 11 - May 17 1997. The focus of the conference was on describing and predicting tree or forest response to variable growth limitations ranging from rainfall and nutritional limitations to the impacts of pollution, pests and diseases of forest growth.

A major limitation to plantation production in South Africa is water availability. So important is this issue that the South African government has introduced a water tax on

any industry consuming water, which has major implications to plantation growers, as plantations were viewed as major consumers of water. CSIR (government part funded research organisation) was conducting research into more water use efficient clones of *E. grandis* in an effort to reduce water use while maintaining plantation productivity. Water use efficiency is defined as the amount of water consumed per unit of wood produced. In conjunction with industry elite clones of *E. grandis* and *E. grandis* x *E. camaldulensis* and *E. grandis* x *E. tereticornis* hybrids were screened for efficiency of water use in order to use this trait as a breeding objective. Water use efficiency was measured as sapflow measurements over 12 months to estimate the volume of water used for growth rates across 4 different sites. Sap flow was found to vary amongst clones but this was not necessarily consistent across sites. It was suggested that specific clones be targeted for different areas depending on the amount of water stress expected within the planting site. Companies, which either maintain their own breeding population or rely on ICRF (Institute for Commercial Forest Research) for the lesser planted species, have yet to incorporate this information into their breeding populations.

Figure 5: **Harvested *E. grandis* plantation**

5.2 Hans Merensky Holdings/Northern Timbers

Hans Merensky Holdings owns an estate of 11,000 ha near Tzaneen in northern South Africa, near the Zimbabwe border. The estate comprises *E. grandis*, *E. saligna* and *E. grandis* x *E. camaldulensis* hybrids with an average MAI of 23/m^3/ha/yr on clay loam soil with a rainfall of 1200mm/yr.

The main products from the plantation estate are sawlogs and mining structural timber. Breeding selection is on growth, basic density, splitting, timber colour, brittle heart and eucalypt diseases. Selection is carried out in typical progeny trials except for selection against disease susceptibility where high performing clones are inoculated with disease in order to identify clones most susceptible. Diseases selected against include *Cryphonectria*, *Botryosphaeroa, Endotheidea*, *Endotia*, and *Conothirium*. Sawlog characteristics are selected for using log splitting which is scored at harvest age for progeny trials using a scoring system which incorporates the number of splits and the extent of the splits. If the overall "split" score is greater than 30 then the clone is rejected for breeding purposes.

Nursery production for the deployment population is 800,000 cuttings per year. Mother plants consist of *E. grandis, E. saligna, E. camaldulensis* x *grandis, E. urophylla x grandis* up to age of 3 years, with cuttings taken all year around. Cuttings are approximately 10 cm long and consist of foliage 30-40 days old. Only the top pair of leaves, halved, are left on the cutting. The base of the cutting is angle cut through a leaf node and dipped into a fungicide solution, a hormone treatment and set into a pot with vermiculite. The cuttings are kept in the greenhouse for 30 days, under 40% shade for 30 days, under 20% shade for 30 days, and then into the open to harden off. Root emerge from pots within 12 days of setting.

Northern Timbers also contract out the production of 900 000 seedlings per year to supplement their cuttings program. The seedlings are returned to Northern Timbers for hardening off. There are some problems with quality control through this contracting system.

5.3 SAFCOL - South African Company Limited

SAFCOL was formed in the early 1990's and is the privatised arm of what was the South African government's commercial forest service. SAFCOL research was initiated in 1993 and encompasses genetic improvement, nursery production, growth and yield modelling and entomology.

SAFCOL manages approximately 18.4% of the total forested area (approx 210,000 *Pinus* spp and 22,000 ha eucalypt spp) in South Africa and is involved primarily with sawlog production. SAFCOL produces 47% of South Africa's pine sawntimber and 54% of South Africa's eucalypt sawntimber.

The major thrust of SAFCOL research is to plant up marginal land to plantations and increase productivity on existing sites. The focus with pine plantations in genetic improvement is to match families to sites, and with eucalypts to match clones to sites. Major eucalypt species are *E. grandis*, and the hybrid between *E. grandis* and *E. teriticornis* or *E. camaldulensis*, on marginal land for drought tolerance, and *E. grandis* x *E. urophylla* for drought and disease resistance. *E. grandis* is generally used as female parent in these crosses.

Selection for 2nd generation *E. grandis* is based on volume growth (60%), disease resistance (20%) and splitting (20%). First generation clonal selection was based on similar criteria plus rooting.

Splitting is calculated on a similar scoring system to that used by Northern Timbers. A score greater than 30 (0.3) eliminates a tree from the breeding program. SAFCOL believes that heritability for splitting is quite low, but persists in selecting for splitting for commercial reasons. Investigating correlations between traits has found a positive correlation between disease susceptibility and rooting, and a negative correlation between splitting characteristics and lignin content of wood which results in a conflict between pulp timber and sawtimber selection. Sawlogs need a higher lignin content

and therefore suffer less splitting, pulplogs should have a lower lignin content where splitting does not matter.

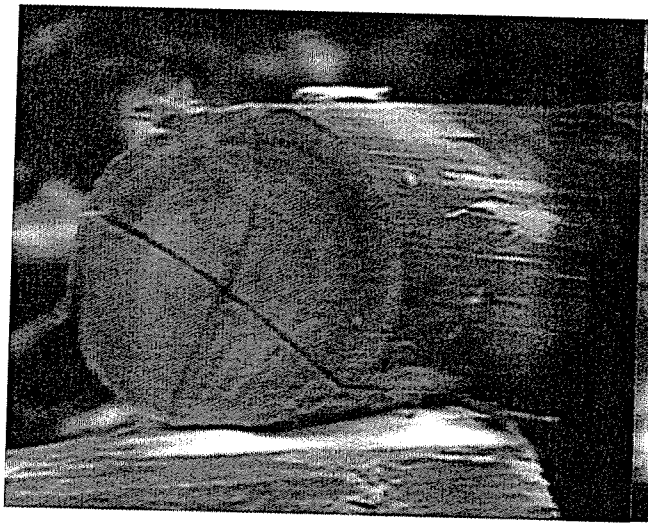

Figure 6: Checking found in *E. grandis* sawlogs

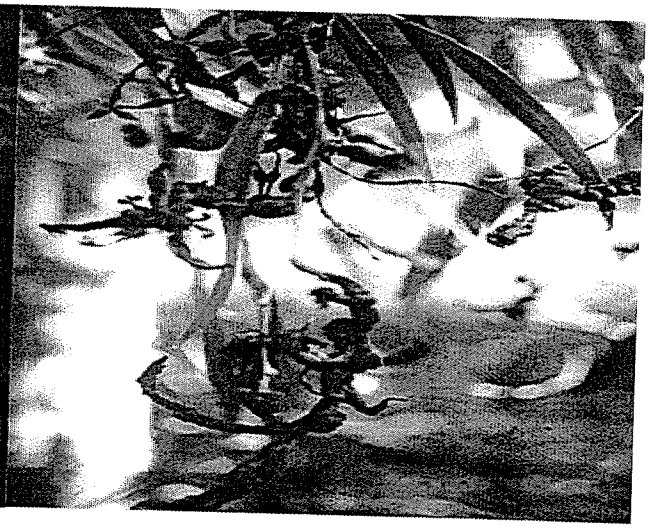

Figure 7: Disease susceptibility of *E. grandis*

The eucalypt breeding program has a large emphasis on selection for disease resistance in *E. grandis*. There is a large problem with disease in eucalypt plantations since the 5 year drought which stressed trees making them more susceptible to infection.

Eucalypt cuttings are collected using kitchen scissors and are dipped in hormone powder and set in a 98 cc pot containing a vermiculite/perlite mix. Hygiene is of utmost importance in maintaining a disease free environment. The cuttings are held in a misted green house with 25 degrees bottom heat, 21 degrees top heat for 30 days, then put out to 50% shade for 30 days then 10% shade for 30 days. Cuttings are collected over 11 months of the year with the mother plants being rested in July when maintenance is undertaken in the nursery. Cuttings are ready to be dispatched to the field in 120 days.

The SAFCOL tissue culture lab had just been completed and was to be used for bulking up of elite clones. The rooting of tissue culture clones was found to be directly related to striking ability of cuttings for that clone.

5.4 ICFR - Institute for Commercial Forest Research

ICFR is funded by industry and is undertaking special projects not covered by other research facilities. ICFR inherited the cold tolerant eucalypt breeding program from CSIR and is looking at species such as *E. nitens*, *E. macarthurii, E. benthami*, *E. badjensis,* and *E. fastigata*.

ICFR is managing an *E. nitens* seed orchard planted in 1985 at 1600 sph. The seed orchard was established from Australian provenance material. Provenances from northern NSW performed better than those from Victorian. The seed orchard was thinned at age 9 years to seed orchard density (100 sph) in one culling. The trial was measured for height and dbh at 2 years, then dbh at 4, 6, 9 years and selection based on superior growth. A major problem with *E. nitens* breeding facilities in South Africa is the low level of flower production. Paclobutrazol, applied as a soil drench 1 to 2 metres around the trunk, has been applied to promote flowering at some sites, but no response has been found to this flowering stimulant in areas which have cold nights and very high daytime temperatures.

Figure 8: E. *nitens* seed orchard managed by ICFR

ICFR also manage an *E. macarthurii* trial established in 1987 from Australian stock plus 1st generation selections of South African stock. The 1st generation South African stock has much improved stem form compared to the Australian provenances as this stock was derived from selections based on form.

Bulking up of selected cold tolerant eucalypts for breeding populations is undertaken by grafting. Cleft grafting is undertaken in spring with newly grafted plants kept in a humid environment for one week to improve take. ICFR achieved a 40-60% take for *E. nitens* but lost 60% through incompatibility with rootstock for *E. macarthurii.*

ICFR publish a regular newsletter which provides summaries of the work undertaken by the Institute. These newsletters are available on application to ICFR.

Figure 9: *E. macarthurii* seed orchard comprising Australian native stock and 1st generation South African selections

5.5 CSIR - Environmentek

CSIR Environmentek have focussed on breeding *E. grandis* with a program which was initiated in 1959 with a breeding population based on 2400 individuals. CSIR is preparing to measure the 3rd generation breeding population of about 650 families.

CSIR also has a program of hybrid *E. grandis* crosses. This focus has come about because of lack of sufficient *E. grandis* sites leading to "off site" planting. Robust hybrids perform superiorly with respect to drought (*E. grandis* x *camaldulensis*, *grandis* x *teriticornis*, *grandis* x *urophylla* and *grandis* x *saligna*) and insect resistance (*grandis* x *urophylla*). Each of these hybrids has between 100-300 families in the breeding population and is somewhere between the 1st and 2nd generation. CSIR is also looking at *E. resinifera* for drought tolerance in addition to investigating backcrossing to produce new families with new combinations of traits.

CSIR run their eucalypt breeding program on families rather than clones. CSIR do not recommend trying to match clones to sites as the logistics in the nursery and field would be unmanageable, and the potential to get it wrong too great.

Minor breeding programs with *E. nitens*, and other cold tolerant eucalypts, are undertaken by ICFR, and CSIR has a very small breeding population of *E. globulus*. CSIR supplies seed to a co-operative organisation which bulk up clones. CSIR basically supply the sawlog producers SAFCOL and Northern Timbers, and NCT, with genetic material, whilst MONDI and SAPPI run their own breeding programs.

CSIR breeding selection is on volume, splitting and density. Heritability of log splitting is 0.6 for F_1 and 0.3 for F_3. The average basic density for *E. grandis* is approximately 500 kg/m^3 but an extreme *E. grandis* x *camaldulensis* hybrid with a density of 900 kg/m^3 has been produced.

CSIR are also involved in MASP (Marker Aided Selection Program) trying to identify markers for "growth". Marker aided selection is most useful when properties are not expressed at early age, such as various wood properties, and it would reduce generation time as selections could be made much earlier based on this information. Three generations of pedigreed seed are needed to be able to definitively identify markers for particular characteristics. At present this lack of 3 generations is holding back marker aided selection. The initial focus was on investigating markers for resistance to the disease *Cryphonectria*. Age-age correlation for disease resistance

between *E. grandis* age 3 to age 6 is approx 0.98, and the genetic correlation between 6 and 10 years for growth is also good.

5.6 SAPPI

SAPPI manage 350, 000 ha of forest, of which 50% is pine, and 50% eucalypt. SAPPI manage 2 main pulp mills in South Africa, nGodwana kraft mill just outside of Nelspruit and an acid bi-sulphite dissolving pulp mill at Richards Bay. 45% of fibre requirements are still sourced outside of their current plantation estate.

The research program has 4 streams overseen by a research manager - genetics (with 3 sub programs - softwood, cold tolerant eucalypts , *grandis* + *grandis* hybrids), propagation, land management and silviculture. The breeding strategy is reviewed every year by an independent organisation.

Cold tolerant eucalypts (CTEs) *E. dunnii* and *E. macarthurii* flower sufficiently, whereas *E. nitens* and *E. smithii* do not, and are being treated with paclobutrazol to encourage flowering. *E. nitens* has exhibited an abortion rate of approximately 70% when treated with paclobutrazol. SAPPI are also using *E. grandis* x *urophylla* hybrids from SAFCOL and have reduced their *E. grandis* breeding population from 3000 to 1000. Some work has been undertaken with both *E. grandis* x *E. camaldulensis* and *E. grandis* x *E. tereticornis* with the *E. tereticornis* hybrid appearing to have the most merit. SAPPI are currently grafting cold tolerant eucalypt selections, planting in seed orchards, applying paclobutrazol at 2 years (if required) and assessing for synchronous flowering to ensure adequate cross pollination.

As an alternative to costly control pollinations of individual flowers SAPPI is investigating mass pollination of *E. dunnii* x *macarthurii* crosses. This requires somebody inspecting flowers daily and emasculating immediately the operculum is about to open, and then applying mass pollen onto the flower without any bagging.

Bee hives are placed in orchards to enhance cross pollination. A trial looking at bee movement in a seed orchard recommended that trees be planted in groups of 3 so that the bees would inter-mingle between the trees and lessen the chance of self pollination.

SAPPI Forest Research produces an annual report that summarises the research program and allows findings to enter the public arena. This publication has a dual purpose of focussing and summarising the research undertaken and in justifying the research program.

Figure 10: Mass pollination of *E. dunnii* in a breeding arboretum

5.7 MONDI Forests

Mondi Forests manages 650, 000 ha of which 456, 000 ha is forested. This is 50% eucalypt and 50% pine. Products from the forest include sawntimber and mining timber, and both kraft and mechanical pulp. Total nursery production is 60.5 million

(both pine and eucalypt) from 8 nurseries of which 31 million is eucalypt cuttings and 8 million is eucalypt seedlings. Wood quality and biotechnology are major research emphases with ongoing genetic improvement.

Tree improvement began in 1968. *E. grandis* is the dominant eucalypt but MONDI have a major clonal hybrid program with *E. grandis* x *urophylla*, *E. grandis* x *tereticornis* and *E. grandis* x *camaldulensis*. There are also promising results with *E. grandis* x *nitens* (Ebor northern NSW) hybrids.

The research program has breeding, biotechnology/physiology and nursery programs. Silvicultural research is carried out in the regions rather than from the head office in Pietermaritzburg.

Figure 11: *E. grandis* mother plants for cuttings production

Clonal forestry is expected to increase kraft pulp yield to 54% from the current pulp yield of 53%. Major savings in harvesting costs through uniformity of stands with clonal forestry are also expected. Seedling MAI of 9-22 m^3/ha across all sites has increased to clonal productivity of 20-40 m^3/ha across all sites (slowest site was not the same in both cases).

The eucalypt breeding program has two streams: subtropical - basically *grandis* and associated hybrids - and cold tolerant eucalypts. The cold temperate eucalypts include hybrids between *E. grandis* x *nitens*, and *E. grandis* x *saligna*, and co-operation with ICFR is investigating *E. smithii, E. macarthurii, E. elata, E. fastigata, E. dunnii, E. fraxinoides, E. benthamii* and *E. badjensis.*

MONDI have established a 3rd generation clonal seed orchard with *E. grandis* and a 1st generation clonal seed orchard with *E. saligna, E. macarthurii* and *E. dunnii.* For clones to achieve approval as "commercial"/deployment clones they must go through two testing phases, one in the breeding program itself and one through the clonal propagation phase. Less than 3% of selections achieve commercial production status. MONDI currently have 2 pure *E. grandis* and 30 *E. grandis* x *camaldulensis* hybrids classified as commercial clones.

Figure 12: *E. grandis* cuttings in the greenhouse

The nucleus breeding program has a main population of 300 trees and an elite population of the best 40 clones per generation. In total they have 1600 *E. grandis* in the subtropical program and 200 *E. saligna*, 97 *E. grandis* x *nitens* and 100 *E. grandis* clones in the cold tolerant program. Breeding selections are based on volume, disease resistance, form, canopy density (for weed control), wood density, pulp yield and for sawn timber, splitting. For pure *E. grandis* volume growth has improved 31-42% over 1st generation selections. Average MAI for *E. grandis* x *nitens* is 10-40 m^3/ha at age 3. Growth performance of selected *E. grandis* x *camaldulensis* clones was 250% better than *E. grandis* seedlings.

MONDI also have an organogenesis program for sub tropical eucalypts. Tissue cultured plants are subsequently planted out as hedge trees for cuttings to be taken. Cost per plant of cold temperate eucalypt is much greater than cost per plant of subtropical eucalypts largely because of the difficulty in forming roots. Cold temperate eucalypts can take between 3-8 weeks to root, once shoot elongation has been achieved and are too variable for commercial production. *E. nitens* seed orchards (2) used for research have paclobutrazol applied and they abort 60-70% of flowers.

Nursery *E. grandis* x *urophylla* cuttings are achieving a 60% strike rate with bed temperature kept 3°C above air temperature for cuttings and a media mix of vermiculite, perlite and palm peat. Cuttings are kept in the green house for 6 weeks with mist spray and heated beds and are then sent to the shade house to harden off. The local Mountain Hut nursery has an annual production of 10 million cuttings. Mother plants are used for 6 years in production.

Breeding selection is based on rooting potential, wood properties, herbicide resistance, disease resistance and water use efficiency. BayFocus 2000 is a program trying to ensure that uniformity of product is provided to mill and that forest growers ARE responsible for the quality of their wood. This program is also investigating a differential selling price based on the quality of the wood being sold to the mills.

Research in wood properties is undertaken in cooperation with other research institutes and other areas of Mondi (i.e. Mondi Kraft, Mondi Paper, Mondi Timber). MONDI Forests are also members of the tree pathology co-operative and also MSCP Molecular Screening Co-operative program.

5.8 University of Stellenbosch

The University is undertaking public good research into alternative eucalypt species to plant in dryland zones. As there are significant areas of South Africa under communal control some work must be done to ensure that the "3 C's" to forestry - community, conservation and commercial - are investigated.

A project investigating community forestry in the Transkei area is trying to encourage indigenous tree planting for either fruit or firewood. This area has 300mm rainfall per year and breeding for improved volume or fruit production is at a very early stage.

Eucalypt species trials on Western Coast above Cape Town are identifying optimum species to plant in low rainfall areas (450 mm/year). This is supported by South African government with a view to produce cash crops (poles) from fast growing eucalypts.

5.9 Implications for Australian Eucalypt Breeding

South Africa, like Zimbabwe, has concentrated on sub tropical eucalypts such as *E. grandis* which performs well in summer rainfall zones. South Africa is looking to plant up marginal sites for plantation growth and is trying to breed in drought tolerance, disease resistance and frost tolerance through hybridisation of *E. grandis* with other relatively tolerant eucalypts. This approach has the benefit of being able to vegetatively propagate the eucalypt hybrids as *E. grandis* roots relatively well from cuttings. The forestry industry in South Africa has sufficient critical mass to be able to support ICFR to undertake the breeding of the cold tolerant eucalypts so that individual companies do not have to run too many individual breeding programs.

A major issue in South Africa eucalypt forests is disease. This has not received much attention in Australia to date but is gaining in importance as breeding stock improves. Most Australian breeding programs are in their first or second generation and are still focussing on volume growth and wood property improvements. As breeding becomes more advanced focus is likely to shift to alternate means of improving productivity, through focussing on disease and drought tolerance. As Australian plantations move into more marginal areas these factors will take on greater importance.

Appendix 1

Eucalypt Breeding Questionnaire

Company/Organisation

Responder

1. With which eucalypt species is your organisation involved?

	E. globulus	*E. nitens*	*E. grandis*	Other
current area of plantation (ha)				
area established 1996 (ha)				
area to be established 1997 (ha)				
non land owner				

2. Primary purpose for which eucalypts are grown (please circle)

kraft pulp other pulp sawntimber veneer/peeler log

other (specify)

3. Current source of genetic stock for deployment (tick or percentage):

	bulk native stand	selected prov. native stand	seed orchard			vegetative propagation
			converted trial	seedling SO	clonal/grafted SO	
E. globulus						
E. nitens						
E. grandis						
Other						

4. Basis for selection of eucalypt genetic stock (please circle):

volume growth wood density pulp yield sawlog quality

other (specify)

5. Current projects in eucalypt breeding (please circle)

active in house breeding program	yes	no	
developing own seed orchards	yes	no	
purchasing outside seed	yes	no	
research projects	cuttings	clonal forestry	hybrid crosses
	tissue culture	family forestry	

6. Approximate % of eucalypt research/development budget dedicated to eucalypt breeding?
(this is to provide an indication of the importance of eucalypt breeding to various organisations)

Total euc breeding	"In house" euc breeding	STBA co-ordinated euc breeding
%	%	%

Thank you for taking the time to complete the questionnaire.
Results will be summarised in the Gottstein report
"Investigating Eucalypt breeding in Southern Africa".

Reply to fax number (03) 51337955

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Appendix 2
Itinerary for southern African investigation of eucalypt breeding

Zimbabwe:

Technical Attachment to 15th Commonwealth Forestry Conference

April 27-30	Forestry Commission Headquarters	Harare
May 1-2	Zimbabwe Forestry College	Mutare
May 4-5	John Meikles Forest Research Station	Eastern Highlands
May 6	Border Timbers/Mutare Board and Paper Mills	Mutare
May 7	Chinhokwe sawmill/Muguzo	Chimanimani

South Africa

May 11- May 17	IUFRO Forest Conference - Environmental Constraints to Forest Function	Kruger Nat. Park
May 19	Hans Merensky Holdings/Northern Timbers	Tzaneen
May 20	SAFCOL - South African Forest Company	Sabie
May 21	ICFR - Institute of Commercial Forest Res.	Sabie
May 22	CSIR - Environtek	Nelspruit
May 23	SAPPI	Horwick
May 26	MONDI	Pietermaritzburg
May 28	SAFCOL radiata breeding program	Western Cape
May 29-30	University of Stellenbosch	Cape Town