SILVICULTURA DE PLANTACIONES DE EUCALIPTOS PARA PRODUCTOS DE MADERA SOLIDA DE ALTO VALOR EN EL SUR DE AUSTRALIA

T.G. Baker [1,2], P.W. Volker [2,3]

RESUMEN

Australia es el hogar natural de los eucaliptos y hace relativamente poco tiempo el manejo de bosques nativos de eucaliptos para producción de madera sugiere que la necesidad de desarrollar plantaciones de eucaliptos es reducida. En tiempos recientes ha habido dos presiones fuertes que han incrementado las plantaciones con estas especies. La primera está dada por un fuerte incremento durante los últimos 20 años de áreas designadas como de conservación y excluidas de la actividad forestal comercial, como resultado de decisiones políticas ante la creciente presión de la sociedad. La segunda también responde a políticas gubernamentales, Visión 2020, cuyos objetivos buscan triplicar el área de plantaciones en Australia a unos 3 millones de hectáreas en el año 2020.

La mayoría de las plantaciones de eucaliptos han sido establecidas en la región templada ed Australia; Western Australia, South Australia, Victoria y Tasmania. *Eucalyptus globulus* es la principal especie en superficie y casi todas las plantaciones tienen por objeto la producción de pulpa en rotaciones cortas. En Victoria y Tasmania, como en Chile, *Eucalyptus nitens* ha sido empleado como sustituto de *E. globulus,* particularmente donde el frío es una limitante para esta última especie.

La creciente reserva de bosques naturales para conservación, que habían sido la fuente tradicional de madera para aserrío, ha conducido al interés por generar productos de madera sólida con las nuevas plantaciones, sin embargo hay resistencia por parte de la industria a utilizar madera de plantaciones con este fin porque dudan que la madera sea de calidad y que las trozas sean adecuadas para proceso. Se requiere aún mucha investigación para resolver estas dudas.

Los programas de investigación han evolucionado con el incremento de las plantaciones, inicialmente la investigación apuntaba a las técnicas de establecimiento de plantaciones, el mejoramiento de la productividad y de las propiedades de la madera para pulpa, principalmente a través de genética y nutrición. En la medida que el interés por la producción de madera sólida ha aumentado, la investigación se ha orientado hacia la silvicultura intensiva con podas y raleos, la durabilidad de la madera y el manejo de plagas y enfermedades.

Este trabajo describe algunos resultados de investigación en silvicultura y propiedades de la madera en el sur de Australia y las actuales actividades y prioridades de investigación.

SILVICULTURE OF EUCALYPT PLANTATIONS IN SOUTHERN AUSTRALIA FOR HIGH-VALUE SOLID WOOD PRODUCTS

SUMMARY

Australia is the natural home of *Eucalyptus*, and until relatively recently the management of native eucalypt forests for timber production meant that there was little need to develop a eucalypt plantation estate. In recent time there have been two strong influences which have driven increases in eucalypt plantation establishment. The first has been a large increase over the last 20 years in the area of forest designated as conservation reserves and excluded from commercial forestry activity. This increase has occurred largely as a result of State and Federal Governments decisions in response to increased community pressure. The second influence was the release of the Vision 2020 Policy Statement by the Federal Government in 1997, which aims to triple the area of plantations in Australia to about 3 Mha by 2020.

The majority of the eucalypt plantations have been established in the temperate region of Australia in Western Australia, South Australia, Victoria and Tasmania. *Eucalyptus globulus* is the primary species by area, and nearly all plantations are aimed at short rotation pulpwood production. In Tasmania and Victoria, as in Chile, *E.nitens* has been used as a substitute for *E. globulus*, particularly where cold temperatures are limiting for the latter species.

The increased reservation of natural forests, which have been the traditional source of sawn timber, has led to interest in producing solid wood products from these new eucalypt plantations. There is resistance to utilisation of eucalypt solid wood from plantations, particularly from the processing industry due to concerns about wood quality and processing suitability of the logs. There is still much research required to address these concerns.

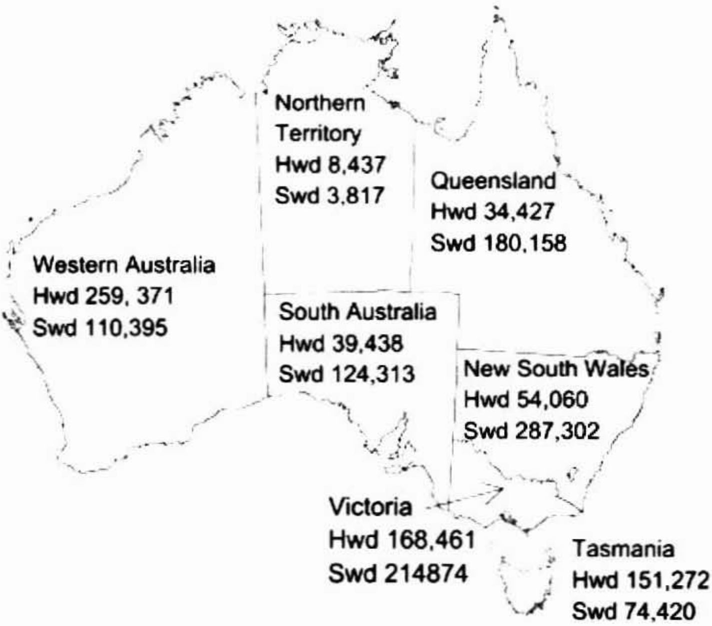
Research programs have evolved with the increase in the plantation estate. Initial research was aimed at establishment silviculture and improving productivity and wood properties of pulpwood plantations, primarily through genetics and nutrition. As the interest in solid wood production increased, research began examining pruning and thinning silviculture as well as wood decay and pest and disease management.

This paper describes some results from silvicultural and wood property research in eucalypt plantations in southern Australia, and current research priorities and activities.

INTRODUCTION

Australia is the natural home of *Eucalyptus*. This genus comprises of over 400 species, many of which are highly valuable for their fibre and timber properties. The natural eucalypt forests, which provide the majority of forest produce, comprise approximately 68% of Australia's total forest cover of 164 Mha. The tall eucalypt forests, which provided the majority of high quality timber and fibre, comprise about 37 Mha (22%). These forests are generally harvested for solid wood products from older regrowth (60+ years) to old-growth (up to 450 years). *Eucalyptus regnans* is an example of one of the species that is utilised extensively for solid timber production. In old-growth natural forests it can reach heights of up to 100 m. Due to the magnificent state of these native eucalypt forests and increasing community pressure for conservation more than half of these highly productive native eucalypt forests have been excluded from commercial wood production. Federal and State Governments have designated them as conservation reserves in the past 20 years in response to these community concerns. This has resulted in reduction in the availability of high quality hardwood logs, particularly eucalypts, for processing industries. There is a long-established pine plantation resource in Australia, but it is apparent that there is a continued demand for high quality eucalypt timber in the Australian market. The challenge for research is to determine the similarities and differences of the new plantation derived timbers with their native forest counterparts.

Australia's plantation estate is presently comprised of 1.0 Mha softwoods and 0.7 Mha hardwoods (National Forest Inventory 2005; Figure N° 1), a total of about 1% of the total forest area. In 1997 the Australian Government released its Vision 2020 Policy, which aims to increase the area of plantations by three times by 2020, resulting in a plantation area of about 3 Mha. At about the same time, governments, large-industrial growers and vertically integrated pulp and paper companies began to sell their plantation assets. Recent plantation development has been driven by Managed Investment Schemes which pool together funds from small investors who wish to engage in the business of growing trees and receive the tax benefits available to other primary producers. This has resulted in a rapid expansion of plantation area (0.5 Mha) during the last 10 years. This expansion has been dominated by *E. globulus* planted for pulpwood in southern regions and subtropical species in northern New South Wales and Queensland.



Hwd = Hardwood, predominantly *Eucalyptus* spp. Swd = Softwood, predominantly *Pinus* spp.

Figure N° 1.

PLANTATION AREAS (ha) IN EACH STATE OF AUSTRALIA

In south-eastern Australia, particularly in Victoria and Tasmania, *E. globulus* and *E.nitens* are the primary plantation species. As in Chile, *E. nitens* is used where cold temperature limits the use of *E. globulus*. The historically important and magnificent *E. regnans* is less favoured as a plantation species due to difficulties in managing natural pests and diseases and its preference for only the highest quality sites. In south-western Western Australia, and south-eastern South Australia, *E. globulus* is the most important species by area and most plantations are managed for pulpwood with no pruning or thinning treatment. In subtropical and tropical Australia, the main species planted include *E. grandis*, *E. pilularis*, *E. dunnii,* and *Corymbia* spp and hybrids, with solid-wood regimes being investigated. There is increasing interest in tropical *Acacias* for fibre production and *Tectona grandis* for timber.

Farm forestry is a developing feature of the Australian rural landscape, especially where there is a tradition of sawmilling and other industrial forestry activities. The plantation area established by individual landholders (farmers) is much less than that established by state and industrial organisations, but involves a wider range of species (e.g. including *E. cladocalyx*, *C. maculata*), often in lower rainfall areas (< 600 mm year^{-1}) and primarily managed for sawlog production. There is also a number of environmental service benefits associated with farm forestry plantations and these are promoted as a secondary benefit of plantation forestry in agricultural landscapes.

In Tasmania, the potential for higher-value sawlog and veneer log production from eucalypt plantations over rotations of 20 to 30 years was recognised by Forestry Tasmania the early 1980's. A program of intensive silvicultural management commenced in 1990 (Figure Nº 2) and is continuing. In recent time, state enterprises and private industry began to adopt similar regimes in a range of eucalypt species throughout Australia. There is still uncertainty about the quality of logs and processed products that can be achieved from these plantations (Nolan *et al.*, 2005).

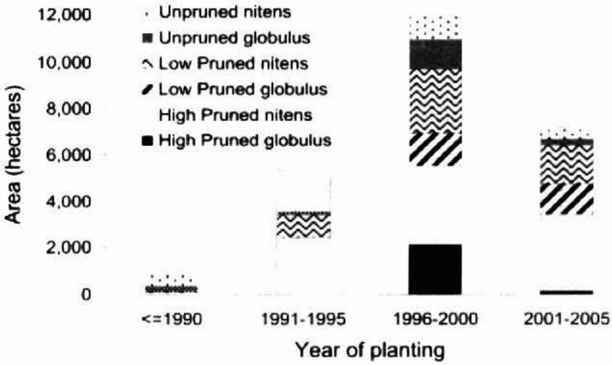


Figure Nº 2.
AREA OF EUCALYPT PLANTATION AND SILVICULTURAL MANAGEMENT OWNED BY FORESTRY TASMANIA

It is increasingly recognised that wood production from hardwood plantations for higher-value solid and engineered wood products requires a focus on genetic improvement and silvicultural management (e.g. INFOR, 2004a,b; Waugh, 2004; Nutto and Touza, 2004; Nolan *et al.* 2005). These practices affect the quantity and size classes of logs, incidence of defects (e.g. size of knotty core and spread of wood decay), wood properties (e.g. tension wood development) that affect processing performance, and serviceability and use of the final product. In Australia, initial research has focused on optimising density (spacing) for yield and control of branch size (Neilsen and Gerrand, 1999; Gerrand and Neilsen, 2000; Pinkard and Neilsen, 2003), pruning to achieve knot- and decay-free wood (Wardlaw and Neilsen, 1999; White *et al.*, 1999; Pinkard, 2002) and early thinning to allow more rapid diameter growth of the retained trees to a sawlog size (Gerrand *et al.*, 1997; Stackpole *et al.*, 1999, 2004).

Silvicultural research initiated in the early 1980s is now providing rotation-length results for solid wood regimes and particularly material for processing studies (peeling, sawing and drying) and utilisation in service.

SILVICULTURE RESEARCH RESULTS

In Victoria and Tasmania, growth rates (total underbark volume) of unthinned *E. globulus* and *E. nitens* established at densities of 1000 – 1200 trees ha^{-1} in 800 – 1200+ mm mean annual rainfall areas, where nutrition is adequate, are typically in the mean annual increment (MAI) range 20 to 30 m^3 ha^{-1} $year^{-1}$ at age 10 years (Figure Nº 3). Growth rates of *E. nitens* on the most productive sites approach 50 m^3 ha^{-1} $year^{-1}$ and this species is now favored over *E. regnans* on such sites because operational success of establishment with *E. nitens* is more certain and because of pest and disease problems with *E. regnans*.

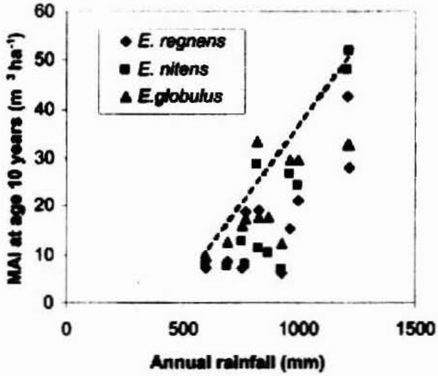


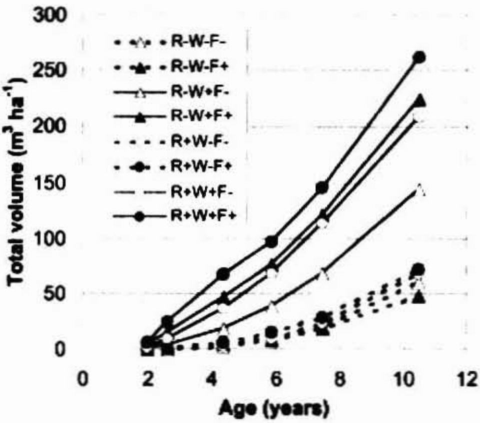
Figure Nº 3.
MEAN ANNUAL INCREMENT (MAI) AT AGE 10 YEARS OF UNTHINNED *Eucalyptus globulus*, *E. nitens* And *E. regnans* PLANTATIONS IN RELATION TO RAINFALL AT TWELVE SITES IN EASTERN VICTORIA. DATA FROM DUNCAN ET AL. (2000).

Growth of *E. globulus* on some sites with particularly favourable characteristics is greater than the nominal rainfall envelope limit indicated in Figure Nº 3. For example, on very deep well structured soils in the Mediterranean climate of south-western Western Australia, and in south-eastern South Australia where trees can access additional water (e.g. groundwater) by judicious planting in the landscape. Growth can often fall short of the site's potential because of poor management, particularly poor control of competing vegetation and inadequate nutrition, and such losses cannot be recovered by later intervention.

Much Australian silvicultural research on eucalypt plantations during the 1990s aimed to optimize establishment practices for pulpwood production, including studies of soil cultivation (to reduce soil strength; increase aeration, water availability and drainage; and improve tilth), weeding (to reduce competition for water, nutrients and light) and fertiliser application (to avoid nutrient deficiencies and optimise nutrient availability). Genetic research also aimed to increase volume yields, pulp quality of the fibre, and pest and disease resistance.

The importance of establishment silviculture practices is illustrated for *E. globulus* on a former agricultural (grassland) site in north-eastern Victoria (annual rainfall approx. 1200 mm) in Figure Nº 4. Here, first- and second-season weed control using herbicides was of prime importance, since otherwise early survival was unacceptably low (< 60%). With weeding, the responses to soil cultivation (ripping to 0.8 m depth) and N and P fertiliser applied at age

1 year were additive and continued through to the nominal pulpwood rotation age. The responses to these treatments were surprising since from soil morphological description the soil is apparently well structured, without an impeding layer, and there had been a history of fertiliser application for agriculture.



(Treatment: - absent and + Present)

Figure N° 4.

GROWTH RESPONSES TO AGE 10 YEARS OF *Eucalyptus globulus* TO COMBINATIONS OF SOIL RIPPING (R), WEEDING (W) AND FERTILISER (F) TREATMENTS APPLIED DURING PLANTATION ESTABLISHMENT IN NORTH-EASTERN VICTORIA.

The relative responses and therefore the practical importance of establishment silvicultural practices varies across sites (e.g. Duncan and Baker, 2004), and considerable research effort continues to be invested in relating growth to soil physical and nutrient properties, developing rapid methods of measurement of these, and application into models and decision support systems. Good establishment practices will also be the foundation for management of plantations over longer rotations for solid wood products. With such practices the trees will 'capture' the site rapidly (and recapture the site after thinning), resulting in greater uniformity and better form within the young stand therefore facilitating selection and spacing of trees for pruning. Adequate nutrition during establishment (prior to canopy closure) may reduce early branch senescence and provide for more rapid recovery after pruning.

Tending silviculture involves thinning, pruning and fertiliser application to manage the site's biological potential, or the stand's established growth, for a yield of log product (e.g. sawlogs, peeler-logs) that meets market / processor specifications. In doing this, protection from or management of interactions / risks with pests, diseases, drought, wind and fire, maintenance of long-term productive capacity of the site and minimization of off-site impacts is assumed.

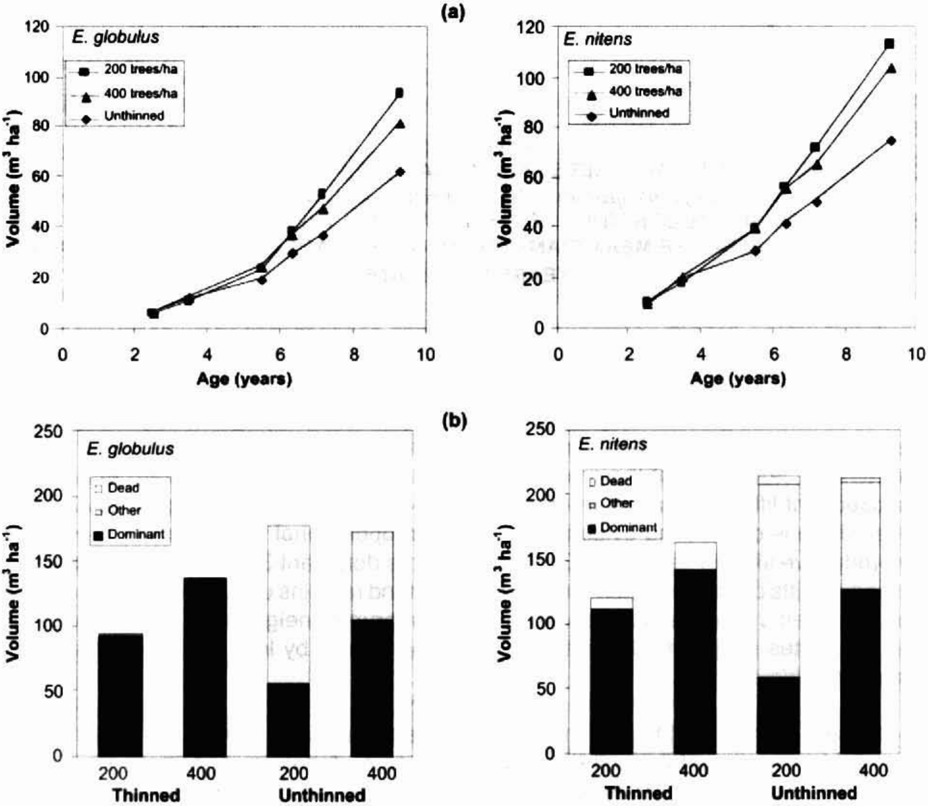
The primary silvicultural decisions on initial planting density (stocking) and espacement affect early tree growth (height, form, branch size and senescence), and the selection ratios that can be applied, and therefore planting density interacts with tending practices. Conventionally, thinning practices are concerned with tree diameter distributions, tree form and stem shape as they may be affected by timing, intensity and spacing / symmetry of thinning, and impacts on epicormics, upper stem branches and windthrow. Pruning practices are concerned with log defect / clearwood as affected by timing, intensity, height and diameter-over-stubs of pruning lifts. Management of nutrition, by application of fertilisers, is concerned with the growth / vigor of the trees, as affected by the quantity and timing of application of specific nutrients. The effects of thinning, pruning and nutrition management may interact. It is increasingly apparent that log and wood properties relevant to processing performance, such as core to outer- wood proportions, density and growth stresses (e.g. tension wood) can be impacted or ameliorated by silvicultural practices (e.g. Washusen *et†al.*, 2005).

Conceptually, tending silviculture regimes for solid wood products from larger-scale eucalypt plantations in Australia have aimed to maximize the volume production of higher-value defect free clearwood on large diameter sawlogs and peeler-logs. However, financial imperatives to obtain intermediate revenue(s) from thinnings have required some compromise in practice. Active tending silvicultural regimes that are less intensive and therefore less costly, and that yield higher volumes per hectare targeted to engineered solid wood products, have not been explicitly investigated. Tending silviculture practices at the farm forestry or agroforestry scale particularly trade-away total volume production, aiming to produce very high value individual logs, particularly where pulpwood markets are absent or distant.

Competition commences relatively early in fast growing eucalypt plantations established at conventional densities (c. 1000 to 1200 trees ha^{-1}). For example, growth responses of the dominant 200 trees ha^{-1} of both *E. globulus* and *E. nitens* to non-commercial thinning at age 3 years were evident by age 5.5 years on a productive site in north-eastern Victoria (Figure Nº 5a). Furthermore, the growth trajectories of the dominant trees from the thinned treatments (residual densities of 200 and 400 trees ha^{-1}) indicate that inter-tree competition had recommenced from approx. age 6 years.

It is clear that non-commercial thinning reduces total volume production over a rotation. For example in a productive *E. globulus* plantation in south-western Western Australia, thinning to 125 trees ha^{-1} at age 6 years resulted in approximately half the volume growth at age 15 years compared to the unthinned treatment (Figure Nº 5). The density at which the growth of the selected (and pruned) dominant trees is not affected by competition appears to vary between sites. In the Western Australian example, the growth of the largest 125 trees ha^{-1} in the thinned treatments (residual densities 125 to 500 trees ha^{-1}) was the same, and only different from that in the unthinned treatment (Figure Nº 5). Whereas, growth of the largest 200 trees ha^{-1} in *E. globulus* and *E. nitens* in the north-eastern Victoria example differed between residual densities of 200 and 400 trees ha^{-1} (Figure Nº 5a). And more markedly so in *E. nitens* in Tasmania following non-commercial thinning where growth of the largest 200 trees ha^{-1} was different between treatments with residual densities of 200 and 300 trees ha^{-1} (Medhurst *et al.*, 2001). The Western Australian example, and other *E. globulus* experiments on two potentially highly productive irrigated sites in Victoria (Baker *et al.*, 2005; Forrester and Baker, 2005) suggest that where resources (water, nutrients) are relatively abundant a higher total density of trees can be retained without loss of growth on the select dominant trees.

The evidence suggests site productivity is a factor in selecting a silvicultural regime that optimises volume (or financial) trade-offs between non-commercial thinning and commercial thinning treatments. In *E. globulus* and *E. nitens* in north-eastern Victoria (Figure Nº 5b), approximately one-half to one-third into a nominal 20-30 year sawlog rotation, the standing volume is such that a commercial thinning yielding approx. 70 to 150 m^3 ha^{-1}, depending on final density, is feasible. The production trade-offs between increased volume and diameter growth on the dominant trees arising from non-commercial thinning, by forgoing a commercial thinning option are evident for both species.



(a) Dominant 200 trees ha^{-1} to age 9.5 years and (b) Dominant 200 or 400 trees ha^{-1}, Other trees and Dead trees at age 9.5 years.

Figure Nº 5.

VOLUME GROWTH OF *Eucalyptus globulus* And *E. nitens* IN UNTHINNED AND NON-COMMERCIALLY THINNED TREATMENTS (RESIDUAL DENSITIES OF 200 OR 400 TREES ha^{-1} AT AGE 3 YEARS) IN NORTH-EASTERN VICTORIA

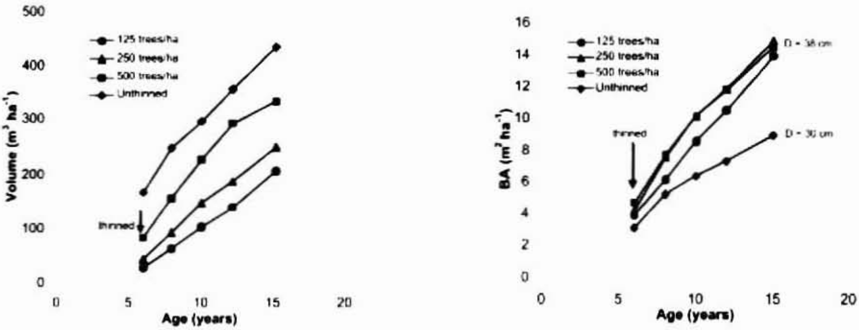


Figure Nº 5.
TOTAL VOLUME GROWTH (ALL TREES), AND BASAL AREA (BA) GROWTH OF THE LARGEST 125 TREES ha^{-1}, OF *Eucalyptus globulus* IN UNTHINNED AND NON-COMMERCIALLY THINNED TREATMENTS (RESIDUAL DENSITIES OF 125, 250 AND 500 TREES ha^{-1}) IN SOUTH-WESTERN WESTERN AUSTRALIA. THE MEAN DIAMETER (D) OF THE LARGEST 125 TREES ha^{-1} AT AGE 15 YEARS IS INDICATED.

Timely green-branch pruning (ahead of branch senescence) commencing at age 2 to 4 years is essential to achieve clearwood production in these plantations (Montague *et al.*, 2003), and regimes requiring 2 or 3 lifts to a total height of 6 – 7 m over 3 years can be applied to the dominant trees usually without significant disadvantage in either unthinned or thinned stands. From experiments in both *E. globulus* and *E. nitens* the initial pruning lift should leave at least 50% of the green crown length (Pinkard, 2002; Pinkard *et al.*, 2004), with subsequent lifts to a maximum diameter-over-stubs of 10 cm (Stackpole *et al.*, 2004). However, there is contrasting evidence emerging in operational plantations of *E. nitens* on highly productive sites in Tasmania. On these sites the dominant 350 trees ha^{-1} are pruned in three separate lifts of approximately 2 m each. If the stand remains unthinned, there is evidence that pruned stems may be suppressed by their unpruned neighbours. This is especially prevalent on sites subject to defoliation of the upper crown by leaf eating insects such as *Chrysoptharta bimaculata*.

Current pruning and thinning regimes (Forestry Tasmania, 1998) have been derived from available experimental results supported by some modelling, principally for *E. nitens* (e.g. Candy et al., 1997; Gerrand et al., 1993). This has required extrapolation to rotation ages of about 30 years from available results to age 10-20 years as demonstrated in Figure Nº 6.

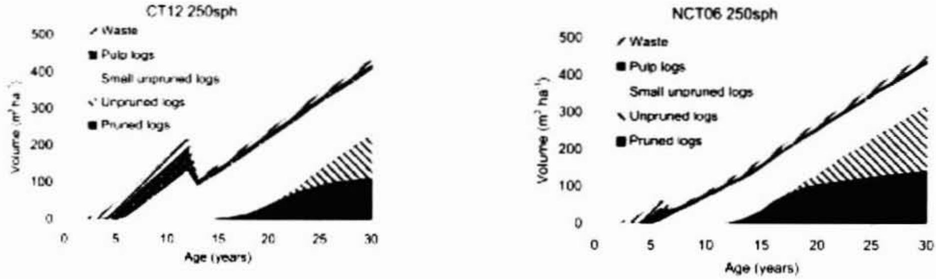


Figure N° 6.
LOG GRADE YIELDS FROM TWO REGIMES OF *Eucalyptus nitens* ON A MEDIUM QUALITY SITE IN TASMANIA. CT12 250sph IS A COMMERCIAL THINNING AT AGE 12 YEARS TO 250 STEMS PER HECTARE. NCT06 250sph IS A NON-COMMERCIAL THINNING AT AGE 6 YEARS TO 250 STEMS PER HECTARE. IN BOTH CASES THE RETAINED STEMS HAVE BEEN PRUNED IN THREE LIFTS TO A HEIGHT OF 6.4 m.

Commercial thinning yields can improve the overall financial performance of the regime. Non-commercial thinning has the effect of bringing forward the availability of larger dimension pruned logs, which are usually highly valuable. The results in Figure N° 6 demonstrate that there is little difference in the final-harvest volume of logs produced in both regimes, but the proportion of logs in higher value, larger dimension grades is increased and brought forward by early thinning. This is clearly demonstrated in Figure N° 7 where the MAI of total log value reaches a maximum much earlier than for commercial thinning regimes.

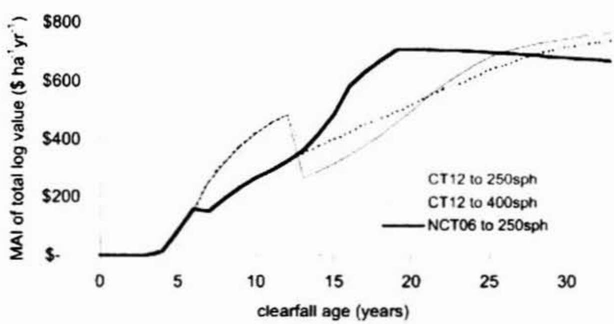


Figure N° 7.
MEAN ANNUAL INCREMENT (MAI) OF TOTAL LOG VALUE FOR THREE REGIMES OF *Eucalyptus nitens* AGE 12 YEARS TO 250 STEMS PER HECTARE. CT12 PLANTATION ON A MEDIUM QUALITY SITE. CT12 250sph IS A COMMERCIAL THINNING AT 400sph IS A COMMERCIAL THINNING AT AGE 12 YEARS TO 400 STEMS PER HECTARE. NCT06 250sph IS A NON-COMMERCIAL THINNING AT AGE 6 YEARS TO 250 STEMS PER HECTARE. IN ALL CASES THE RETAINED STEMS HAVE BEEN PRUNED IN THREE LIFTS TO A HEIGHT OF 6.4 m.

RESEARCH OBJECTIVES

While there has been relatively enthusiastic uptake of intensive pruning and thinning regimes for agroforestry or farm forestry, albeit totalling very small areas, the mainstream plantation industry has not generally adopted high-value solid-wood regimes. The primary limitation is financial, particularly the expected return on investment compared to alternatives, exacerbated by uncertainties/risks in volume yields, log quality and future log prices (Nolan *et al.*, 2005). The current plantation investment structure in Australia favours short rotation (pulpwood) plantations.

Current research is now utilising the products of early pruning and thinning experiments established in young plantations in the early 1990s (see Gerrand *et al.*, 1997). This work is being coordinated across Australia with a number of contributing research and industrial partners through the Co-operative Research Centre for Forestry (CRC Forestry). Recently one of these *Eucalyptus nitens* pruning and thinning experiments in Tasmania has been harvested at age 22 years. In this experiment, trees were pruned to 6.4 m and thinning was carried out at age 6 years to residual densities of 400, 300, 200 and 100 trees ha^{-1} as well as an unthinned control treatment. The tree dimensions have been measured annually since the experiment was established. Logs from the pruned section of the tree have been sawn in both back and quarter sawing patterns. Boards have been kiln dried and are now ready for assessment. Prior to and during the harvesting, the trees were measured intensively including diameter at various heights up the stem, crown dimensions (depth and width) and biomass sampling of various tree components were taken. Non-destructive evaluation techniques have also been used to assess growth strain and wood properties. The aim is to relate these non destructive techniques to the performance of the processed boards. Tree measurements will be used to develop improved growth models for pruned and thinned stands.

There are similar trials in Tasmania and Victoria in both *E. nitens* and *E. globulus* which can be utilised for further study of the relationship between silviculture, wood properties and product performance of solid wood from eucalypt plantations.

CONCLUSION

In the first phase of eucalypt plantation development in Australia the primary production objective was to produce pulpwood. This was to capture the benefits of increased pulp yield and to supplement the production of eucalypt pulpwood from native forests. Federal and State Government decisions and policies have reduced the amount of native forest available for harvesting. This has led to an increased interest in eucalypt plantations to provide solid wood products that have traditionally been sourced from native eucalypt forests.

There is doubt that the plantation resource will deliver the same characteristics in log and wood properties and serviceability of the processed products as that derived from native forests. Research is now examining the best way to manage plantations to produce high quality solid wood for processing. Parallel processing studies are being undertaken using material sourced from these well-designed and managed silvicultural trials.

The lesson for foresters in this experience is that there is little understanding in the processing industry of the effects of silviculture on wood properties for processing. There is also a lack of understanding in the wider community that plantations may not deliver the same products and benefits as material sourced from native forests. These are challenges for foresters throughout the world.

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