



An Australian Government Initiative



Blackwood Management:

Learning from New Zealand

*Proceedings of an International Workshop
Rotorua, New Zealand, 22 November 2002*

**A report for the RIRDC/Land & Water Australia/
FWPRDC/MDBC Joint Venture Agroforestry Program**

Edited by A.G. Brown

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Foreword

Declining availability of cabinet timbers from Australian native forests has increased attention to their cultivation and to the management of native forests from which they may be obtained. Blackwood is a species of special interest — it is amenable to cultivation and management, it has an extensive natural range in eastern and southern Australia encompassing rural communities seeking to diversify land use and economic activity, it is well suited to high-value-added products, and it has an established favourable reputation as a furniture timber.

Relevant interest groups are widely dispersed in Australia and New Zealand, and there has been no focal point for strategic interaction or exchange of information. The workshop which is the subject of this report is the third in a series intended to bring these interests together and to develop a basis for ongoing interaction and mutual assistance. A framework for this interaction was established at the first workshop at Lorne, Victoria, in November 1996 in the form of the Blackwood Industry Group. The second workshop was conducted under the auspices of this group. Further activity and the long-term outcome is in the hands of participants in the group.

The three workshops (Lorne – 1996, Smithton – 2000 and Rotorua –2002) have been supported by funds from the Joint Venture Agroforestry Programme (JVAP).

The JVAP partners are- Rural Industries Research and Development Corporation (RIRDC), Land & Water Australia (LWA), Forest and Wood Products Research and Development Corporation (FWPRDC) and the Murray-Darling Basin Commission (MDBC). These agencies are funded principally by the Australian Government.

This report, a new addition to RIRDC's diverse range of over 1000 research publications, forms part of our Agroforestry and Farm Forestry R&D programme, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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- Purchases at www.rirc.gov.au/eshop

Simon Hearn

Managing Director

Rural Industries Research and Development Corporation



*Managed blackwood – age 20 y
pruned and nurse crop removed
DBHOB = 39 cm, form = good*



*Unmanaged blackwood – age 20 y
unpruned and nurse crop left
DBHOB = 7 cm, form = very poor*

Photos: Andy Warner

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1

Opening Address

Roslyn Prinsley

General Manager, Research
Rural Industries Research & Development Corporation, Canberra



It is with great pleasure that I welcome delegates to this the third blackwood workshop. RIRDC is pleased to have continued involvement in the furthering of knowledge about blackwood, one of our valuable cabinet timbers.

These workshops (Lorne - 1996, Smithton - 2000 and Rotorua - 2002) have been supported by funds from the Joint Venture Agroforestry Programme (JVAP). The JVAP is an initiative of three R&D Corporations — Rural Industries, Land & Water Australia, and Forest and Wood Products, as well as our new partner, The Murray Darling Basin Commission. These Corporations are funded principally by the Federal Government.

We have identified blackwood as a species of special interest because it is:

- A high-value species capable of filling a market niche created by the declining availability of cabinet timbers from native forests;
- It has an established favourable reputation as a furniture timber;
- It is amenable to cultivation and management in plantations;
- It has an extensive natural range in Tasmania, and eastern and southern mainland Australia;
- Blackwood plantations could support rural communities seeking to diversify land use and economic activity;
- It is well suited to high-value-added products.

It seems a long time ago that BIG was formed at Lorne in 1996. Although quiet for a period, the resurgence in activity is a tribute to those who have

continued to foster the group's activities with both workshops and newsletters.

We are very pleased to see the international linkages developed in this workshop, encompassing Chile, South Africa, China and of course New Zealand which has so kindly hosted this meeting. This sharing of knowledge will help all those involved with blackwood.

It has been gratifying to see the development of interactions between those involved in the blackwood industry in New Zealand and Australia, especially the links between BIG and AMIGO. We hope to see these maintained, and stress the need for the blackwood industry group to maintain a presence in its industry. The final session of the workshop, 'The Future of BIG', should help identify the key issues to be addressed.

RIRDC would like to see as outcomes from the workshop:

- Australians having more confidence in management systems for blackwood and where, it is appropriate to do so, being prepared to put into practice what they see in New Zealand;
- I also hope that delegates gain a better understanding of where the use of other species as nurse crops is appropriate;
- A clearer understanding from the meeting of how to move BIG forward.

The knowledge and experience gained from the pre-conference tour, the workshop and the field day will stimulate discussion and provide new ideas for all involved. I am sure that by the end of proceedings many of you will be able to say for their blackwood management, 'Yes I did learn from New Zealand'.

I thank you for the invitation to open this workshop and have pleasure in declaring it open.

2

Blackwood in New Zealand: An Overview

Ian Nicholas

Forest Research, Rotorua

Blackwood is well established as a plantation species in New Zealand. It has been planted as large-scale forests in a few areas, but is more commonly seen as small woodlots on farms. A total of about 3000 ha have been established, with mostly in the 1980s. Experience and research with the species have developed an awareness of the silviculture required to produce acceptable sawlogs, but there are still many questions to be answered on the best genetic material to use. A blackwood growers group (AMIGO) and Forest Research, with Ministry of Agriculture and Forestry (MAF) Sustainable Farming Fund support, have produced a grower's handbook to summarise current information.

Material grown in New Zealand is now being processed; it is developing a strong but small market niche, but problems with supply will limit the use of blackwood in the short term.

Introduction

This workshop is titled 'Blackwood Management Learning from New Zealand'

Why are we having an international workshop on an Australian species in New Zealand?

New Zealand is not the only country growing blackwood as a plantation species: South Africa, India, Sri Lanka, Chile, Hawaii and China have all experimented with plantation blackwood with varying success.

This combined meeting between the New Zealand *Acacia melanoxylon* Interest Group Organisation (AMIGO) and the Australian Blackwood Industry Group (BIG) is an excellent opportunity to learn from each other. I believe New Zealand blackwood growers can contribute to international blackwood knowledge because we have developed some unique methods to grow blackwood in our environment. This is a different environment from many countries, especially with regard to climate and insect attack. The relatively young soils with reasonable fertility and the New Zealand psyche of plantation silvicultural techniques also provide a unique environment for growing blackwood.

Early plantations

Blackwood has been on the forest scene in New Zealand for a very long time. It was first planted in

Taita in the Lower Hutt in 1896, but the first plantation was 29 ha planted in Whakarewarewa Forest in 1906.

The next plantation activity was small-scale planting by the New Zealand Forest Service (NZFS), possibly generated by encouraging comments from two of New Zealand's most influential forestry people, Harry Bunn and Neil Barr. Harry visited South Africa in 1959 and brought back ideas on enrichment planting, culminating in research trials with blackwood and other species in Mamaku (Rotorua) and Te Wera (Taranaki) Forests, while Neil Barr visited Australia and through his writing in the NZ Farmer extolled the virtues of blackwood, amongst many other species.

One of the first forestry organizations to plant blackwood was the Auckland Regional Authority under the guidance of Ian Barton, who established about 60 ha from 1960 to 1980.

Evaluation

The NZFS symposium on 'The Role of Exotic Genera other than *Pinus* in New Zealand Forestry' in 1968 provided some encouraging comments on blackwood, but little planting eventuated. Weston (1957) also commented positively, but considered that it was 'A minor species, grown at close spacing on suitable sites and given adequate silvicultural treatment, good strains of blackwood could yield a valuable decorative cabinet and furniture timber.'

The next major thrust was a combined project with NZFS and Forest Research on the potential of blackwood. A field survey in 1978 evaluated site and soil conditions as well as blackwood growth at 69 locations in the North Island. This work showed that shelter and growing conditions (mixtures, plantations, etc.) have the greatest influence on growth and form of blackwood (FRI 1978). A later survey of South Island stands reached a similar conclusion (B. Cosslett, *pers. comm.* 1985).

NZFS workshop and policy

In 1979 a New Zealand Forest Service (NZFS) workshop brought together forest managers, timber utilisation officers, forest policy analysts, forest researchers, farm foresters and furniture manufacturers to evaluate the role of 'exotic minor species'. The purpose was to develop a policy on the potential of such species and their future role in the New Zealand forestry sector (Purey Cust 1979).

Species not considered in the workshop were radiata pine (*Pinus radiata*), Douglas-fir (*Pseudotsuga menziesii*), and indigenous species. This was because the former two exotic species were considered to be part of the existing resource base and were adequately catered for in NZFS management plans, and the latter because there was an indigenous management policy in place at that time.

The workshop covered three main topics:

- Current and projected domestic consumption of indigenous and imported timbers used for specialist end uses.
- Current resource and management of 'exotic minor species' in state and private ownership.
- Current research information on utilisation and management of potentially useful species.

A key to the success of the workshop was a definition of timbers from special-purpose species coined by Kininmonth and Hellawell (1979) who stated that: **'special purpose timber is one suitable for any purpose where radiata pine is not entirely satisfactory'**. This definition focussed the workshop and set the boundaries for constructive discussion.

Kininmonth and Hellawell also strongly suggested that any species list developed should be short and based on specific wood properties. These were important concepts because earlier papers from forest managers had described a multi-species resource scattered throughout the country, generally of poor quality, and usually with no official status or interest from managers or timber processors. It was also considered that, because of the natural

independence and enthusiasm of forest managers, the plethora of species was likely to continue unless lessons were learnt from the past.

From the information presented, and based on conclusions from the steering committees, a policy on Exotic Special Purpose Species was developed by the NZFS (NZFS 1981).

It recognised the need to establish a resource of high-quality furniture timbers and suggested a combined annual planting target of 2100 ha of special-purpose species in state forests.

The special-purpose species list and their potential uses included in the 1981 policy are given in Table 1.

Table 1. Species and end uses in the NZFS 1981 policy

Species	Uses
<i>Acacia melanoxylon</i>	Furniture and cabinet work, turnery
<i>Cupressus macrocarpa</i>	Exterior joinery, boat building
<i>Eucalyptus botryoidea</i>	Furniture and cabinet work, handles, cross arms
<i>E. delegatensis</i>	Turnery and veneers
<i>E. fastigata</i>	Furniture and cabinet work, turnery, handles and veneers
<i>E. regnans</i>	Furniture and cabinet work
<i>E. saligna</i>	Furniture and cabinet work, turnery, handles and veneers
<i>Juglans nigra</i>	Furniture and cabinet work, turnery, and veneers

The 1981 policy saw more blackwood planted by the NZFS and by farm foresters as experience and confidence in the species grew (Nicholas 1979, 1981, 1983, 1988). In the 1980s most of the blackwood was planted on the West Coast of the South Island, where about 1500 ha have been established, but in the 1990s most of the planting has been by farm foresters. About 3000 ha have been established in New Zealand, with most plantings in the last fifteen years (Fig. 1). This estimate is based on state forest data updated to 1989 (Nicholas, unpublished data) while data for the 1990s is estimated from nursery sales from 30 of the main forest nurseries (and therefore may be optimistic for the areas actually established). Currently, farm foresters are continuing with small-scale plantings.

Genetics

In 1984 a series of blackwood genetic trials were established on 10 sites. These evaluated 29 seedlots: 6 provenances from Tasmania, 2 from Victoria and

1 from New South Wales, as well as seedlots from exotic plantations: 14 from South Africa, 5 from New Zealand and 1 from Chile.

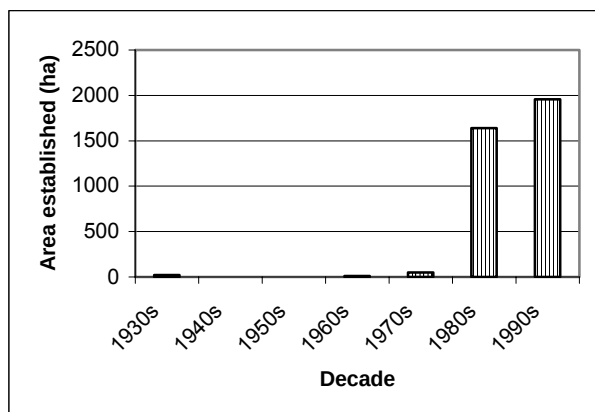


Figure 1. Area of blackwood established in New Zealand, by decades

The results from an evaluation of three North Island sites in 1992 at age 8 y showed that Victorian and Tasmanian (Smithton) provenances and a New Zealand (Waipoua) seedlot had the best growth and form of the seedlots tested.

South African seedlots had on average performed poorly, with only a few seedlots proving superior (Stehbens 1992).

Recent measurement of one of the trials (Whakarewarewa) in 2002 at age 18 y indicated that a Victorian, a Tasmanian (Smithton) provenance, a New Zealand (Waipoua) and a South African seedlot were the better performers.

A new progeny trial testing 78 seedlots is being established in the summer of 2002/2003.

Commercial clones have been released (Cornell 1986), but have yet to develop consistent production capability.

Sample plots

A large number of Permanent Sample Plots (300) have been established, most in the North Island. These have provided data for assessing growth and yields across a wide range of sites.

Regime trial series

In 1987 Forest Research established regime trials on five sites in the North Island and one in the South Island. Although the later was abandoned because of survival and growth variation, the other sites are providing an excellent data source for regime evaluation and they have provided important results on pruning and timing of thinning.

AMIGO

In 1989 a NZ Farm Forestry Association action group based on *Acacia melanoxylon* was set up: AMIGO (*Acacia melanoxylon* Interest Group Organisation). This group of over 200 people holds annual field days and produces at least two newsletters annually. It has also recently produced a growers handbook.

Form pruning

Forest Research and Ian Brown, a noted blackwood farm forester, both independently evolved blackwood pruning techniques to successfully produce butt logs in single-species plantations (Nicholas *et al.* 1994a; Brown 1997).

Utilisation

New Zealand plantation-grown blackwood has wood properties similar to those of Australian material, with the same issues of density and colour variation (Haslett 1986; Nicholas *et al.* 1994b). John Mortimer and Eric Williams, of Hamilton, pioneered blackwood utilisation, setting up markets and creating a supply framework that has seen at least two manufacturers developing specific blackwood lines, largely because a constant supply of material was available. The new owners of their operation will have a challenge in servicing these markets.

Growth model

The culmination of measuring sample plots and the collection of data from the regime trials is a database with 1722 measurements from 229 plots, suitable for the development of growth models. A preliminary growth model has been developed, allowing the evaluation of alternative regimes.

Handbook

With support from the MAF Sustainable Farming Fund, AMIGO in association with Forest Research has recently published a blackwood handbook which provides basic information for blackwood growers and processors.

Yields

If one assumes New Zealand has 3000 ha of blackwood on a 35-year rotation yielding 300 m³ ha⁻¹ over the rotation, and assumes replanting, the country has a sustained yield supply of nearly 26 000 m³ y⁻¹. The resource however has a major age imbalance, most being established in the 1980s. This feature will require that a coordinated approach be adopted to ensure that a strong and consistent market is developed over time. With half of the New Zealand resource currently in one ownership, such a coordinated approach is even more vital.

Economics

Early economic evaluations showed a positive return with IRRs of 5-8% (Herbert, 1994; Cavanna and Glass 1995). Recent assessments, using current prices in New Zealand, indicate IRRs of 10% are possible (Nicholas and Brown 2002).

New Zealand issues

The issues with growing blackwood in New Zealand are:

- The lack of a mature resource to satisfy current demand.
- The ease and cost of silviculture at the forest level. Most blackwood plantings the ownership of which changed from NZFS to large-scale forestry companies have received minimal silvicultural treatment.
- A lack of interest in high-quality hardwoods from the pine-dominated forest industry, fuelled by the perception of costly silviculture for a low-yielding hardwood, has resulted in little planting of blackwood for at least a decade.

In the meantime, small-scale planting by farm foresters has seen the emergence of blackwood as a regular species choice on farms, and farm foresters have often applied labour-intensive silviculture to generate good butt logs. These plantings, which tend to be relatively well managed, will provide quality logs in the future.

Thus in the future the blackwood market will have a dichotomy of logs, ranging from small-piece-size, low quality material to larger well-pruned butt logs.

- Issues of markets and clonal performance have yet to be addressed.

- Health is also an issue, particularly potential insect problems from Australia, and the random deaths in plantations.

Conclusion

In the 1978 North Island survey, evaluations were possible on only 69 locations, but if a similar survey was to be undertaken now, 24 y later, with over 200 sample plots, a similar number of new locations would be available for assessment. This indicates that over this period blackwood has gone from a relatively unknown species for plantation forestry to one that can be planted with some confidence. In the current industrial forestry scene in New Zealand, with a myopic focus on one species, blackwood is likely to remain, at the national level, a small-time player. In contrast, in the farm forestry scene, it has real advantages and should remain an integral part of that scene for many years.

The result of these activities in understanding the management of blackwood as a plantation species means that New Zealand can give some guidance to overseas forestry people in growing blackwood. Certainly some of our conditions are different, but many aspects like stocking and thinning are constant whatever the country.

I hope that the information gathered from the workshop and field visits will provide everybody involved with a new learning experience. The challenge will be to use the information presented in the workshop and field trips to everyone's advantage and to develop a strong and focused blackwood industry.

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3

Forest-scale Blackwood Plantations: The New Zealand Experience

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Blackwood has been established as large-scale forestry in Hunua forest near Auckland and on the west coast of the South Island. In Hunua forest a regular planting program by forester-in-charge Ian Barton saw a total of about 70 ha established, commencing in the 1960s. These plantings were supported by establishment and silvicultural trials that demonstrated the potential of the species to be grown as a plantation. Changes in ownership have seen less commitment to blackwood, but with a maturing resource the next challenge will be its successful marketing.

Timberlands West Coast Ltd manages about 1600 ha of blackwood. The resource was established mostly in the 1980s as a government initiative to compensate for transferring native forest areas into a World Heritage Park. Extremely variable soil and topography has resulted in a resource mixed in growth rate and quality, but with improved health in the stands new plantings have shown that site selection is of paramount importance. Concern regarding the regeneration of blackwood into native forest areas has not been supported by the results of studies. Utilisation studies have shown that the resource will match planting objectives by providing a high-quality timber product.

With almost half of New Zealand's blackwood resource in one ownership, the successful marketing of the Timberland's estate will be vital to the New Zealand blackwood industry.

Introduction

Acacia species have a long history in New Zealand. *Acacia* fossil records indicate they were well established in New Zealand, but were wiped out during the Ice Age (one million years ago). *Eucalyptus* and *Casuarina* species had a similar history (Stevens 1980). Blackwood was first planted at Taita in the Hutt Valley in the North Island in 1896. The first major plantation was established in the Whakarewarewa Forest (Rotorua) in 1906, but this stand of 29 ha received no tending. At age 96 y trees have been measured with heights of nearly 45 m and diameters over 1 m, but these are exceptions rather than the norm.

For the next fifty years there was little interest in blackwood. Most plantings from the 1960s on were small in scale, and blackwood developed a reputation for being very difficult to grow for sawlogs. Many people considered it could be

managed only in an enrichment situation to produce good form, or that it involved so much leader correction that it was

suitable only for farm forestry on a small scale. Reviewers of specialty timber species supported the role of blackwood in the specialty timber species list (Burdon and Miller 1995).

Although blackwood was established in many forests in both islands by the New Zealand Forest Service (NZFS), the changes in forest ownership since 1987 and the scattered small resource has seen no forestry expertise with the species develop from these plantings.

The objective of this paper is to document the development of the two main blackwood resources established in New Zealand, namely Hunua forest, local-body-owned, near Auckland, and the state-owned exotic forests of South Westland in the South Island.

Hunua Forest

Hunua forest (2469 ha) has a prime function as a water catchment for Auckland city. It is located in the Hunua ranges south-east of Auckland and close to the city. The ranges rise up to about 500 m asl and have mainly clay or clay loam soils. A large portion of the ranges is still covered in regenerating logged indigenous forest. From 1880, however, efforts had been made to farm about 6500 ha, but poor access and the depression of the 1930s saw some farmers walk off the land. These and the other remaining farms were progressively purchased for water catchment purposes prior to 1960.

In 1961 Ian Barton was appointed by the Auckland Regional Authority (ARA) as forester-in-charge of Hunua forest. At the time there was a feeling that radiata pine was not the best species for afforestation in water catchments because of its perceived high water use.

Consequently other species were trialled, including blackwood, the growth of which showed promise. Two small areas (each less than 1 ha) planted in the mid-1960s proved to be the first successfully managed blackwood plantations in New Zealand.

Following these successes, small areas were planted on a regular basis, generally on good sheltered sites. For the next 30 y, establishment continued with planting from 2-10 ha most years, reaching a peak in the early 1980s when in 1982 and 1984 close to 10 ha was established in each year. There were, of course, some failures mixed in amongst the successes. The total blackwood area in Hunua forest is about 70 ha.

Ian Barton's tenure from 1961-1986 is notable for the numerous trials he established. These included establishment, fertiliser, pruning, thinning, stocking and enrichment trials in cut-over indigenous forest. These trials substantially increased knowledge of the species (Messina and Barton 1985). Forest Research staff were involved in several of these trials, and following Ian's departure Forest Research staff have continued to collect considerable data from the best of his long-term trials.

Silviculture

An area of 3.5 ha of regenerating native forest was underplanted with a number of exotic species including blackwood (0.6 ha) and some native species. The blackwood was the most successful in this experiment. In another trial about 0.8 ha was underplanted beneath *Eucalyptus saligna*, but the eucalypt failed.

Most if not all stands planted have had some lift pruning to 4 m, while at least two areas had variable pruning to 6 m.

Thinning has also been variable, some being late (age 20 y), but more recently stands have been thinned at age 10 y and one even at 6 y. Apart from experimental thinning trials, stocking has ranged from 260 stems ha⁻¹ in the late-thinned stands to between 400 and 500 stems ha⁻¹ in the more recent 1980s plantings. These later plantings were probably intended to receive a further thinning, but due to management changes this has not occurred.

From 1986 to the early 1990s the late Andrew Dakin was forester in charge of ARA, and blackwood management continued along the path planned by his predecessor. Andrew was successful in the marketing of some 22-y-old thinnings by achieving prices of \$600 m⁻³ for timber cut on a portable sawmill in 1992.

In 1987 Forest Research established a regime trial on a hard site, providing a valuable contrast to stands on better sites treated in the same way.

In 1988 a plus-tree survey was undertaken; 55 trees were selected and root cuttings collected, about half of which were successfully propagated. These and other rooted cuttings were established in a potential seed orchard on private property just north of Auckland.

Forest management changes occurred within the Auckland Regional Council: Northern Forests took over the management of the forestry assets in a caretaker role, apparently concentrating on pine silviculture and discontinuing blackwood establishment and silviculture.

In 1998 management and cutting rights were purchased by a private company, Waytemore Forests Ltd, which is most interested in the major resource, pine. Logging and establishment priorities have kept the company fully occupied and little attention has been given to the small blocks of blackwood. In addition, the logging operation is not appropriate for the relatively small areas of blackwood. There has been some interest from a prospective blackwood buyer, but the price offered was not sufficiently high to recover the cost of relocating a logging gang for the one or two day's work required to harvest the small quantity of blackwood logs sought. In this situation these small blocks, often with short, small-diameter logs, may be viewed as a nuisance which complicates management.

Waytemore Forest staff, however, have been impressed with the regeneration from a block of 1 ha that was logged about 10 y ago. Here the

regeneration (seed and no doubt suckers) has been very dense and the boles of the current pole stand are virtually clean to a minimum height of 8 m, and some thinning is planned.

Apart from a dedicated start to blackwood afforestation, there has been little activity for the last decade. The next major activity will be marketing of logs. This will determine the success of blackwood in Hunua forest.

South Westland

In Central and Northern Westland (West Coast of the South Island) small trials of many exotic species including blackwood were planted by the New Zealand Forest Service in the 1960s.

Afforestation in Westland covers a myriad of soils, ranging from alluvial terraces to coarse gravels and pakahi soils, many of which have impeded drainage. Most of the variation is a consequence of previous glacial activity. The altitude of forest plantings ranges from 50 to 300 m asl.

The first small trials of blackwood in South Westland, established in 1978 by Ian James (at the time a Forest Research native ecology scientist), were in a hand-cut lane planting in regenerating scrub in Wanganui Forest and in a tractor-cleared lane in Ianthe Forest in 1979. Both plantings grew well with good form. In 1981, on the strength of these small 2-y-old trials, blackwood was identified as the species most likely to yield an economic return on such sites. Further development of a NZFS policy on special-purpose species (NZFS 1981) provided some confidence with this approach, and the NZFS started planting up to 5 ha y⁻¹, nearly all of which was in small research blocks, to evaluate fertiliser and establishment techniques.

About the same time the government of the day added two large blocks of virgin native forest in South Westland to the Westland National Park. To compensate for these land transactions, the government initiated a project to establish an estate of up to 10 000 ha with Special Purpose Species which included blackwood, to create employment and future forestry options.

The potential of blackwood for the coast was also recognised by the late Curt Gleason, who favourably reviewed its world performance (Gleason 1986).

With the demise of the NZFS in 1987, the New Zealand Forestry Corporation continued planting blackwood at a rate of 150 ha y⁻¹, with Treasury covering the establishment costs. This arrangement lasted for only about three years as the New Zealand Forestry Corporation was in turn succeeded by Timberlands West Coast Ltd (a state-owned

enterprise created in 1990). In 1990, however, the government provided compensation to Timberlands West Coast Ltd in recognition of its commercial focus. This support consisted of \$6 million as a suspensory loan for the continuation of the special-purpose species estate in areas of cut-over forest, particularly in South Westland. Although problems of poor form and defoliation caused by psyllids and leaf miners resulted in a change in emphasis from blackwood to cypresses (mostly *Cupressus lusitanica*), Timberlands did support a comprehensive study of insect attack on blackwood (Appleton 1999).

Blackwood establishment continued under Timberlands West Coast Ltd, but at a much lower rate 3-5 ha y⁻¹, with much more care being taken to select the best sites for the species. From 1993-1994 to the present there has been increased planting of *C. lusitanica* at the rate of about 150 ha y⁻¹, and blackwood establishment has been on the back burner. Now that a parasite is reducing the numbers of blackwood leafminers, however, the situation looks more favourable, and the rate of establishment may increase, perhaps up to 10 ha y⁻¹.

The managers have learnt that site quality governs establishment success and that site variability has a greater influence than silviculture. The key is to confine blackwood to the best sites, and consequently the species will be only a small component of the annual planting program.

Silvicultural treatment has been intermittent and confined to good sites where growth justifies the investment.

There has been some concern that blackwood might invade Westland's native forest adjoining the estate. To investigate the weed potential of blackwood in the Timberland estate, in 2001 a field study was conducted in stands ranging from 34 to 17 y old. There was no evidence that blackwood will invade native vegetation and become a threat to the native ecosystems of Westland (Nicholas 2001a). Where blackwood regeneration was occurring in stands, the active native vegetation was out-competing the young blackwood regeneration.

A wider review and study of North Island sites recognised that existing planted areas are likely to remain as blackwood areas, especially if soil disturbance occurs during logging, although at this point in the forest management cycle control or management options can be undertaken if desired (Nicholas 2001b).

To determine the utilisation potential of their plantation blackwood, Timberlands undertook a pilot study of a sample of trees in 1999.

Five 32-y-old trees, and a 19- and a 20-y-old tree were extracted by helicopter from two forests for evaluation. The heartwood content of the 32-y-old trees was high (70-90%) but in the younger trees it was much lower (20-30%). The importance of age, site or genetics on this incidence is unknown.

The seven trees with an average SED of 280 mm yielded 12 sawlogs and one veneer log. Tension in logs from two trees caused some sawing problems, and a multi-saw edger had some difficulty because of the hardness of the wood. One log had significant decay from a dead branch. The recovery of sawn volume was 50%. Grade recovery was excellent, with 64% being dressing, 31% select appearance and 5% standard (beech grading rules). The main defect reducing dressing grade recovery was large knots, and the prominent defect in the poorest grade was decayed knots. Veneer was cut from one log length after the log was soaked in hot water at 75°C for two days, but this appeared insufficient to adequately soften the wood as during slicing some difficulty was experienced with knots. The veneer dried well, however, producing flat and attractive sheets.

The timber machined well and was considered very suitable for furniture and joinery applications (S. Boon, *pers. comm.*).

Westland has the largest single plantation area of blackwood in Australasia, about 1600 ha (Solari 1994), but management of the resource has been mixed. The various managing organisations have attempted to juggle social forestry and investment objectives while keeping on top of blackwood's silvicultural requirements. This and the huge variation in site topography and characteristics have resulted in a variable crop. The Westland resource, nevertheless, has the potential to dictate the role of blackwood in New Zealand.

Conclusion

New Zealand forest owners have established plantations of blackwood. Most have managed them on a principle similar to that used for pine, with as few silvicultural interventions as possible. This approach and the difficulties with form control, as well as significant internal changes to company structures, have seen little long-term commitment to blackwood forestry. The exception is Timberlands, for whom siting and availability of skilled labour have been key constraints to optimum management.

Many people have contributed to our knowledge of the species when grown in plantations. The early trials established by Ian Barton (Hunua) and Ian James (Westland), to name just two people, were pioneer efforts that have enabled researchers,

managers and growers, particularly members of the NZ Farm Forestry Association with access to better land, to successfully establish larger blocks (10-15 ha) of fast-growing blackwood. Because the NZ forest industry has been so accustomed to establishing and managing pine monocultures over large areas, blackwood has provided an ongoing learning experience for everyone involved. There is undoubtedly still much to learn, but what is exciting is the growing awareness of the potential value of blackwood to both growers and the New Zealand furniture industry. And then of course there is always the export potential, but we have to first establish a substantial resource in New Zealand.

The two examples of forest-scale plantations discussed in this paper highlight the need for consistent and committed management to create a valuable resource of blackwood. Both plantations represent a successfully-established resource of varying quality; the next challenge will be to market their blackwood in an efficient and effective manner.

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4

Managing Blackwood in Native Forests in Tasmania

Sue M. Jennings

Forestry Tasmania

Tasmania's blackwood timber industry is based in the far north-west of the State. The 8500 m³ of blackwood sawlog volume targeted annually from public land is produced mainly from the blackwood swamps and as 'arisings' from harvesting of wet eucalypt forests, with a much smaller volume produced from riverine rainforests. Regeneration systems are available for these three vegetation types, which rely on germination of ground-stored blackwood seed, protection from browsing, and side-shading of lower branches by native shrubby vegetation to produce good form. Fencing is the most effective method of browsing control but is expensive, ranging from \$350 to \$800 ha⁻¹. Economic analysis of fencing costs has shown that at its best, blackwood fencing only achieves a 5% return. This will never compete with short-rotation plantations, but is a higher return than other long-rotation native forest systems. The traditional supply of blackwood from the swamps will continue through their sustainable management on rotations of about 70 y. Increasing the future blackwood resource by fencing eucalypt coupes increases the flexibility in both the sustained yield cut and wet-weather harvesting.

Introduction

Blackwood (*Acacia melanoxylon* R. Br.) is widespread across southern and eastern Australia and Tasmania. It occurs at altitudes from sea level to 1500 m in northern NSW and 1000 m in central Tasmania. Blackwood is a hardy tree, but is most common in cool humid areas of low frost intensity. In Tasmania; although widespread, blackwood reaches its best development in the lowland wet forests in the far north-west of the State.

Blackwood has a wide ecological range and is commonly found as an understorey tree in wet eucalypt forests, as a co-dominant tree in riverine rainforest and as the dominant tree in blackwood/teatree swamps. These forest types are described in Jennings (1998). Blackwood has a higher tolerance of saturated soil conditions than most eucalypt or rainforest canopy species and therefore tends to become a significant component of stands in swampy or seasonally flooded sites. A substantial area of blackwood is reserved with 24% of mapped blackwood forest, 27% of wet eucalypt forest and 64% of lowland rainforest included in the reserve system (RPDC 2002).

Blackwood has a long history of use for shingles, palings, barrel staves, sawn boards and veneers. The different forest types have different harvesting constraints and different regeneration systems. They produce different quantities and quality of blackwood sawlog. Managing blackwood in native forests in Tasmania involves predominantly swamp

and eucalypt understorey blackwood in the north-west of the State.

Blackwood timber production

Tasmania's blackwood timber production has been based in the north-west of the State for more than a century. This is still the case, with about 70% of the State's blackwood produced from public land over the last five years coming from Murchison Forest District, which covers the north-western corner of Tasmania. Figure 1 shows the statewide blackwood sawlog volume for all products over the last five years by Forest District.

The statewide blackwood sawlog sustainable yield is currently set at 6500 m³ y⁻¹ of Category 4 (high quality) sawlog and 2000 m³ y⁻¹ of Utility grade (lower quality) sawlog for swamp forests and arisings from the wet eucalypt forests (Mesibov 2001).

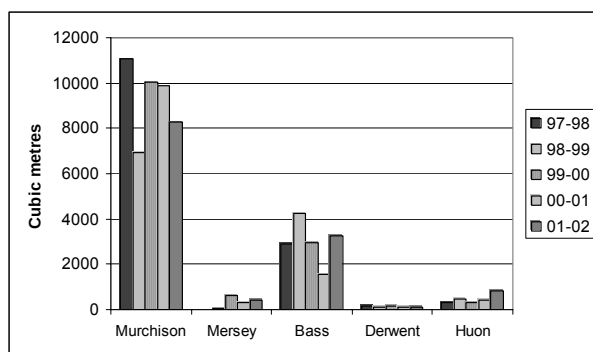


Figure 1. Statewide blackwood cut over five years by Forest District

Although the cut varies from year to year it has averaged approximately 6300 m³ Category 4 sawlog and 2900 m³ Utility log y⁻¹ over the last five years (based on the product percentages from Murchison District). Some blackwood (Out-spec) is also cut from logs which do not meet the minimum sawlog specifications. Current blackwood sawlog specifications are included in Appendix 1.

In Murchison District, the volume of sawlog products can be traced back to the forest type from which they were cut. Figure 2 shows the volumes of blackwood sawlog that were produced from harvesting the blackwood swamps, as 'arisings' from clearfelling of wet eucalypt forests and from riverine rainforests over the past five years.

The proportion of the annual sawlog volume produced from the swamps is highly variable. This is a result of the weather (especially variation in summer rainfall), the market for blackwood and, most importantly, the amount of blackwood sawlog currently being produced as arisings from other forest types. A 5650 ha area of blackwood swamps is being managed to produce a sustainable supply of sawlogs over a 70-y rotation (Mesibov 2001), although swamp coupes are not necessarily harvested every year.

The arisings are dependent on the area of wet eucalypt forest currently being harvested and regenerated or converted to plantation. The current blackwood sawlog production from arisings is not sustainable, as there is no provision for an ongoing blackwood cut from the plantation conversion areas, and Jennings and Dawson (1998) showed that the current regeneration system used for most wet eucalypt forests produces only low densities of understorey blackwood. As the blackwood from arisings decreases, more blackwood will be targeted from the swamps. Additional volume will become available from existing and new blackwood plantations, and from specially managed eucalypt regeneration areas when they come on line.

The swamps tend to produce a greater quantity per hectare, of higher quality blackwood than the wet eucalypt forests. Figure 3 shows the volume of each of the blackwood products produced from the different forest types in Murchison District.

During the five-year period from 1998 to 2002, 12 swamp coupes were harvested and almost 60% of the sawlog produced was Category 4. An almost identical volume of Category 4 sawlog was produced from 104 wet eucalypt coupes, but this comprised only 40% of the volume cut from that forest type. The single riverine coupe produced product proportions similar to the swamp coupes. An average of eight of the swamp coupes showed a blackwood sawlog volume per hectare of 96 m³ (range 32 – 146 m³ ha⁻¹), while a sample of 32 of the wet eucalypt coupes averaged 5 m³ ha⁻¹ of blackwood sawlog (range 1-17 m³ ha⁻¹).

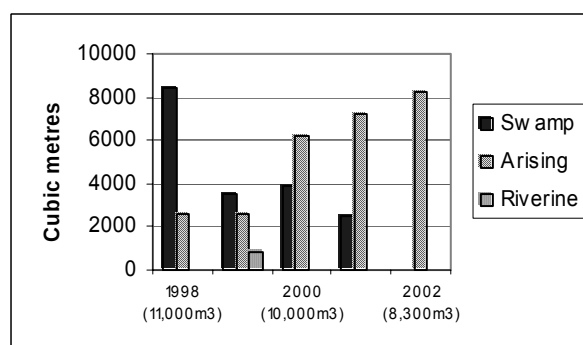


Figure 2. Murchison blackwood sawlog volume by forest type

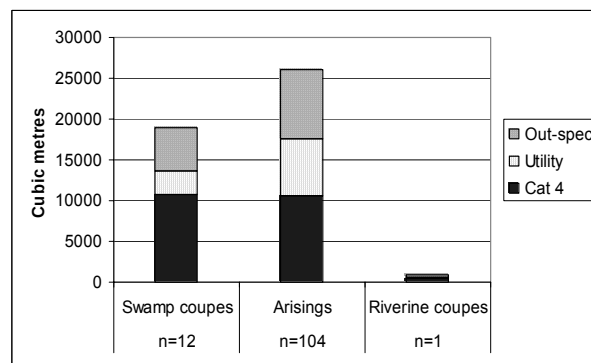


Figure 3. Volume of sawlog products cut from each forest type

Regeneration systems

Blackwood germinates profusely from ground-stored seed after fire or disturbance but is heavily browsed by native mammals (Jennings 1998). The key to blackwood regeneration is to make use of the ground-stored seed resource and provide effective browsing control. Regeneration systems have been developed for the different forest types, which

satisfy these criteria and can be carried out operationally.

Blackwood swamps

Harvesting of blackwood swamps results in varying levels of disturbance depending on the volume of blackwood within the stand. In very productive areas it approaches a clearfell operation as all blackwood sawlog is removed. In less productive areas it is more like a selective logging system as other species (often rainforest trees in the older successional stages of swamp development) remain standing after harvesting. Swamp harvesting can be carried out for only a few months in summer.

Early swamp regeneration systems made use of fire to germinate the blackwood seed and fencing to exclude browsing. The regeneration process dramatically changed these areas, with little concession to structural diversity or biodiversity. Fencing in the swamp environment using bulldozers for site preparation and agricultural equipment for fence construction also changed the natural drainage channels and resulted in local flooding and water retention in some areas. Regeneration was not successful where drainage was badly impeded.

After an ecological study of the swamps (Pannell 1992; Duncan *et al.* 1994) the swamp regeneration system was changed and fire and fencing were removed from the prescription. Trees of other species that were not harvested were retained for biodiversity. Unburnt swamp coupes (even if clearfelled) are believed to retain greater biodiversity than burnt ones due to the continued presence of some of the rainforest elements (Duncan *et al.* 1994). An assessment of the success of various regeneration treatments previously trialled (Jennings *et al.* 2000) showed that harvesting disturbance was adequate to stimulate germination in the absence of fire but that alternatives to fencing, such as poisoning of the browsing mammals with 1080 (sodium monofluoroacetate) poison, were not effective.

Fencing returned as a browsing control method in 1998 but the construction methods were low-impact. Excavators were used to clear and prepare the fenceline and drive in the posts while all other tasks used only 4wd motorbikes. This increased the window of opportunity for swamp fencing and reduced the disruption to drainage patterns.

The disturbance in these coupes is produced entirely by the mechanical harvesting techniques and it is only in these disturbed areas that blackwood regeneration can be expected. This presents a problem in areas of patchy blackwood distribution. Scrubrolling is a useful method of maximising

regeneration in understocked patches within or adjacent to areas of commercial blackwood harvesting. It can also be used to square-up the boundaries of coupes to increase their suitability for fencing.

The cost of blackwood regeneration treatments in the swamps varies widely, depending on the size and shape of the coupe and the level of blackwood stocking before harvest. Fencing is an expensive treatment and has a requirement for reasonably straight boundaries. The economics of fencing are also very sensitive to the area/perimeter ratio (Jennings and Dawson 1998). Some indicative costs for regeneration treatments derived from five swamp coupes fenced in Murchison District are shown in Table 1.

The economics of scrubrolling additional understocked patches within or adjacent to commercially-harvested swamp areas were examined by Jennings and Dawson (2000). The options were labelled 'log and leave', 'best-patch fencing' and 'maximum-area fencing'. These are diagrammatically portrayed in Figure 4.

Table 1. Indicative costs from swamp coupes fenced in 2001-2002

Element	Cost	
	(\$ km ⁻¹)	(\$ ha ⁻¹)*
Scrub rolling	-	100
Fenceline	1630	170
Materials	2450	260
Construction	2370	250
Total for regeneration	6450	780

*Average coupe size - 18 ha



Figure 4. a. Log and leave; b. Best-patch fencing; c. Maximum-area fencing

- 'Log and leave' involves the harvesting of all blackwood sawlog from within the harvest boundary but with no follow-up regeneration treatment.
- 'Best-patch fencing' involves rationalising a fence boundary from the area that has been harvested with no additional preparation work.

- ‘Maximum-area fencing’ involves additional scrubrolling and coupe preparation to achieve the maximum area of regeneration within the coupe boundary. This may mean fencing areas that were not originally harvested.

These scenarios were run for two real-life coupes from Murchison District where the area, perimeter and timber volumes were available. The results of the economic analysis were extremely sensitive to discount rates used and whether some additional volume could be salvaged up during the scrubrolling operation. At low rates of return (less than 3% p.a.), the additional benefits of future harvest revenues far exceed the costs of scrubrolling and fencing. ‘Maximum-area fencing’ is clearly the preferred option, and becomes even more attractive where additional volume can be salvaged.

At discount rates between 3% and 5%, the picture is less clear and coupes need to be evaluated on a case-by-case basis, examining the relationship between establishment costs and expected future revenues. Additional scrubrolling may be hard to justify and ‘best-patch’ fencing becomes the preferred option, unless sufficient extra volume can be salvaged to pay for the scrubrolling.

At discount rates over 5%, future revenues are insignificant and on a purely commercial basis, fencing or scrubrolling would take place only where the additional revenue from the scrubrolled area is expected to be greater than the establishment costs. However, Forestry Tasmania is committed to regenerating native forests after harvesting, so the do-nothing approach of the ‘log and leave’ scenario (although attractive economically) is not a viable silvicultural option because of browsing. Similarly, scrubrolling should not be used without fencing as a treatment for blackwood regeneration, as most of the seedling regeneration will be browsed and despite the financial investment a future crop will not be established.

As blackwood swamps are not suitable for conversion to plantations of fast-growing tree species, their returns can be compared to standard unfenced regeneration of native eucalypt forest. Blackwood swamp investment is equivalent to, or better than, long-rotation native forest, which generally gives internal rates of return of between 2% and 4% (Jennings and Dawson 2000).

On current blackwood swamp coupes, regeneration surveys are carried out to assess regeneration success at year five. The standards also include the necessity for woody vegetation to have colonised the site to ensure that there is lower branch suppression in the blackwoods.

Wet eucalypt forest

Most of the wet forest containing a significant blackwood understorey in Murchison District lies within an area that has been selectively cut-over for eucalypt sawlog since the turn of the century. Much of this area has subsequently been burnt by wildfires, resulting in a mosaic of cut-over oldgrowth and well-stocked regrowth with an understorey of well-formed blackwood.

The usual harvesting method for these areas is clearfelling and removal of all commercial eucalypt and understorey species followed by a hot slash burn and aerial sowing of eucalypt seed (Forestry Tasmania 1998). Blackwood germination is stimulated by both the mechanical disturbance and the fire. Selected coupes which are to be managed for blackwood production are fenced with wire netting to protect the blackwood seedlings from mammal browsing (Jennings and Dawson 1998).

A survey of eucalypt regeneration coupes (both fenced and unfenced) between four and eleven years old showed that blackwood stocking on fenced coupes averaged 2500 stems ha⁻¹ (range 600-4700 stems ha⁻¹). Unfenced coupes averaged 70 stems ha⁻¹, with a range of 20-100 stems ha⁻¹ (Jennings and Dawson 1998). Form of the young blackwoods in fenced areas was also very good with understorey species such as *Pomaderris apetala* producing dense side-shading and lower branch suppression.

Experience has shown that in the absence of any mammal browsing, the eucalypt establishment on these sites is very good and that satisfactory eucalypt densities and stockings can be achieved using about half of the usual eucalypt seed rate. Although these areas are being managed for maximum blackwood sawlog volume, eucalypt seed is still sown on the coupes as it helps to ensure that the whole coupe is commercially stocked despite patchy distribution of blackwood ground-stored seed.

The fences on the wet eucalypt coupes are generally cheaper to construct than swamp fences for several reasons:

- A firebreak is cleared around these coupes before the slash burn. At only slightly higher cost this can be prepared to fenceline standard.
- The eucalypt coupes are rarely inundated with water and a lighter (cheaper) gauge of wire netting can be used for fence construction.
- Standard agricultural machinery can be used during fence construction.

However, where machine access is not possible (steep gullies etc.) a hand-construction rate is paid and the cost of fence construction rises. Indicative

costs prepared from four coupes fenced in Murchison District in 2002 are shown in Table 2.

Table 2. Indicative costs for fencing wet eucalypt coupes

Element	Cost	
	(\$ km ⁻¹)	(\$ ha ⁻¹)*
Materials	1630	150
Construction	2770	250
Total	4400	395

* Average coupe size – 50 ha

These costs can be offset slightly by a reduction of about \$50 ha⁻¹ for eucalypt seed for fenced coupes.

An economic analysis of fencing costs by Jennings and Dawson (1998) showed that if you are committed to long-rotation eucalypt silviculture, fencing coupes for blackwood increases the profitability of these forests.

The financial success of blackwood fencing is due to two things:

- It is done opportunistically where the costs of eucalypt regeneration are already accepted and the only cost of this treatment is the cost of fencing, and
- It produces a high-value product, which attracts a higher stumpage than eucalypt sawlog.

However, many of these sites are suitable for plantation development. Even at its best, blackwood fencing achieves only a 5% return, whereas short-rotation eucalypt plantations usually achieve returns of between 5% and 12% depending on the crop and the regime (Jennings and Dawson 1998).

There are other long-term advantages to increasing the blackwood resource in eucalypt coupes which include increased flexibility in both the sustained yield cut and wet-weather harvesting.

Riverine rainforests

Blackwood occurs as a co-dominant species in the cool temperate rainforest along the banks of major rivers in Tasmania. These areas are disturbed by occasional flooding and have relatively high light intensity due to the open river corridor. Successful establishment of blackwood of good form requires 'light wells' which are gaps in the rainforest overstorey resulting from mortality, windthrow, flood damage or other disturbance. Light wells provide sufficient overhead light for growth while providing side shade for branch suppression. This blackwood forest type is multi-aged, resulting from many mini-disturbances rather than even-aged, resulting from major catastrophic disturbances.

Clearfelling is not recommended as a silvicultural system for riverine blackwood flats. It does not produce a suitable nurse crop as disturbance-stimulated sclerophyllous trees and shrubs are locally uncommon. There are other aesthetic, environmental and policy reasons for not clearfelling these areas of high visibility on the banks of major rivers. Instead, selective logging can be used to perpetuate the multi-aged blackwood forest. Ground-stored seed is available in the seedbed of river sand and silt, and the snig tracks and canopy gaps from the harvesting operation will provide light wells for blackwood establishment. However, myrtle (*Nothofagus cunninghamii*), the predominant tree species on the river flats, is susceptible to myrtle wilt caused by the fungus *Chalara australis* which enters through tree wounds often caused by logging or other disturbance (Packham 1991). Extensive death of the nurse trees can result from logging damage. Browsing control is a problem in these areas. Any fencing erected is at risk from windthrow of retained trees and from periodic flooding. Poisoning with 1080 is not effective as there is continual reinvasion by browsing species of the harvesting area, which retains adequate shelter and food to maintain a browsing population.

To minimise these problems, blackwood should be selectively logged down to a commercial sawlog limit (30-40 cm DBHob) with care taken not to damage the retained myrtle trees during logging. All advance growth should be retained for future sawlog. Seed should be collected from the felled blackwood heads during harvesting. A survey should be carried out two years after logging to establish the number of stems present. No further treatment is required where the residual stocking of blackwood advance growth with sawlog potential is 50-100 stems ha⁻¹. Where residual stocking is less than this, the area may be stocked with blackwood seedlings which germinated as a result of logging disturbance and survived browsing. If the area is understocked, it may be necessary to plant individually-caged seedlings in natural light wells. This should be done while access is still easy and before planting spots are colonised by weeds, sedges and ferns. Microsite requirements for blackwood seedlings are difficult to fulfil, with problems commonly resulting from too much or too little light. Enrichment planting is an expensive operation with low success rates when used on an operational scale.

Conclusion

The traditional source of blackwood supply from blackwood swamps will continue through their sustainable management on rotations of about 70 y.

The supply arising from clearfelling of wet eucalypt forests is expected to diminish, except where regeneration has been ensured by the additional fencing treatment. In fenced areas the rotations may be as short as 60 y if thinning is applied; otherwise rotations of 90 y are planned. Some blackwood will continue to be sourced from riverine rainforests although supplies will be irregular and confined to limited areas that occur outside riparian reserves. No set cutting cycle is defined for these areas.

These sources should be adequate to maintain the designated sustainable cut of 6500 m³ of high quality blackwood sawlog per annum. There is potential for this supply to be increased by the intensive management of fenced regeneration for blackwood sawlog production.

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Appendix 1.

Forestry Tasmania Special Species Timber Sawlog Category 4 (Cat 4) and Utility Log Specifications, June 2000

Specifications for silver wattle, blackwood, sassafras, celery top pine, leatherwood, tea-tree and other special species timbers.

Specification	CAT 4	UTILITY
Minimum length	3.1 m	2.5 m
Minimum small end diameter	30 cm	25 cm
Limbs and bumps ¹	3 of 4 faces clear (in 3.1 m lengths)	2 of 4 faces clear (in 2.5 m lengths)
Spiral	1 in 8	1 in 8
Sweep	1 in 7	1 in 7
Scars ²	¼ face - 3.1 m in 3.1 m	½ face - 2.5 m in 2.5 m
Borers ²	Nil evident	No significant evidence
End defect	End-diameter 30-40 cm ub minimum of 10 cm radial ring clear of heart and sap End-diameter > 40 cm ub as per Sawlog End Defect Limits Table	End-diameter < 30 cm ub - Nil. End-diameter 30-40 cm ub minimum of 10 cm radial ring clear of heart and sap. End-diameter > 40 cm ub as per Sawlog End Defect Limits Table

BLACKHEART (in sassafras)

To be classified Cat 4 or Utility sawlog, the blackheart **must be** visible in 1/3 of the radius in 3 of 4 quarters at **both ends** and extend from the core (pith) to beyond ½ of the radius at least twice at **one end**.

OUT-SPEC Special Species Timbers Logs

Minimum length of 2.1 m

Special Species Timber logs, which cannot meet the specification tables, may be classified as OUT-SPEC.

5

Forest-scale Blackwood Plantations: The Tasmania Experience

Libby Pinkard and Bill Neilsen

Forestry Tasmania

Introduction

Tasmania is the largest producer of blackwood timber, with production of around 7000 m³ y⁻¹ of sawlog-grade material. All of this currently is derived from native forest sources, and while it is anticipated that this will be the main source into the future, there has been an effort to establish blackwood in plantations in the two main blackwood nodes in Tasmania (far north west and south). To date about 900 ha have been established, and a further 250 ha will be planted over the next five years.

Producing quality blackwood timber in plantations is costly and labour intensive. It involves:

- Long rotations;
- High establishment and maintenance costs; and
- Generally no income throughout the rotation.

All of these make it an uncertain investment. In addition there has been no genetic improvement work done, and our understanding of the control of desirable characteristics such as dark colour and wavy grain is verging on non-existent.

Forestry Tasmania has undertaken research into the silviculture of blackwood plantations over the past 15 y. This paper presents some of the outcomes of that research, and discusses appropriate silviculture for large-scale plantations with consideration of operational and economic factors.

Growth rates

In order to improve the economics of growing blackwood in plantations, short rotations and hence fast growth rates are required. Forestry Tasmania has determined that rotation lengths of around 40 y, with production of about 300 m³ ha⁻¹ of sawlog (minimum small end diameter of 25-30 cm), are necessary to compete with production from managed native forest stands. It is uncertain whether

this can be achieved in large-scale plantations. In Tasmania blackwood plantations on good sites can grow at around 1 cm y⁻¹ (Fig. 1, Neilsen and Brown 1996), which is similar to values reported in New Zealand (Nicholas 1988) and South Africa (de Zwaan 1982). This suggests that 40-y rotations are optimistic.

Growth rates can be improved with appropriate siting of plantations and silviculture. Research has shown that blackwood performs best on sites with good soil fertility, and with well-drained soils at least 1 m deep. Protection from frosts and wind is important (Neilsen and Brown 1996).

Growth rates can be increased by treatments such as fertilising. For example, applying phosphorus at 68 kg ha⁻¹ increased height growth by 1.5 m in the three years following fertilising (Fig. 2). Applying phosphorus has been shown to improve root nodulation and root growth, and improve whole tree nutrition. On some sites there may also be a response to application of nitrogen, but these will often be sites with poor root nodulation.

Establishment

Blackwood has a high protein content in its foliage (de Zwaan 1982), which makes it very palatable to browsing animals such as rabbits, wallabies and pademelons. All are abundant in Tasmania, and browsing control is essential for successful blackwood plantation establishment. Where browsing animals have been identified as a problem, the site must be cleared of all debris that could harbour animals, and fenced with chickenwire. This type of fencing costs around \$250 - \$350 ha⁻¹, depending on the size of the plantation. Shooting and/or poisoning also may be required.

The alternative is individual tree guards. While these can significantly increase growth and survival in the first year by protecting from browsing and frost, they are considerably more expensive per tree

in large plantations than fencing (Neilsen and Brown 1996).

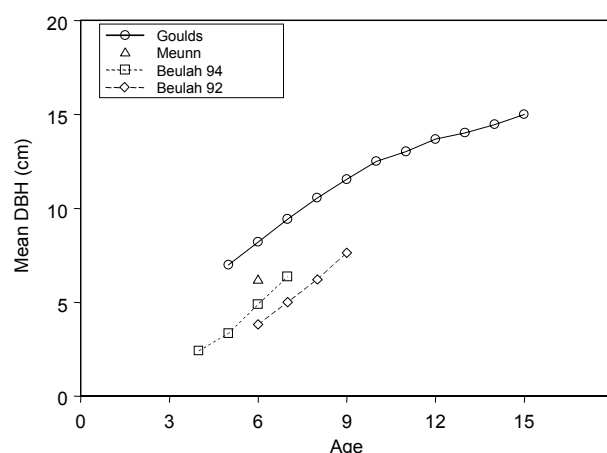


Figure 1. Mean DBH of blackwood growing at three sites in Tasmania

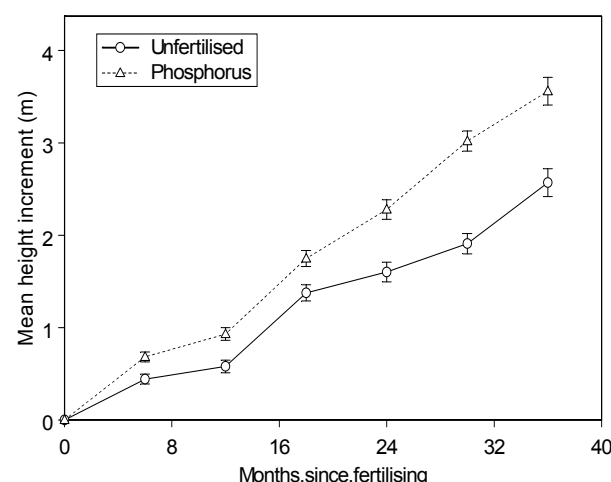


Figure 2. Effects of fertilising with phosphorus on mean height increment of blackwood

Attaining good stem form

In native forest, surrounding vegetation provides sidelight suppression and results in straight, tall trees with minimal branches on the lower bole (Unwin *et al.* 2000). In plantations this is not the case. Pure blackwood plantings can result in relatively short, very branchy trees unless regular form pruning events occur. Following research with both pure and mixed stands, Forestry Tasmania has opted for a combination of nurse crop and form pruning to achieve acceptable stem form. It is considered that this approach can reduce the number of operational interventions required to achieve good stem form, and can improve blackwood

survival (Table 1). Height growth also is improved in a nurse crop system (Table 1).

Table 1. Mean seedling survival and height after six years, of blackwood grown alone and with a nurse crop. Results are from Meunna, a very cold site in north-western Tasmania.

Nurse crop	Survival (%)	Mean height (m)
None	72	1.52
<i>Pinus radiata</i>	88	2.53
<i>Eucalyptus nitens</i>	88	2.85
<i>E. globulus</i>	86	2.23

The nurse crop species most commonly used in Tasmania are *Pinus radiata*, *Eucalyptus nitens* and *E. globulus*. Eucalypts are generally planted row-for-row with blackwood, while *P. radiata* is planted either row-for-row or in a 2:1 pine:blackwood system where the *P. radiata* is also managed for clearwood. In the row-for-row systems rows are spaced at 3 m with 800 stems ha⁻¹ of the nurse crop and 400 stems ha⁻¹ of blackwood. The final blackwood stocking is 200 stems ha⁻¹. In the 2:1 system, rows of *P. radiata* are 5 m apart and the blackwood is planted between every second pine row. Hence the blackwood is only 2.5 m from a pine row. The *P. radiata* and blackwood are planted at 800 and 500 stems ha⁻¹ respectively, with a final stocking of 200 and 250 stems ha⁻¹ of pruned trees for pine and blackwood respectively. The *P. radiata* clearwood is then harvested at around 25 y of age, providing some intra-rotation income. Research into appropriate initial and final stockings is ongoing (Neilsen and Brown 1996).

A number of problems with nurse crop systems have been encountered. Firstly, the row spacings mean that there is little early nursing of the blackwood, and consequently form problems may emerge early.

Closer row spacing, however, is not operationally feasible because it restricts access for maintenance and thinning operations. Secondly, it is easy to miss-time the removal or thinning of the nurse crop so that the blackwood becomes suppressed. This is a problem because eucalypts and *P. radiata* generally have much faster growth than blackwood (Fig. 3).

In addition, if the nurse crop becomes too large, it becomes virtually impossible to fell it without damaging the blackwood. While chemical stem injection can be used to overcome this problem with eucalypts, it has not proved successful with *P. radiata*. Thirdly, even when thinning is done at the appropriate time, it is relatively expensive.

There is evidence, however, that nurse crops do improve blackwood stem form (Medhurst and Worledge 2001), and therefore reduce the number

of times form pruning is required. Forestry Tasmania incorporates three form pruning events into its blackwood management regime. Form pruning is done when trees have a mean dominant height of 5, 7 and 9 m, at about 5, 7 and 9 years of age.

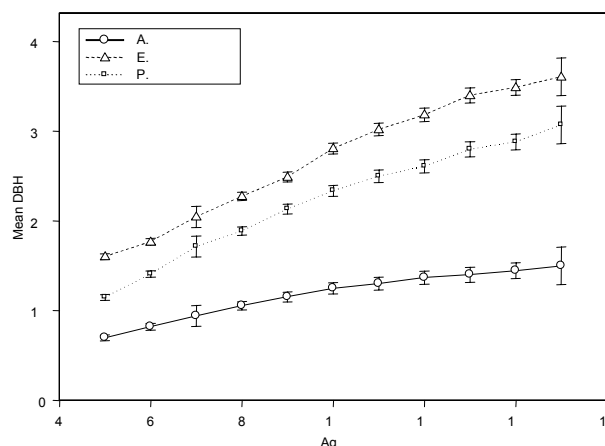


Figure 3. Mean DBH of *Acacia melanoxylon*, *Pinus radiata* and *Eucalyptus nitens* growing at Goulds Country, north-eastern Tasmania

There is evidence from recent research that form pruning should commence from an earlier age. Form pruning removes large branches and multiple leaders, and is generally a light pruning. Research results (Medhurst and Worledge 2001) indicate that

removal of 25% of foliage area should not reduce blackwood growth.

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6

***Acacia melanoxylon*: Its Potential in Chilean Forestry**

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Some species of genus Acacia that are grown in Chile (Acacia melanoxylon, among others) are well adapted to local edaphic and climatic conditions, thus establishing quickly and exhibiting rapid growth, as well as having a variety of uses. Such characteristics make the acacias economically attractive to the Chilean forest industry.

Currently, these species are not widely used in Chile as basic information regarding growth, productivity and industrial potential is not well known, and moreover there is no established market. These uncertainties make it difficult to project future plantation areas, yields and wood supply. Knowledge of its yield characteristics along with the availability of suitable genetically-improved stock, and appropriate silvicultural treatment and management regimes, for the species alone or combined with other species (Eucalyptus), would make it possible to answer these questions, and so forecast its likely use in both the pulp and sawmilling industries.

A network of tests has been established to obtain data related to acacia growth and use.

Permanent plots have been set up for every test, thus enabling essential information to be obtained annually or at other appropriate intervals. The plots are clearly demarcated and monitored in a standard manner. Information for the main biological analyses, and wood samples for determination of physical-mechanical characteristics, is being obtained from these plots as well as from other temporary ones.

In pursuit of the project's genetic objectives, and in accord with the interests of the participating private companies, a collection of open-pollinated families was imported through CSIRO from the best sources as defined by INFOR, while families from Chile were also selected. Seed will be harvested from selected trees in the tests and/or other plots or plantations.

The main results of our investigation of historic yields and growth, models for height, basal area and volume, and a strategy for genetic improvement of the species are presented.

Introduction

The research that has been carried out by Instituto Forestal (INFOR, *Forest Institute*) has shown that *Acacia melanoxylon* should be managed under specific regimes to realize the high potential value of its timber. It is a valuable tree for furniture manufacture. The timber has high tensile and crushing or compressive strength, while having good characteristics for its use in carpentry, veneers, flooring, lining and lathing, and in general, for parts or pieces exposed to shock and vibration (Toledo 1978; Pinilla 2000). This species produces sawn timber of an excellent quality when 15 to 20 years old.

INFOR has conducted research since the 1990s to obtain first-class information on, and material of, the genus ***Acacia***. This research has explored genetic improvement, silvicultural

practices and forest ownership in order to provide a new option for forest production. Taking advantage of this experience, INFOR will further develop the project by coordinating activities with different customers, forest companies and small-sized owners.

Acacia melanoxylon plantations in Chile are spread out over about 1000 ha in forest stands between parallels 35°30' and 40°S; and between meridians 73°30' and 72°30' W. In addition there is an unknown area, composed of pure or mixed stands, in river catchments, windbreaks or forest derived from natural regeneration (Fig. 1).



Figure 1. *Acacia melanoxylon* in a windbreak, and a young stand of *Acacia melanoxylon*

In the south of Chile, plantations of *Acacia melanoxylon* from 16 to 20 y old have a density of 1000-1600 trees ha⁻¹. They also feature a 24 cm average DBH; 20-25 m average height, and a volume of 600-800 m³ ha⁻¹. Mean increments are 30-40 m³ ha⁻¹ y⁻¹ in volume, 0.77-1.22 cm y⁻¹ in DBH, and a 0.64-0.93 m y⁻¹ in height. The species shows moderate growth during its early stages, increasing to a maximum at ages ranging from 16 to 22 y (Pinilla 2000). Arauco features a 28-y-old forest stand with an average DBH of 22.5-cm, 18.8 m high. On the other hand, forest stands aged about 44 y have a DBH of 38 cm and are 28.6 m high.

Measurements carried out from Cautín to Valdivia by Cerda (1994), and quoted by Salinas (1995), show a 30-y-old stand with a density of 1000 trees ha⁻¹ would be expected to have a DBH of 30.9 cm and height of 29.6 m. Total volume would be 1103 m³ ha⁻¹ and average volume increment 36.8 m³ ha⁻¹ y⁻¹. On the other hand, a 17-y-old forest stand with a density greater than 4000 trees ha⁻¹ would not exceed 360 m³ ha⁻¹, and a mean volume increment of 21.2 m³ ha⁻¹ y⁻¹ (Pinilla, Molina, Villarroel and Gutiérrez 2000; Pinilla 2000).

The characteristics of these stands, and the edaphic and climatic conditions under which they are growing, are quite variable.

However, stands with an MAI of 36 m³ at 10 y of age, as well as 22 cm DBH and 22 m high have been recorded within the same area (Freire). This confirms the high yield potential of blackwood in some areas southern Chile (Fig. 2)

We can infer from the available data that the greatest volume increment occurs during the first 20 y, rising from modest values at age 10 y. It is also clear that the higher the tree crown is, the lower will be diameter-related growth. Therefore, any management the species

may be subjected to has to focus on the capability of carrying out moderate pruning, with the purpose of preventing growth from being too delayed (Pinilla 2000).

Background information that has been collected with respect to site productivity for this species in Chile has confirmed that is actually greater than that indicated by existing literature. This is despite the fact that the forest stands that have been studied in Chile have been located on eroded soils or sites showing edaphic problems. All these are drawbacks for optimum growth (NAS 1980; Simmons 1987; Toledo 1997; INFOR 2001). Thus Chile may be quite an attractive country from which to get blackwood accepted in international commerce.

Another important issue to be taken into account is the industrial interest in this species. Owners of medium- and small-sized forests may directly benefit from the research we are undertaking: since they own areas likely to become part of an economically-important resource they may be able to increase their income.

This paper will present data on the growth of *A. melanoxylon* in Chile, as well as supporting tools for forecasting yield and production from particular silvicultural regimes.

General objectives

To generate relevant information and knowledge regarding *Acacia melanoxylon*, and its genetic improvement and forestry practices, which make it a new option for production forestry in Chile.

Growth and yield

Information has been collected from plantations of *A. melanoxylon* in Chile between parallels 35°30' and 40°S; and meridians 73°30' to 72°30'W. Annual rainfall in the area is 600-1500 mm.

For the mensuration study, 37 permanent (Table 1, Fig. 2) and 35 temporary plots were used. The stands had an average density of 1189 trees ha⁻¹. Plot dimensions were 500 m². The permanent plots were re-measured 1-3 y after the first measurement. The stand ages covered by permanent plots comprise the normal rotation period for this species in Chile (30 y). Measurements were made from July 1999 to July 2001. The data obtained have been used in

current research (García 1994; INFOR 2001; Pinilla 2002).

With the information obtained from the permanent plots, models of stand growth - for height, basal area and total volume per unit area - have been developed. Information gathered from the temporary plots has been processed to obtain volume equations for individual trees.

Table 1. General description of the database used

	Dq ^a (cm)	Dominant height (m)	Stand density (stems ha ⁻¹)	Stand basal area (m ² ha ⁻¹)	Stand age (y)
Min	7.1	7.1	460	5.0	6
Max	22.0	27.3	2840	107.5	45
Mean	19.0	15.3	1137	32.3	21.4

^aQuadratic mean diameter (cm)



Figure 2. Permanent plot and stand

It was not possible to develop a model of natural mortality because few tree deaths were recorded during the study, so at this stage mortality was set to decrease over a range from a 2% to 1% annually.

Model of height growth

Height-based growth equations have been developed from information gathered from the permanent plots. Even though the age range of existing data is limited, the information available did make it possible to develop a general model. The functions were adjusted by means of non-linear regression. The model corresponds to the Chapman and Richards equation (Draper and Smith 1967; Alder 1980; Piennar *et al.* 1986):

$$H = 37.1 \{ 1 - [1 - (S/37.1)^{0.9767}]^{t/tc} \}^{1/0.9767}$$

where

H = Dominant height (m), arithmetic mean height of the 100 thickest stems per hectare

S = Site index

t = Stand age (y).

tc = Stand age index (10 y).

$R^2 = 0.95$; Average quadratic error (5) = 13.4

The height equation was used to generate site index curves for Chilean-grown blackwood (Fig. 3).

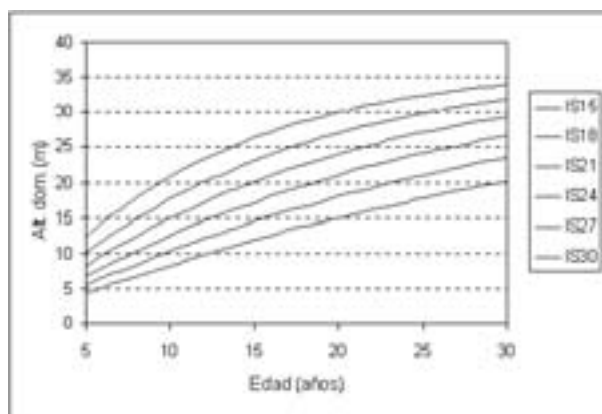


Figure 3. Dominant height growth curves for different site indices for blackwood

Model for basal area yield

Basal area yield has been obtained from the project's permanent plots. The following was the best expression:

$$G_r = \frac{\text{EXP}(-2.695-(9.2633/E))}{N^{(0.4699+(1.956/E))} H^{(1.010-(3.525/E))}}$$

(Clutter *et al.* 1983; Piennar *et al.* 1986)

where:

G_r = Stand basal area (m² ha⁻¹)

H = Dominant height (m), arithmetic mean height of the 100 thickest stems per hectare

N = Stems per hectare

E = Stand age (y)

Model for total volume yield

Models of total volume per hectare were developed with data from the permanent plots. The model that showed the best results was:

$$V = G [15.96 - 0.003647 (NH)/G - 77.82 (1/H) + 40.28 (H/N) - 2.246 (H/N^{0.5})]$$

where:

G = Stand basal area (m² ha⁻¹)

H = Dominant height (m), arithmetic mean height of the 100 thickest stems per hectare

N = Stems per hectare.

The growth predicted by this preliminary model (Fig. 4) can be compared with that of Chilean-grown *Pinus radiata* or *Eucalyptus*.

The height asymptote for *A. melanoxylon* is about 37.1 m, although there may be some error as there was a lack of data for the final adjustment. The basal area model can be used to determine the initial basal area for a given age, height and density. The errors of the volume function turned out to be acceptable.

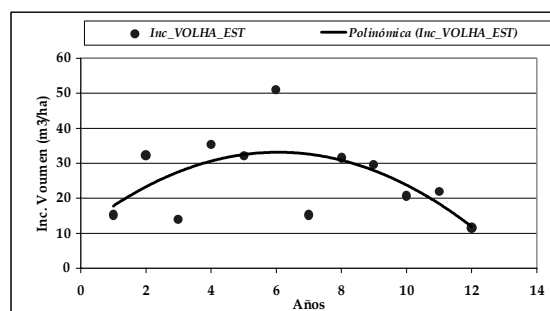


Figure 4. Modelled volume increment of blackwood in Chile

The model of blackwood growth and yield is intended to be reliable in use, despite the limited information on which it has been based. The availability of data from the permanent plots has turned out to be critical, as these cover a wide range of ages and sites. The various components of the model provide fairly logical outcomes within the age range over which they are expected to work (3 to 30 y).

This research by INFOR is the first on Chilean-grown blackwood. It has covered a broad geographic range and has provided acceptable results: a model of growth and yield for this species. This information is critical for decisions by future or potential customers interested in the growth of this alternative forest species.

Yield table

The above models have been used to produce an Excel-type table, with protected cells (Fig. 5). Volume, height and basal area for a given age can be read from the table. As no growth function is available so far, it is not possible to make projections for extended periods, while making backwards projections is not convenient. Projections can be made within only a small range from a given starting point. Access is simple and the system is user friendly.

Tabla experimental de rendimiento para *Acacia*
INFOR - Concepción
Versión 1.0 - Diciembre 2001

Edad :	8	(5 - 30)							
Hd :	12		21.9	Altura media de los 100 árboles más gruesos, a los 20 años (10-30)					
Mortalidad anual (%) :	2.5		18.8	Si Hd es desconocido, para estimarlo (Hd - est) ingresar altura media :					
N :	1500		21.9						

A. dealbata - A. melanoxylon

Edad (años)	Hd (m)	G (m ² /ha)	V (m ³ /ha)	N (árbo/ha)	Dom (cm)
5	-	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
8	-	-	-	-	-
9	12.0	18.8	99.2	1800	11.5
10	13.1	20.1	109.2	1764	12.1
11	14.1	21.7	127.8	1729	12.6
12	15.1	23.1	148.0	1684	13.2
13	16.1	24.6	163.8	1660	13.7
14	17.0	26.0	181.0	1627	14.3
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-
21	-	-	-	-	-
22	-	-	-	-	-
23	-	-	-	-	-
24	-	-	-	-	-
25	-	-	-	-	-
26	-	-	-	-	-
27	-	-	-	-	-
28	-	-	-	-	-
29	-	-	-	-	-
30	-	-	-	-	-

Figure 5. Preliminary stand table for *Acacia dealbata* and *A. melanoxylon*

The permanent plots of *A. melanoxylon* have stand volumes which vary from 100 to 400 m³ ha⁻¹. An average volume of 327 m³ ha⁻¹ has been reported at an average age of 17 y. The reported total stand volumes at rotation age (20 y) seem to be quite attractive, reaching values ranging from 400 to 500 m³ ha⁻¹.

Data from permanent plots indicate an average MAI for volume of 10 m³ ha⁻¹, and on sites of good quality, maximum values of 50 m³ ha⁻¹.

The above data are based on careful research over broad areas in southern Chile, and thus they may be used as a point of reference by any interested producer. However, as the figures reported in this paper have been obtained from forest stands featuring no silvicultural management and which have been established using genetically unimproved seed, the figures presented may really be a lower datum for this species in Chile.

Supporting models: a single-tree volume table for *A. melanoxylon*

Information gathered from temporary plots was processed to obtain volume equations for individual trees. Diameters were measured along the boles of felled trees at intervals of 1m, up to a minimum diameter of 5 cm.

Volumes for individual trees can be obtained by various procedures. One of the best-known scaling formulas is that of Smalian (a reduced paraboloid):

$$\text{Smalian : } v = (g_b + g_s) * \frac{l}{2}$$

where:

g_b, g_s = Sectional areas of the lower and upper section of the log.

l = Length of the log

Using this formula to assess the volume of the metre-long sections of each sample tree, we obtained estimates of the volume of each tree, and then modelled the results as:

$$V = 0.005704 - 0.000006512 \text{ DBH}^3 + 0.00003742 D^2 H$$

$$R^2 = 97\%; \text{ standard error} = 0.02204 \text{ m}^3$$

where:

V = Volume of individual tree (m^3_{ssc}), to a diameter limit of 5 cm

DBH = Diameter at a height of 1.3 m, in cm with bark

H = Overall height of the tree (m)

This model was used to generate volume tables for *A. melanoxylon* in Chile. The purpose of these double-entry tables is to provide a given tree's volume, based on easily-measured parameters (diameter and height). This table is unique in that it is based on the most extensive research conducted on this species to date, and it has therefore become a valuable tool for those interested in this species from a production viewpoint. Results so far show that predictions are reliable, while undoubtedly more data would provide the basis for improvement.

Improvement strategy for *Acacia melanoxylon* in Chile

Origin of the improvement program

Research by *Instituto Forestal* on the genus *Acacia* in Chile started with species introduction programs and became consolidated by the mid-90s, when provenance tests were established. The first procedure identified the most promising species, and concluding that the growth and quality of *A. melanoxylon* make it suitable for specific areas in Chile. The next step was to assess the extent and nature of genetic variation throughout the natural distribution of the species. The outcome made it possible to procure seed from the most suitable

sources for the base population in a genetic improvement program.

During the last few years, seeds from individual trees in natural populations have been acquired from CSIRO, Australia. These seeds provide the base population for the first generation of a genetic improvement program. They will be planted as progeny tests, using randomised single tree plots, STP. The material in our base population is listed in Table 2.

Preliminary strategy

Acacias are considered to be secondary species within Chilean forestry, but they have great potential to be used in sawn timber production, in the rehabilitation of degraded land and as component of pulp production. Because of this diversity of uses, any genetic selection must consider multiple characteristics. However, it will be easier, especially in early generations, to confine selection to general-purpose traits, i.e. volume production and form.

This simple goal, as well as the species' fast growth and precocious reproduction, makes it possible to design a simple strategy for rapid improvement, utilising a wide genetic base and high selection intensity. Due to the fairly limited nature of the initial base of the program, however, selection intensities will be moderate, at least in the case of the first generation. Subsequently the intensity may be increased provided that the selection population can be significantly augmented. The genetic improvement strategy proposed is based on four general considerations, which make it possible to characterize it as a simple strategy:

- short generations and a high selection intensity;
- the infusion of new material in each generation;
- management of the improvement population by means of open pollination,
- simple and multifunctional field tests (selection, progeny tests and commercial production of improved seed).

Table 2. Progeny collection that makes up base population for the improvement program

Provenance	Number of progenies	Location	State	Latitude	Length	Altitude (m)
1	8	Mt Mee-Sellins Rd	QLD	27°06'	152°44'	500
4	3	Rennick	VIC	37°50'	141°00'	60
5	10	Otways	VIC	38°41'	143°33'	300
6	10	13.2 km NNW Welshpool	VIC	38°34'	146°22'	250
7	10	Gellibrand River	VIC	38°43'	143°15'	50
8	10	25 km SE Mount Gambier	SA	37°57'	140°56'	40
9	3	King Island	TAS	39°55'	144°02'	60
10	15	South of Burnie	TAS	41°09'	145°56'	200
11	5	E Launceston District	TAS	41°11'	147°21'	150
12	5	St Helens District	TAS	41°18'	147°52'	600
13	7	W Launceston District	TAS	41°29'	146°42'	300
14	6	Queenstown District	TAS	41°56'	145°31'	400
Total	92					

Progeny tests that have already been set up for an INFOR project (Figs 6, 7) have been adopted as the as first-generation base population. These tests will become the source of the remaining populations in the improvement cycle (improvement population and production population).

These populations, along with infusions, will provide the base populations of further generations. At about half the age of their commercial life cycle (10 y), first-generation base populations will be culled, preserving the best 20% of individuals. This selected population will perform two functions. First, the 40 to 50 top trees will make up a production population for genetically improved seed. Seed from such trees may be harvested on a yearly basis until a better source of seed can be obtained.

The same selected population will also form the improvement population, in which the best individuals will be crossed among themselves by open pollination. At the end of a two-year period, seed will be collected from the best 2% of trees; these seeds, along with the corresponding infusing populations, will make up the second-generation base population. Such a second-generation base population will be strongly influenced by the many individuals in the infusing population, since the number of the original families remaining will be few. Starting from the third generation, however, the infusing population will comprise just 30% of the new base population. This proportion ensures that the variability required for gain in further generations is maintained, while it does not dilute the gains obtained in previous generations.

This research has developed the basis of a strategy for the genetic improvement of *A. melanoxylon*. The further development of this strategy will depend on

preliminary results of the progeny tests that have been established, as well as on production targets and market behavior (Barner *et. al.* 1992; CMG 1995; Ipinza 1998; Ipinza and Gutiérrez 1998). The domestication process starts by defining the targets and carrying out the selection procedure. Several distinct populations are managed through the framework of the genetic improvement program, the 'Improvement Cycle'. Figure 8 presents a simplified schematic view of the improvement program.

Individuals having desirable volume growth and form will be identified and added to the production population of genetically improved material, as well as becoming part of the improvement population (progeny tests). From all this material those individuals that will become the advanced generations of the improvement program will be selected.

The successful establishment of the initial broad genetic base will be a great contribution by the project, as it will provide the foundation for an effective on-going program of genetic improvement.



Figure 6. Progeny trial (6 years) and plant of *Acacia melanoxylon*



Figure 7. Root system of a plant produced in container, and a progeny test (2 years)

Conclusions

Results of our research have shown that both species and provenances of the genus *Acacia* provide interesting options for Chilean forestry, as well as for the pulp and sawn timber industries. Further research work, over a longer time, on *A. melanoxylon* is necessary to optimize establishment and management, and especially to take its commercial potential into full consideration.

The information that has been gathered has been analysed, and the results represent a milestone for both the research program and for this species. Results have already been transferred to our research partners. This, however, is just the beginning. Further research, longer time horizons and new options for technological development, as well as product and market analysis, are required. The results will provide new options and management tools with which to perfect use of blackwood in Chile.

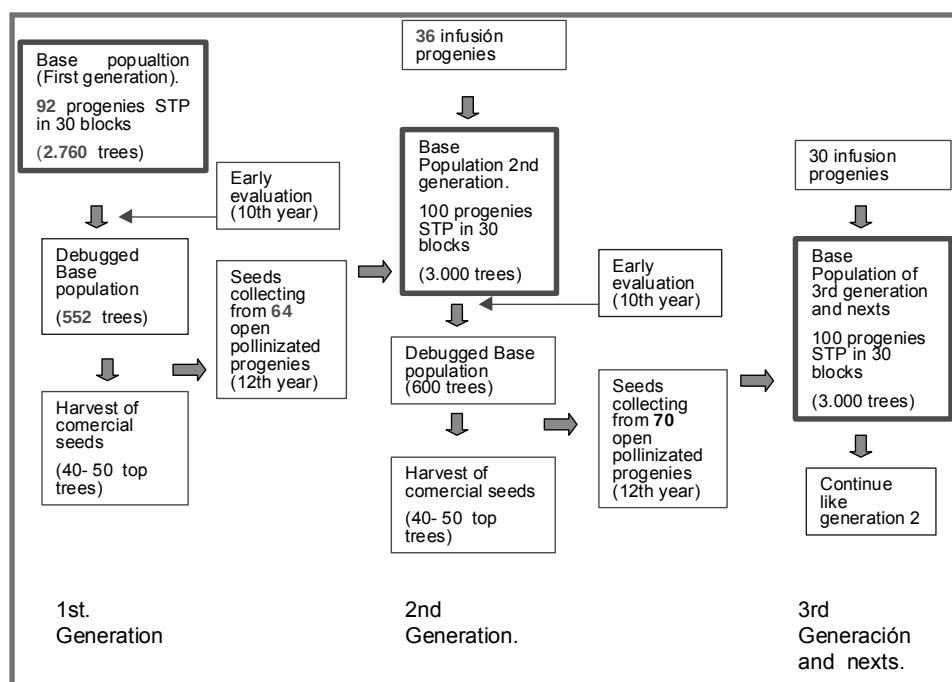


Figure 8. Strategy for genetic improvement of *A. melanoxylon* (INFOR)

Finally, a new effort, for the purpose of expanding the number of such species and the area in which they might be grown, is required.

All of this will provide real opportunities for forestry in Chile.

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***Acacia melanoxylon* in South Africa: Commercial and Conservation Issues in Resource Management**

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Acacia melanoxylon (Australian blackwood) was introduced from Australian rainforests and planted extensively in the southern Cape indigenous forests since 1909. It has since become well established in the forests, and invaded open areas outside the forest. It is also a useful and valuable timber tree that contributes more than 60% of both the timber volume and revenue obtained from the indigenous forests. This paper covers both the conservation and timber management of this introduced species in the natural forests of South Africa, as well as the status of growing blackwood in timber plantations. It has the characteristics of an aggressive invader plant, but it does not aggressively invade closed, evergreen forest. In closed forest its population diameter distribution is bell-shaped, a curve typical of pioneering populations in maturing vegetation. Outside the forest it is a serious invader of open and disturbed sites, as is shown by its high recruitment rate along rivers and forest margins, i.e. a curve typical of expanding populations. In the forest it requires large gaps to grow fast. In the larger logging gaps (but generally small gaps) mean diameter growth was 0.9 cm y^{-1} over 22 y. In the larger gaps (1200 to 1500 m^2) of the Blackwood Group System diameter growth averaged 1.6 to 1.9 cm y^{-1} , and the largest tree of 58 cm averaged 2.6 cm y^{-1} over 22 y. Volume growth was 10.5 to $13.4 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$. The surrounding forest had a suppressive effect on the diameter and height growth of blackwood trees on the gap margin. A wide range of indigenous forest canopy tree species regenerated and became established in the understorey of the blackwood Groups. Crown volume is significantly related to DBH and total tree height. The large emergent crown and very shallow root system make the large trees very susceptible to strong gusty winds. The species is recognized as a useful, fast-growing, shade-intolerant pioneer tree that reacts to disturbance. It has value as timber tree, but its invasive properties and general inferior timber quality outside of the forests have prevented large-scale planting in commercial plantation stands.

Introduction

Natural evergreen forests worldwide have been and still are a source of timber products. As such the forests are often over-utilized, degraded and now the focus of conservation efforts. In several countries and regions alternative timber resources had to be developed to provide in the development needs. Introduced species of particularly pines, eucalypts and acacias have been planted in commercial plantations. Many of the introduced species have naturalized and caused invasion problems. Invader plants are often considered as a threat to conservation of the biodiversity of natural forests. Conflicts between the commercial value and ecological impacts of introduced species arose between the owners of commercial plantations and conservationists.

South Africa is one such an example. The country has a very small area of natural forests, covering less than 0.1% of the country in many, scattered, small forest patches. The largest complex of natural forest covers 60 500 ha in the southern Cape at about 34°S (Geldenhuys 1991). Commercial timber plantations cover an area of roughly 1.487 million ha, comprising 53.2% pines of various species, 39.2% eucalypts of various species, and 7.6% acacias (mainly *Acacia mearnsii*) and other species.

Acacia melanoxylon (Australian blackwood) is often not even mentioned in the statistics of commercial timber plantations. It is a multi-purpose species used for furniture timber, high-quality timber-frame constructions, shelter belts and landscaping (Geldenhuys 1986). Attempts to eradicate it from the forest failed because of its timber value and the dependence of the furniture industry on this species as a supplement for the limited supply of the traditional indigenous timber species (such as

Ocotea bullata [Lauraceae] and two yellowwoods (*Podocarpus falcatus* and *P. latifolius*).

This paper covers both the conservation and timber management of this introduced species in the natural forests, as well as the status of growing blackwood in timber plantations in South Africa.

History of blackwood in South Africa

A. melanoxydon was introduced to South Africa from the Australian rainforests, arrived in Cape Town in 1848 and planted in the southern Cape forests since 1856 (Phillips 1928). It was extensively planted since 1909 to suppress the weed growth on exploited forest sites and to assist natural regeneration of indigenous tree species (Phillips 1928). These plantings were stopped about 1930 (Stapleton 1962) after Phillips (1928) reported that the species depletes soil moisture, suppresses indigenous tree seedlings and spreads throughout the forests. Since its introduction the tree has naturalized in most forested parts of South Africa from the Cape Peninsula and Cedarberg in the west (34°S, winter rainfall area with mainly sclerophyll shrubland), through the Cape and KwaZulu-Natal and to the northern parts of the country (to 23°S, summer rainfall area with predominantly grassland and woodland) (Stirton 1978). It has since become well established in formerly disturbed forests, in forest ecotones and riverine situations and invaded shrubland and grassland areas outside the forest. It is the focus of eradication programs in many areas.

Plantings of blackwood in pure and mixed stands were undertaken. The blackwood survey of 1957 – 1959 (Donald 1959) gave utilisable growing stock levels of 112 860 m³ in plantations and 34 870 m³ in the indigenous forest. Only 18 500 m³ of plantation blackwood was considered of high quality. On Donald's recommendation, almost all the blackwood plantations were felled and replaced by other species, but the forest blackwood was considered a highly valuable asset that should be perpetuated by new inter-planting to prevent breaks in yield. Von Breitenbach (1967) stated that plantation blackwood is of extremely poor quality (small dimensions, unreliable colour, knottiness) even where established on the best sites, but that forest blackwood became a best-seller in the local luxury timber industry due to its highly satisfactory colour and the absence of knots.

Since 1968 a Blackwood Group System was implemented in parts of the Tsitsikamma forests, i.e. eastern part of southern Cape forests (Geldenhuys 1996). The objectives were to ensure successful establishment of blackwood, to reduce damage to

the surrounding forest when the trees are eventually felled and to produce good quality timber. Single trees or small tree groups of even-aged, mature blackwood were felled, to use the timber. Initially the created gaps were small, but subsequently gap size was increased to about 0.2 ha to permit the felling of trees without damaging the surrounding forest. The gaps were cleared and planted with blackwood plants, 1 to 1.5 m tall, at a spacing of 2.7 x 2.7 to 4.6 x 4.6 m. The plants were raised in large polyethylene bags in the nursery. A mesh wire tube fitted to three wooden droppers about 2 m long was used to protect each individual plant after planting. Unprotected plants and natural regeneration in the gaps were completely destroyed by bushbuck (*Tragelaphus scriptus* Pallas 1776). Plantings in Lottering and Storms River forests (smaller gaps) were done October to December 1968. The larger groups in Bloukrans forest were planted between April 1970 and October 1971. Most of the groups received a light thinning during 1979, and again during 1990/91. Information on the intensity or the size of trees of the thinning is not available. This system was abandoned in 1973 because it was claimed that the large gaps, the density of the gaps and the narrow forest strips between gaps in many cases caused changed microclimatic conditions favourable for the spread of blackwood. Furthermore, the system resembled a plantation system and required silvicultural treatments such as thinning and pruning.

In 1981 the Department of Water Affairs and Forestry adopted a policy to stop the planting of blackwood in forest gaps but to start again its growing in plantation stands in suitable sites outside the forest where its spread can be controlled. A period of at least 30 y was considered necessary to build up a plantation resource of quality blackwood. In the interim a management plan was compiled to ensure the orderly utilisation and eradication of blackwood in the forest. No tree >10 cm DBH may be eradicated.

Blackwood timber industry in South Africa

Records of timber sales of blackwood cut from the southern Cape forests show fluctuations between about 500 m³ and 3 400 m³ y⁻¹ between 1959 and 1994 (Seydack in press). This gives a total of 57 500 m³, i.e. somewhat more than the utilisable blackwood growing stock available during 1959. Table 1 shows the volumes of blackwood timber sold mainly at the timber auctions held in the southern Cape forests for the indigenous timbers (unpublished records, Department of Water Affairs & Forestry, Knysna Office). Blackwood timber contributed generally more than 50% of both the

timber volume and revenue obtained from these forests (Geldenhuys 1996). Currently it is the perception that the market is very stable, but that the demand for high-quality blackwood is larger than can be provided for. Sometimes not all the S-grade timber can be sold, but that is considered to be rather the exception. The timber is primarily used in the high-quality furniture industry, although from time to time it is also used for high-quality paneling and timber frames. In general, the timber buyers still hold the view that blackwood timber from the forest is of a higher quality than timber from plantations.

Management of plantation blackwood

Most of the former timber plantations in South Africa managed under the government Department of Water Affairs and Forestry had been or are currently in the process to be privatized.

Table 1. Australian blackwood timber sold from the southern Cape indigenous forests at auctions between 1982 and 2001. Timber grade categories are: S = Serviceable; M = Merchantable; A = Average; P = Prime. The current value of one US dollar is about SARand10.50. (Source: Department of Water Affairs & Forestry, Knysna, South Africa. 2002)

Year	Timber volume sold (m ³)					Average price (R/m ³)				
	S*	M*	A*	P*	Total	S*	M*	A*	P*	Total
2001	544.56	741.07	36.71	1.15	1323.49	553.18	1474.64	2455.14	2600.00	1123.68
2000	310.09	640.66	9.67	-	960.42	346.02	992.00	1591.83	-	789.47
1999	629.53	774.89	10.34	-	1414.76	434.85	1201.48	2350.82	-	868.75
1998	678.00	908.68	13.67	1.06	1601.41	500.69	1215.23	1856.40	1600.00	918.44
1997	551.09	949.27	40.10	-	1540.46	316.37	932.90	1822.94	-	735.51
1996	784.38	1205.08	79.14	1.66	2070.26	380.38	853.42	1472.57	2200.00	698.94
1995	471.53	818.09	48.99	-	1338.61	402.10	1060.72	1642.77	-	850.02
1994	564.49	1183.32	23.05	6.16	1777.02	374.95	847.82	1631.00	1925.49	711.50
1993	576.85	910.40	61.01	-	1548.26	335.52	821.35	1391.93	-	662.82
1992	950.79	1350.64	119.39	4.58	2425.40	226.92	504.31	1011.03	1100.00	421.64
1991	1314.60	1812.16	95.90	6.15	3228.81	290.33	692.79	1348.57	2460.24	551.77
1990	797.38	1506.43	160.29	5.94	2470.04	438.96	901.53	1478.84	1836.46	791.92
1989	240.87	845.35	144.57	23.66	1254.45	258.72	639.58	998.65	1493.99	623.94
1988	642.45	1758.05	311.16	15.96	2727.62	155.55	441.19	712.59	1105.10	408.76
1987	508.81	1476.32	329.43	13.94	2328.50	158.40	386.44	621.66	956.96	373.30
1986	410.66	878.37	426.73	33.74	1749.50	240.95	384.40	531.12	905.72	396.57
1985	731.51	939.02	246.52	67.75	1984.80	66.66	142.35	263.67	205.82	131.69
1984	351.03	194.60	41.16	7.44	594.23	157.82	374.69	682.24	1045.04	276.28
1983	403.64	468.66	155.17	34.48	1061.95	60.06	184.59	228.19	264.72	146.23
1982	310.08	451.45	142.71	-	904.24	30.87	215.70	319.78	-	168.74

Table 2. Age-class distribution of Australian blackwood plantations under SAFCOL management in the southern Cape, South Africa (G. Nieuwoudt, pers comm. 2002)

Age (y)	Plantation area (ha)							Total
	Jonkers-berg	Bergplaas	Homtini	Buffels-nek	Kruis-fontein	Lottering	Bluelilies-bush	
5-10					31.3		80.3	111.6
11-15					44.9		30.5	75.4
16-20			0.8	0.3	106.5		27.8	135.4
21-25		3.8			49.4		23.4	76.6
26-30		7.4	1.3	2.6	41.0	8.7	3.1	64.1
31-35	17.8		8.0		6.8			32.6
36-40								
41+		0.4	1.1	2.5	12.6		8.3	24.9
Total	17.8	11.6	11.2	5.4	292.5	8.7	173.4	520.6

Table 3. Silviculture for plantation blackwood under SAFCOL management, southern Cape, South Africa (G. Nieuwoudt, pers. comm. 2002)

Rotation	45 years		
Regeneration and spacing	Natural regeneration, reduced to 3.5 m x 3.5 m one year after felling of the standing plantation and before the average height exceeds 1.8 m.		
Thinning	Age (y)	Density (stems ha ⁻¹)	The initial thinning regime was affected by the observation that young, fast-growing trees with heavy crowns bent over at age of 3 y. Thinning must be scheduled at least two years apart (on very good terrain) but not more than three years apart. Adjustments must be made during annual inspections.
	1–2	800	
	6–10	600	
	8–12	450	
	10–15	300	
Pruning	After the first and second thinning (not earlier), prune up to half the tree and, after the third thinning up to 300 stems ha ⁻¹ , prune up to 7 m.		
Weed control	To be undertaken as economically as possible. The first phase of chemical control of undesirable weeds must be done before or during spacing of natural regeneration. The second phase of weeding must be done before the first thinning and the third phase before the third thinning		

Most of the former state blackwood plantations, primarily in the southern Cape, are now managed by the parastatal company, SA Forestry Company Ltd (SAFCOL). The statistics for blackwood compartments under SAFCOL management in the southern Cape (the only SAFCOL area with plantation blackwood) are provided in Table 2. No new plantings are done, and the silvicultural management of these stands has been scaled down. The current silviculture applied to SAFCOL plantation blackwood is described in Table 3.

The following guidelines were provided for the selection of sites for the growing of plantation blackwood (Forestry Department, Forest Management Instruction 37 of 1971):

- The soils should be fertile, with a reasonably high humus content in the A-horizon, and deep, moist but well-drained. Blackwood logs producing the highest yield of prime coloured timber came from trees growing on sandy soils

with abundant moisture (and not from the forest).

- The species is prone to wind throw and exposed sites should be avoided. Although the roots can penetrate to 1.5 m, the tree generally has a strong lateral root system with a concentration of roots in the top 0.25 m of the soil.
- The possibility of the species becoming a weed.

Other considerations included:

- Browsing problems from bushbuck, which would require a higher initial density of plants.
- Diameter growth should initially be stimulated to facilitate wind stability.

Several reasons have been forwarded for the lack of interest in actively growing plantation blackwood. The two general reasons were that

- The timber of plantation blackwood is of inferior quality compared to that of forest blackwood.
- Plantation blackwood creates enormous weed control problems within the plantation estate.

Another very important reason forwarded by the larger timber plantation growers is that

- Allocating small areas of good sites to growing blackwood timber diverts from the core business of growing pulp or structural timber in large-scale commercial pine or eucalypt plantations.

Ecology and management of blackwood in natural forests

Blackwood does occur in other forest areas in South Africa, but on a limited scale and with active eradication programs in place. In the Amatole Mistbelt Forests in the Eastern Cape Province (32.5°S, 1000 m asl) the limited blackwood resources are systematically removed from the forest in the annual forest management activities. Almost all studies on the ecology and management of blackwood in the natural forests were done in the southern Cape forests. The conflict between eradicating blackwood as invader plant from the forest and managing it as a useful timber resource revolves around the perception of what is an invader plant. I defined an invader plant in the indigenous closed, evergreen forest as one which will increase its numbers and biomass to the detriment of the forest substance and life support systems through various processes: continuous regeneration, prevention and suppression of natural forest

regeneration, suppressive growth rate, suppressive crown development, and/or upsetting of the natural disturbance regime (Geldenhuys 1996). I have tried to answer some of the questions around blackwood as invader plant in the forest environment (Geldenhuys 1986, 1996). The most relevant of those and other issues are summarized here in order to clarify the current policy for the management of blackwood in the natural forests in South Africa, particularly the southern Cape forests.

Population demography of blackwood in natural forest

The stem diameter distribution of a species can be very informative about its population dynamics in particular communities (Geldenhuys 1992). The diameter class distribution of different populations of *A. melanoxylon* in entire districts of the southern Cape forests, in selected forests within districts, and for different stands in the Goudveld forests were compared to interpret the rate of expansion of the species in the forest (Fig. 1). The survey data included all blackwood trees >10 cm DBH growing within the natural forest environment. The Goudveld data included only compartments that would include data from only one of the following situations:

- Relatively undisturbed (recently), closed forest;
- Riverine forest in relatively open river valleys; and
- Forest ecotone areas, excluding trees outside the forest.

The Tsitsikamma forests contained many large-sized trees, but showed a decline in recruitment into the smaller diameter classes. By contrast, the Outeniqua forests had relatively few large-sized blackwood trees, but showed a high recruitment rate. Data for the districts and forests combined different development stages, but this information was separated for the Goudveld forest stands. The curve for the total blackwood growing stock shows a slowly expanding population. In the closed forest the diameter distribution is bell-shaped, a curve typical of a pioneering population in maturing vegetation. The small number of stems in the lower diameters was most abundant in windfall gaps. The

mean DBH ranged between 40 and 50 cm. By contrast, the population structure along rivers and forest margins included large numbers of small trees and small numbers of large trees. This indicated that the populations are rapidly expanding in those habitats.

Spread of blackwood in logged forest free of parent blackwood trees

The Groenkop Forest Study Site (24.5 ha) provided an opportunity to study the spread of the species after logging disturbance. The stand was logged in 1969/70. It was free of blackwood before logging but mature blackwood trees occurred in neighbouring stands. In 1973 the stand was subdivided and demarcated (permanently) into 14.1 x 14.1 m plots for a forest inventory study. During January 1984 each of the 1129 plots was searched for blackwood plants. Each plant found was measured for height and DBH (where applicable), its position in the canopy and health condition was noted, and its location was indicated on a map of the study area. During July 1992 only the plants recorded in 1983 were visited and remeasured.

The results indicated that blackwood spread relatively widely from the parent trees, a distance of at least 400 m. The 27 observed plants must have grown from seed stored in the soil at the time of logging because the growth rate and density of the understorey shrub *Trichocladus crinitus*, the fern *Hypolepis sparsisora* and the tree regeneration would have excluded the chances of establishment of blackwood regeneration more than two years after logging. The date of establishment of blackwood plants was taken as January 1970, and the age of the trees were therefore comparable to trees in the Blackwood Group System. Mean DBH of the seven trees >5 cm DBH, until 1984 (14 y), was 9.4 cm, and mean diameter growth was 0.67 cm y⁻¹. The biggest tree, in a large gap, had a DBH of 22 cm, height of 21 m, and diameter growth of 1.57 cm y⁻¹. In 1992 the mean DBH was 21.1 cm and mean growth rate 0.94 cm y⁻¹. The biggest tree, growing freely both in the canopy and at ground level, had a DBH of 47.8 cm and growth rate of 2.12 cm y⁻¹. In 1984 the three trees >10 cm DBH already showed signs of fruiting.

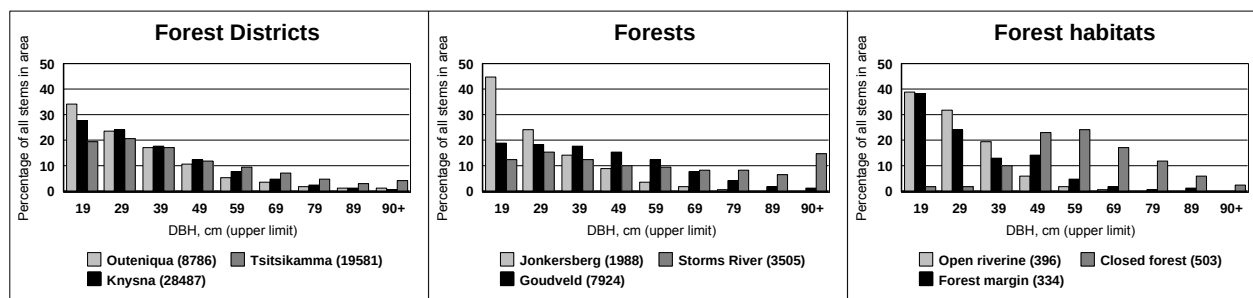
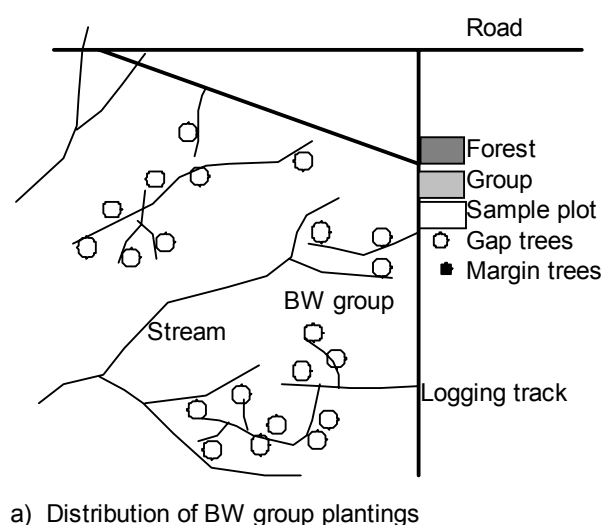
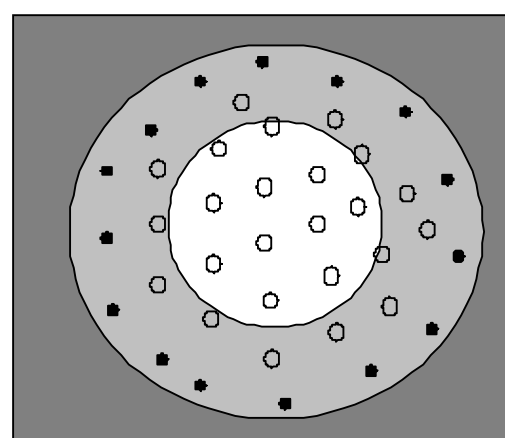


Figure 1. Population demography of blackwood in the southern Cape forest districts, forests within districts and habitats within Goudveld forest (adapted from Geldenhuys 1996)



a) Distribution of BW group plantings



b) Layout of sample plot inside BW tree group

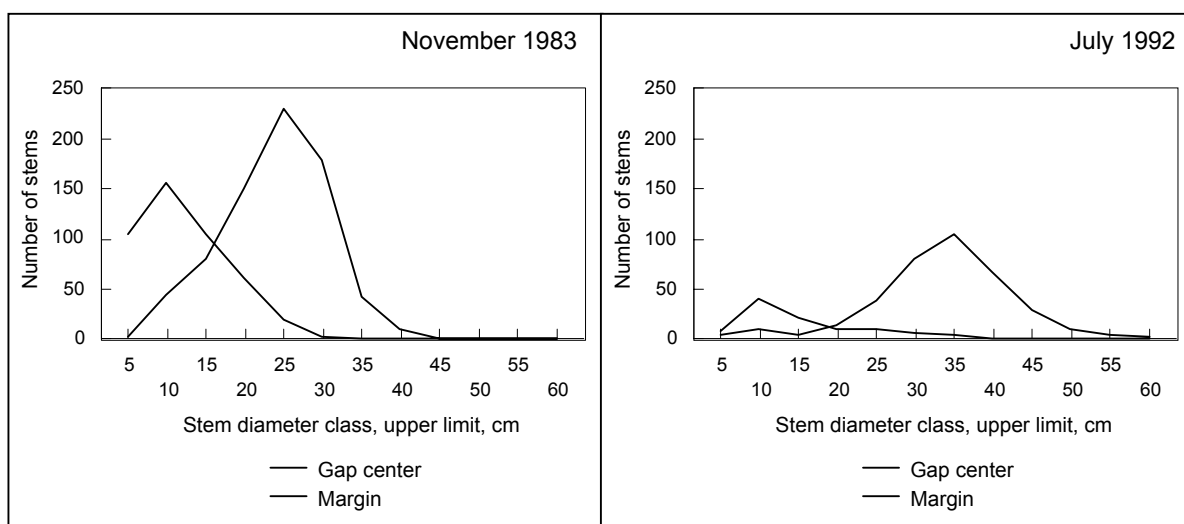


Figure 2. The distribution of blackwood groups in Coviebos, part of Bloukrans forest (a), and the sampling procedure (b). The graphs show the stem diameter distributions of gap center and gap margin trees during the two measurement periods.

Blackwood Group System

The Blackwood Group System, with its known date of establishment, provided an opportunity to determine the relationship between gap size, stand density and tree growth. During November 1983, 16 gaps with blackwood trees planted as part of the Blackwood Group System were selected for study (Fig. 2). The gap size was estimated by measurement of the longest axis and perpendicular axes to calculate area as ellipse, circle or triangle. Within each group a circular sample plot of 0.04 ha was demarcated more or less in the center of the group, where this was possible, to avoid inclusion of many suppressed edge trees. Each tree was measured for DBH. A single measurement was made of the height of the stand. In addition, the DBH of each other tree in the group was measured. A note was made whether a tree was a fringe tree or not. A fringe tree was growing on the border of the group and partly or totally overtopped by the neighbouring indigenous trees. During July 1992 the selected groups were re-visited. The diameters of windblown trees and of the stumps of thinned trees were recorded. In 1983, in the larger groups, the forest species in the understorey of the total gap were recorded by percentage cover and height range. In 1992 each tree sapling >1 m height on a 100 m² circular plot in the center of the gap was recorded by species and height. General notes were made of the understorey vegetation.

Trees within a group showed much variation in growth rate (Fig. 2). The major difference in growth occurred between trees planted in the gap margin and trees planted in the gap center. The surrounding forest had a suppressive effect on the DBH and therefore on the growth of the trees on the gap margin. The smaller gaps had a larger proportion of margin trees. In 1983 the mean DBH of gap center trees of all groups combined was 22 cm, and of the four largest gaps ranged between 24 and 26 cm. DBH of the largest trees ranged up to 41 cm. This represented a mean diameter growth of 1.6 to 1.9 cm y⁻¹, and 3.0 cm y⁻¹ for the largest tree. In 1992 the mean DBH of gap center trees of all groups combined was 30 cm, and of the four largest gaps ranged between 30 and 33 cm. The largest tree had a DBH of 58 cm. The mean diameter growth was 1.3 to 1.5 cm y⁻¹, and 2.6 cm y⁻¹ for the largest tree. The diameter growth dropped slightly from 1983 to 1992. Volume growth per hectare per year varied considerably between groups. Most trees in the groups had uniformly straight stems with good form, relatively few and small branches, and narrow tapering crowns. At 13 y, the colour of the heartwood timber of thinned trees was quite dark. During 1992 the colour of timber from thinnings

were considered to be acceptable within the grading guidelines.

Understorey vegetation varied in composition of herbs, shrubs and trees. All the important forest canopy species were present: *Podocarpus falcatus*, *P. latifolius*, *Rapanea melanophloeos*, *Ocotea bullata*, *Pterocelastrus tricuspidatus*, *Curtisia dentata*, *Olea capensis* subsp. *macrocarpa* and *Gonioma kamassi*.

Blackwood crown development and susceptibility to wind

Mature blackwood trees in the forest form large, dominant crowns and are often subject to windfalls. The possibility is that, even if the windfall ratio is equal to that of the most wind-prone indigenous tree *Olea capensis* subsp. *macrocarpa*, a potentially larger crown of blackwood may upset the natural disturbance regime of the forest. *O. capensis* subsp. *macrocarpa* is the most common indigenous forest canopy tree, has a large crown and is most commonly involved in windfalls (Geldenhuys and Maliepaard, 1983). This idea was tested with 21 sets of canopy trees sampled in different forests. A set consisted of one canopy tree each of blackwood and *O. capensis* subsp. *macrocarpa* from the same area. The following measurements were recorded:

- Total height;
- Stem length to where the crown starts; and
- Crown diameter in a north-south and in an east-west direction.

Crown volume was calculated as the volume of a sphere, i.e. $\frac{4}{3}abc$, where a = N-S crown diameter, b = E-W crown diameter and c = crown depth (total height minus stem length). The relationships between crown volume and the variables DBH, tree height, crown depth and mean crown diameter, were calculated with simple and multiple regression. The results showed that mature blackwood trees emerge above the forest canopy, range wider in stem diameter and crown volume, but do not have a longer crown or larger crown volume than canopy trees of *O. capensis* subsp. *macrocarpa*. A blackwood tree grows vertically into the gap to above the canopy and develops a relatively compact spherical crown above the canopy. The crown of *O. capensis* subsp. *macrocarpa* spreads to fill the gap and does not grow much beyond the forest canopy.

Discussion

The results from the ecological studies show that three factors need to be considered in the management of blackwood in the southern Cape forests (Geldenhuys 1996).

- Firstly, it occurs in all the main forests throughout the southern Cape. The trends in population demography suggests that much of the total blackwood population spread from the areas where planting took place. However, the population did not spread within the forest proper, but spread into the open or disturbed areas. Riverine areas are disturbed by periodic floods, and by more frequent windfalls on the steeper slopes, especially during wetter and windy periods. Forest margins are regularly disturbed by burning of shrubland vegetation in the catchments, or by felling of trees of commercial plantation stands of pines and eucalypts, into the forest margin.
- Secondly, it has the characteristics of an aggressive invader plant, but it does not aggressively invade closed, evergreen forest. blackwood has a widespread seedbank of long-living seeds, and regenerates abundantly and rapidly after disturbance of the forest canopy and floor. It grows fast in large gaps, but is easily suppressed by the surrounding forest canopy. It has a relatively short life-span, and especially prone to windfalls. It cannot regenerate under its own canopy, but nurses the establishment and growth of forest species. The tree requires disturbed sites for continuous regeneration and to become established. This is shown by its diameter distributions in the open or frequently disturbed riverine sites and forest ecotone of Goudveld forest. The diameter distribution of blackwood in closed forest suggests that the population established when the forest was very disturbed, but that the pioneer stand density declined due to low recruitment and high mortality. The behaviour and growth rate of blackwood in the logging gaps in Groenkop forest and in the Blackwood Group System also suggest that the species is intolerant of shade and cannot compete with forest species under shaded conditions. It requires a large gap or fairly open area to grow fast. A wide range of indigenous forest canopy tree species regenerated and became established in the blackwood understorey. This contradicts the earlier statements and some current perceptions that blackwood does not support the establishment of regeneration of forest canopy species (Phillips 1928). This means that blackwood stands create conditions that are suitable for establishment of the main canopy species, which are also commercially useful, and facilitates succession towards forest. It is, however, possible that this process may be slow or may even be inhibited under certain conditions of stand density or soil moisture or soil compaction. The species should rather be seen as a useful, fast-growing, dynamic pioneer

tree which should be managed positively to provide in the furniture timber needs.

- Thirdly, outside the forest it can be a serious invader of open and disturbed areas, but it can also be managed to nurse the expansion of indigenous forest and to provide quality timber from a larger area, depending on what management objectives are pursued.

The recommended strategy for the medium-term involves a combination of zonation and monitoring (Seydack in press): spatially differentiated control intensities; and monitoring of blackwood demography and resilience to control.

Three types of blackwood management zones are potentially relevant.

- Zone A: Blackwood is intensively controlled/eradicated. All nature reserves, declared as such under the Forest Act or not (yet), and surrounding buffer areas in certain cases could be allocated to this zone. Introduced species are unacceptable in nature reserves and should be controlled or removed, irrespective of whether they are considered a long-term threat to the natural environment or not.
- Zone B: No control work should take place in this zone (and zone C) for a 10-y period. During this period, monitoring and possibly other investigations should finally clarify whether blackwood control is at all necessary.
- Zone C: Areas with a good potential for high quality, productive blackwood populations and where active blackwood timber production would be pursued. Indigenous forest utilisation compartments situated within zone B would also be part of this zone.

A two- or three-zone approach may be selected, depending on whether active blackwood timber production is envisaged or not. As active blackwood timber production was not considered compatible with applicable forest conservation objectives, the two-zone option, with special sub-zones in zone B, is being implemented. These sub-zones provide for blackwood control in selected forest edge and riverine areas and areas of aesthetic importance (Vermeulen and Seydack 2000).

The proposed monitoring program should ensure a conclusive knowledge base for sound decision-making on aspects of blackwood control and utilisation over a 10-y period. Two main facets require attention:

- Blackwood population dynamics of selected demographic situations of the forest interior and ecotone (regeneration, recruitment, growth and mortality)

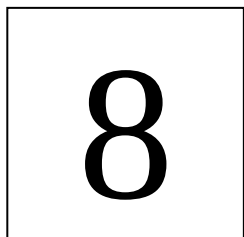
- Resilience in the face of control action, allowing an evaluation of the control success to be anticipated (spread/dispersal, re-emergence and degree of control evasion)

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Specialist Markets in New Zealand

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Introduction

The current firm of Kings Fourth Generation Woodworking Company has a history dating back to 1887 when Daniel Thomas King arrived in Carterton in the heart of the Wairarapa, with his wife and family, after travelling over the rugged Rimutaka Ranges from Tawa Flat, near Wellington, by horse and buggy.

In Carterton, he started a general joinery and contracting shop, which became a well-established part of the town. He served on the town council and was very involved in the Methodist Church.

The company grew in step with the development of the Carterton township, and according to the Encyclopedia of NZ – in 1907. ‘the present fine premises, consisting of a two-storeyed wood and iron building measuring forty-one feet by eighty feet, was erected, containing a showroom, a well appointed office, a factory, and storerooms, all fitted up with a complete plant of wood-working machinery driven by a six horsepower oil engine.’ The same building is occupied today.

Kings Fourth Generation Woodworking Company specialises in laminated benchtops. One of our preferred species is *Acacia melanoxylon*. We have used this species for nearly 15 y after viewing samples first given to us by John Mortimer.

Markets

We have been promoting the use of NZ blackwood for our *Generation IV* Timber Bench Tops on a national basis to the following clients:

- Architects at displays and special promotions
- Kitchen companies
- Joiners generally
- The public, via magazines

We have exhibited our benchtops in at least 15 kitchen and interior shows throughout NZ, where blackwood has been the prime exhibit, or an important part of the display.

We now have twelve large feature showroom counter-tops on display at prime locations in seven different towns and cities. About fifty kitchen companies have racked samples of our NZ Eco-timbers containing NZ blackwood, fastigata (NZ ash), saligna and southland beech as well as our full range of standard timbers.

As a result of this marketing, NZ blackwood is among the top selling timbers we use: - next to say heart and coloured rimu, jarrah and matai.

Our specialist finish is able to densify the softer timbers like pale rimu or macrocarpa and since NZ blackwood is generally denser than rimu, the resin finish works particularly well on that species.

All our current marketing is directed to supporting our network of dealers, and promotions in selected market driven, high profile publications as well as displays at conferences, homeshows and the like. Many of our blackwood benches are already in some of NZ’s best homes, and *Generation IV* timber benches of blackwood can be regularly seen on TV in various dignitaries’ homes or on advertisements. NZ blackwood is now the preferred interior timber for many of our architects, who are now specifying it for a greater range of furniture and fitments.

Properties

Stability

We have had no experiences of NZ blackwood moving excessively or cracking on existing jobs (we guarantee against this).

Colour

- The pale sapwood is not used and is cut to waste.
- The heartwood contains a huge variety of colours that is an advantage to us due to the method by which we manufacture our benchtops which are laminated from 50 mm x 50 mm strips.

Grade

We generally want long lengths (3-4 m) of clear grade, ex 50 x 50 mm, of heartwood (two clean faces are acceptable).

Moisture

This is most important for our type of work. We require the moisture content to be stabilised at 12%. Achieving this is generally no problem as the drying schedule is similar to rimu, so both kiln and air-drying methods are successful.

Price

In 1998, we were paying between \$1200-\$1800 m⁻³ for good grade, dry material, but this year we have had to pay \$3000 m⁻³ for timber of marginal grade. This price is artificially high compared to other equivalent species on the market, due to the shortage in supply.

Issues

Two of the main issues in utilising blackwood in New Zealand are supply and quality control.

Supply

This is the biggest problem facing us. We use about 50 m³ of blackwood timber a year and would use a lot more if it were available. To combat the increase in demand we have had to introduce several other species into the market. These are black totara (logs buried by the Taupo eruption), NZ grown elm, and *Acacia dealbata*. These timbers are now becoming established in the marketplace. In addition, we often have to substitute Australian timber, which is very expensive, and often in very short lengths. In order to limit its usage we no longer use blackwood for our demonstrations.

Quality control

In order for us to supply excellent timber benchtops to our customers, we need to be supplied with timber of the correct grade for our purposes. This is to minimise our waste factor and keep our labour costs as constant as possible so profit margins can be maintained. Our laminations are jointed using a sloping scarf joint to present an invisible joint to the customers, so it is especially important that all timber is supplied to us at the correct grade. Due to poor experiences in the past, we now have a preferred supplier policy.

Summary

In spite of the fact that we offer a range of 42 different timbers for our *Generation IV* bench tops, blackwood is the timber that customers are mostly attracted to. Due to the marketing efforts described above and the jobs we have installed, it is becoming increasingly popular in the kitchen industry and is repeatedly being requested by an increasing number of joiners.

We consider it will always hold its price, and we see it as one of the best long-term forestry projects for NZ conditions. We recommend that NZ blackwood be grown on a widespread basis, especially for forest investment projects. We have planted a small block ourselves and have successfully encouraged others in our trade to do the same.

Our company has been one of the first in NZ to start using blackwood on a regular basis and we now need a lot more. We consider it must be one of the best (if not the best) species for forestry in NZ.

After many years research in NZ, the various criteria for producing the best trees have been determined, so we look forward to seeing more of this beautiful timber grown in NZ.

Acknowledgements

I would like to thank Ian Nicholas for inviting me to present this paper and for his help in doing so.

9

Opportunities for Expansion of Blackwood Sales Particularly in International Markets

Don Britton

Britton Brothers Pty Ltd, Smithton, Tasmania

Introduction

Britton Bros Pty Ltd, now trading as Britton Timbers, has been involved in the blackwood timber industry for almost 100 y. Located in the far north-west of Tasmania, Britton Timbers' sawmill and drying operation is at the centre of the largest sustainable blackwood forests in the world.

The establishment of a Blackwood Management Plan and dedication of 7880 ha of forest into a Swamp Working Circle in our region will enable a 70-y rotation to occur. This secure, sustainable resource, along with arisings from other native forest harvesting, has enabled Britton Timbers to negotiate a contracted 10 y supply from Forestry Tasmania of 5000 m³ Category 4 and up to 5000 m³ Utility and Outspec blackwood sawlogs.

With vagaries of summer logging conditions and availability of supply from private property sawlogs, Britton Timbers expects to be able to process up to 11 000 m³ y⁻¹ of log which on average recovery of 28% is expected to produce approximately 3000 m³ of sawn timber.

The breakup of grade and sizes, under current sawing patterns and practices, is shown in Table 1.

Table 1. Description and yield of sawn blackwood

Grade	Sizes	Yield (%)
Select	50 mm wide x 25, 38, 50mm thick	6
Select	75-125mm x 25mm and thicker	36
Select	150 mm and wider x 25mm and thicker	30
Standard/feature	All sizes	10
Sap inclusive	All sizes	12
Veneer flitch	150mm and wider x 75mm and thicker	5
Other	All sizes	1

Strengths

Beauty of timber

Suzette Searle, in her paper at the last conference, described blackwood: 'This wood is golden brown with waves and highlights, depth and life in its beautiful grain'. Alan Brown's reference to Swain (1928): 'The figured and fiddlebacked blackwood of Tasmania is incomparable, and not even the most beautiful American walnut can vie with it in elegance' Their comments aptly sum up the fact that blackwood in a range of forms has world-class characteristics for high value, elite furniture. The range of colours and grain patterns, make blackwood much more visually exciting and contrasts with the uniformity of timbers such as American oak, European beech, and Burmese teak.

Variations in colour make interesting features in products such as flooring and wall linings and carefully designed furniture. Enough consistency of colour exists for more uniform matching of timber in furniture applications that require this. At present, Britton Timbers do not sort by colour, but if sufficient demand for a range of colours over a complete size range was created, then sorting would be considered.

Sustainable supply

As outlined in the introduction, a secured, sustainable supply of around 10 000 m³ y⁻¹ sawlog is available in Britton's Forestry Tasmania supply area. Blackwood also occurs in lesser volumes throughout other areas of Tasmania and many of these areas have potential to supply sustained volumes if appropriate management regimes are implemented.

Future increases in available sawlogs are planned to be achieved by fencing blackwood-seed-rich eucalypt coupes that will be regenerated. Results to date have shown this to be very successful in

producing good form trees in large quantities amongst the regenerated Eucalypt. Plantations are planned to be a significant future source of blackwood sawlog.

Stability of supply

The Tasmanian blackwood industry has an assured supply of blackwood sawlog which will enable a regular, consistent quantity of sawn timber and veneers to be made available to present and expanded markets. Brittons currently stock over 10 000m³ of logs that due to a summer bias in blackwood logging is necessary to maintain a cut spread over a full year.

Current rack stocks at Smithton are 4000 m³ and pack stocks are 350 m³.

These stocks, along with warehouse stocks in our Melbourne, Sydney and Brisbane outlets, are a solid base from which to expand markets, particularly as they are possibly 15–20% above current demand levels.

Weaknesses

Supply volumes

Britton Timbers produce an annual cut of sawn blackwood of 2500 - 3000m³. If it is assumed that this volume is 30-40% of total blackwood timber produced in Tasmania and Victoria on a regular basis, then a maximum sustainable production level is in the order of 7500 m³ to an absolute maximum of 10 000 m³. Brittons consider that under normal demand conditions in the Australian market there is scope for export for 20-30% of production, which would mean a maximum volume of available of 3000 m³ of sawn timber.

On a world scale of sawn timber usage, it is interesting to consider a large importer such as China and its growing consumption of timber for furniture usage:

Table 2. Timber imports by China, first half of 2001-2002

Item	Imports (m ³)	Change on 2001
Sawn wood total	806 500	39.3%
Hardwood portion of total	512 000	

It can be assumed that year 2001/2002 imports of sawn hardwood timber would be at least 1 034 000 m³. Compare this figure to the total volume available of blackwood from Australia, 3000 m³: it can be seen that even for just one large

country the Australian production is only 0.29% of the imported volume. The problem is compounded by factors such as blackwood being relatively unknown in a world market and length and width specifications being less than that supplied by competitors.

Funding marketing

The relatively small volume of blackwood produced limits the amount of funds available to mount an effective high quality marketing campaign. International and domestic markets require marketing tools such as brochures and a wide range of samples which can be time-consuming and expensive to produce.

Niche markets in high quality furniture sectors take a long time frame to nurture and gain acceptance. An example of this is Japan, which traditionally requires at least five years of constant contact and follow up, achievable only by having a permanent representative based there.

Market/fashion trends

The Australian market for brown/dark furniture timbers suffers dramatically from fashion trend fluctuations. This clearly was the case during the 1980s when solid dark furniture was very popular and solid timber panel kitchen cupboard doors were the height of fashion. Demand exceeded supply until the early 1990s when both furniture and kitchen markets collapsed considerably, leaving companies such as Brittons holding large timber and log stocks.

Research funding

More funding for research in many areas of blackwood growing and processing is still required to follow on from that conducted to date. As a small-scale grower of blackwood, Brittons would like to have access to planting stock that has a high probability of growing the trees of good form that have the capability of producing timber that future markets require.

Opportunities

Despite problems outlined earlier, significant opportunities exist both in Australia and internationally for a beautiful cabinet timber such as blackwood. Increased demand can be expected due to the following factors:

1. More people approaching retirement age who will have larger disposable incomes available for investment in higher quality furniture. These needs can be met by:

- (a) Numerous low-volume designer producers making quality individual furniture products, especially designs suited to apartment-style living. Several Tasmanian producers such as those represented by Style of Tasmania are well positioned to expand in this market.
- (b) Larger volumes of lower-cost standardised designs may have to be manufactured offshore, possibly in a country such as China, and imported into Australia to compete with imported furniture made from non-Australian timbers.

Figure 1 illustrates the rapid growth in demand for imported furniture over the past decade and the volatility of domestic production.

Key point: The value of domestic production has shown volatility with market movements while the value of imports has grown consistently regardless of market conditions. This suggests that local manufacturers would be severely affected in a sharp market downturn.



Figure 1. Retail market value of domestic production and imports of furniture (Source FIAA 2001-2002)

2. Greater awareness by architects and specifiers of the suitability of blackwood for major construction projects requiring high-quality interior fit outs. The recent completion of the County Law Courts in Melbourne, which utilised blackwood extensively, is an excellent example of the ability of Britton Timbers to supply timbers and veneers to satisfy the demands involved in constructing such an impressive and complex structure.
3. Maintenance and expansion of domestic markets in areas such as solid panel doors and kitchen fit outs along with the increase in the use of blackwood in overlay flooring is essential to provide versatility of usage.
4. Opportunities to export the 20-30% production that is projected to exist surplus to anticipated domestic demand are enhanced for the following reasons:
 - (a) Introduction of an Australian Forestry Standard will verify the sustainable forestry practices currently in place for blackwood harvesting and regeneration. As tropical hardwood producers are under significant pressure to be more environmentally accountable and illegal harvesting is outlawed, demand for certified sustainably-produced furniture timbers will increase.
 - (b) Niche markets in selected countries such as USA (especially Hawaii), China and New Zealand have potential for increased sales due to the loss of their own native hardwood timbers. In Hawaii, *Acacia koa* supply of is very limited, and blackwood, which has very similar characteristics, is an excellent substitute. New Zealand and areas of China are familiar with blackwood through growing their own plantations and importation of Tasmanian timber can assist developing markets until their own production becomes available.
 - (c) Production of American USHLA-specification timber, i.e. wider, longer boards with defects included, will increase recovery and decrease handling costs and consequently enable more competitive pricing. This is particularly relevant for markets such as China which normally buy only timber of this specification.
5. Potential exists for greater volumes of blackwood to be produced if successful plantations can be grown in Australia and those existing in New Zealand, China, South Africa and Chile are expanded viably. Whilst timber from these areas might be a threat, it should enhance market presence and acceptability if prudent marketing as outlined above takes place.
6. Maximisation of benefits and assistance from Austrade and the Export Marketing Scheme will assist in decreasing export marketing costs. Other sources of assistance may also be available.

Threats

1. The forest industry in Australia has been continually under resource security threat over the past 25 y. Whilst a degree of security has recently been achieved in the form of Regional

Forest Agreements (RFAs) in some state regions, forestry is still under threat from the environmental 'green' movement. Members are continually lobbying not only for a ban on logging of mature (old growth) forests but ultimately for an end to harvesting all native forests. Any reduction in areas available for sustained blackwood production will seriously jeopardise maintenance of a stable blackwood industry and any future expansion.

2. Lack of plantation development through a lack of research and grower confidence will seriously diminish any expansion of long-term timber supply and negate many of the opportunities previously outlined.
3. A further decline in the Australian furniture industry due to cheaper import replacements made from non-Australian timbers would have a significant impact on blackwood usage.
4. Currency fluctuations, particularly an abnormal rise in the value of the Australian dollar, would result in a higher export price for blackwood timber. Imported furniture would also become less expensive as would imported furniture timbers. As can be seen from Table 3, blackwood is currently reasonably priced (we would say under-priced) in Australia compared with imported timbers.

Table 3. Wholesale kiln dried timber prices Sydney: September 2002

Species	Price*, 150 mm and wider x 25 mm thick (\$ m ⁻³)
Tasmanian blackwood	2900
American black cherry	5365
American black walnut	4080
American hard maple	3970
American white oak	2570
European beech	2565
Jarrah	2500
Brazilian mahogany	4600
Sapele mahogany	2550
New Guinea rosewood	1740
Burmese teak	7500
Tasmanian oak	1700

*Exclusive of GST

Conclusion

Scope exists for 20–30% of Tasmanian blackwood timber production to be exported to three or four niche markets.

Exports should help even out variations in domestic demand for sawn wood and enable prices to be achieved that are more in line with imported equivalents.

Stable demand and potential for increased prices plus plantation regimes that can successfully produce quality sawlogs will encourage greater quantities of blackwood to be grown.

Native forest production levels need to be maintained to ensure that consistent volumes of timber are available to meet domestic and export demand.

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10

Blackwood Features in Demand: A Victorian Case Study

Jon Lambert

Woollybutt Pty Ltd

In an attempt to identify the requirements of blackwood for existing markets in Victoria, ten users were surveyed. Given that blackwood is sold almost entirely into feature markets, medium and small volumes of timber are regularly sold. Larger users of blackwood find that strong, reliable relationships with suppliers are important, however, all users are most concerned with sourcing blackwood of consistent colour that is suited to the products they make. Even sapwood is in demand by some users. Blackwood's unique appearance and traditional name have helped maintain its long-standing use in Victoria for feature products. Blackwood's main native competitors are red gum and myrtle beech, while teak is the highest competing exotic timber. A combination of good woodworking properties, distinctive appearance and consistent demand has kept blackwood in front of many of its competitors. Poor form, small logs and inconsistent colour are the species' biggest disadvantages. Price variations of between \$1500 m⁻³ and \$4500 m⁻³ were found to be related to the size, quantity and features of the wood. Users were most willing to pay a higher price for consistent colour in their orders. The demand for blackwood is highest amongst those organisations that only produce high-value feature products. All users surveyed predicted that the future demand for blackwood would remain stable or increase, confirming the species to be a safe investment for growers. Blackwood is best suited to high rainfall areas with a definite dormancy period to maintain consistent colour. Silvicultural management of plantation resources is likely to improve the value of blackwood by reducing the incidence of crooked and knotty trees.

Introduction

Blackwood (*Acacia melanoxylon*) grows naturally throughout large areas of southern and eastern Victoria, on sites receiving more than 600 mm of average annual rainfall (Costermans 1992). Commercial utilisation of the species is limited to wet sclerophyll forests, most applies coming from the Otways in Western Victoria – see Table 1. The average annual supply of blackwood from State Forests is about 1900 m³ y⁻¹ – see Table 2 – with the balance of supply coming from Gippsland in eastern Victoria. Additional unquantifiable volumes are supplied from private land.

Table 1. State Forest blackwood supply in regional Victoria (Source – DNRE 2002)

Region	Contribution to supply (%)
Otways	88.2
Central Gippsland	5.9
East Gippsland	5.8
Portland	0.06
Dandenongs	0.02

Table 2. Volume of blackwood from Victorian State Forests (Source – DNRE 2002)

Year	Sawlog (m ³ y ⁻¹)	Residual logs (m ³ y ⁻¹)
1989-90	400	
1990-91	1490	
1991-92	2930	
1992-93	2490	
1993-94	3230	
1994-95	1610	
1995-96	2370	7
1996-97	2380	
1997-98	1660	3
1998-99	2300	75
1999-00	2000	50
2000-01	420	13
2001-02	1500	
12-y average	1906	30

Continued reductions in native forest harvesting suggest that future supplies of blackwood will become more dependent on plantation-grown resources. This paper aims to identify the requirements of the existing Victorian blackwood market, in an attempt to guide current and future growers.

Case study method

Ten blackwood users were selected across Victoria to represent the spectrum of products and the variety of organisations using blackwood (see Appendix A). A survey was given to each of these organisations in an attempt to identify their current and future requirements for blackwood.

Discussion

Blackwood users and their products

Blackwood is a timber that is used almost entirely for feature products. The range of products made by the organisations surveyed included:

- Fine furniture (3 organisations) – dining tables and chairs, bookcases, chests, display cabinets and other occasional furniture made-to-order;
- Doors (1 organisation) – solid kitchen and bathroom doors and accessories;
- Flooring (1 organisation) – strip flooring and parquetry;
- General furniture (3 organisations) – dining and coffee tables, television units, buffets, lounge suite components;
- Guitars (1 organisation) – acoustic guitar bodies and necks, and components of electric guitars; and
- Rough sawn and value-added timber (1 organisation) – air- and kiln-dried sawn timber and panelling.

Blackwood log sources and annual requirements

Table 3 indicates the quantities of blackwood logs used by the organisations surveyed, and the areas from which these logs are sourced. An indication is also made as to whether alternative sources of blackwood have been tried.

Table 3 highlights the fact that eight of the ten organisations surveyed source blackwood logs from only one region. Six of these eight have sampled blackwood from alternative sources, but prefer a consistent supply of logs from one region. There are two main reasons for this:

1. Timber colour is one of the most important qualities in some products and large variations seem to exist between blackwood from various regions. Queensland blackwood is consistently thought to be lighter than Victorian and Tasmanian blackwood.

Table 3. Source and quantities of blackwood logs

	Source	Quantity (m ³)	Alternative sources tried?
1	Otways (Victoria)	47	No
2	Otways	336	Yes
3	Otways	1400	No
4	South-west Victoria	6	Yes
5	Tasmania	8	Yes
6	Tasmania	109	Yes
7	Tasmania	Unknown	Yes
8	Queensland	60	No
9	Otways and Queensland	15	No
10	Otways, north-east Victoria and Tasmania	230	Yes

2. Several organisations indicated that they had developed an excellent working relationship with their suppliers (i.e. mills), and this was a major factor in sourcing their blackwood.

Each organisation surveyed either hand-pick blackwood directly from their supplier, or receive timber based on tight specifications. The value of the end product seems to determine how fussy the organisation is in relation to timber selection.

Blackwood and its competitors

Each of the organisations was asked why they use blackwood. A variety of responses were given and these have been listed below in order of importance:

1. General appearance and colour (uniqueness and attractiveness);
2. Name and reputation;
3. Woodworking properties;
4. Consumer demand;
5. Local supply;
6. Price; and
7. Tonal properties.

The main timbers that were found to compete with blackwood did so on the basis of their colour, or their suitability to the end product. These competitors include:

Australian timbers

- Brown stringybark (*Eucalyptus baxteri*);
- Cypress pine (*Callitris* spp.);
- Drooping she-oak (*Allocasuarina verticillata*);
- Jarrah (*E. marginata*);

- Marri (*Corymbia calophylla*);
- Myrtle beech (*Nothofagus cunninghamii*);
- Queensland maple (*Flindersia brayleyana*);
- Silkwood (*Flindersia acuminata*);
- Red gum (*E. camaldulensis*);
- Silver wattle (*A. mearnsii*);
- Sugar gum (*E. cladocalyx*);
- Victorian ash (*Eucalyptus* spp.).

Exotic timbers

- African box;
- American oak;
- Indian rosewood (*Dalbergia latifolia*);
- Mahogany (*Swietenia mahagoni*);
- Monterey cypress (*Cupressus macrocarpa*);
- Rimu (*Dacrydium cupressinum*); and
- Teak (*Tectona grandis*).

The most common competing species are myrtle beech and red gum (Australian timbers), and teak (exotic timbers).

Blackwood's advantages, disadvantages and most appealing features

Advantages

Each organisation was questioned on the advantages of blackwood over its competitors. The responses can be grouped into three main categories – woodworking properties, natural characteristics and supply and demand. Each of these advantages is relative to the timbers they are being compared with.

- Woodworking properties – Blackwood's advantages include the absence of shrinkage, ease of handling, stability, good steam bending and the fact that it polishes well.
- Natural characteristics – Blackwood's distinctive colour and grain is seen as its most important advantage. Its mid-frequency sound is important in guitar manufacture, as is the fact that it is lighter than many other hardwoods.
- Supply and demand – Consistent customer demand, local supply, and blackwood's traditional name are all important advantages.

Disadvantages

The most commonly cited disadvantage of blackwood is the difficulty in colour matching. However one small market exists for extreme colour variations (found where the heartwood and sapwood

meet). This timber is supplied to a South Australian company which manufactures kitchen chopping boards.

Other user concerns include crooked trees, knotty wood and small log sizes, which result in an inconsistent supply of high quality wood. From a wood-working perspective, blackwood can be difficult to machine and work, and is a bit soft. Increasing price is also of concern.

Most appealing features

By far the most appealing feature to the organisations surveyed is the name and reputation that blackwood holds. Other important features include its colour and its ability to remain amenable to modern furnishings.

What drives the price of blackwood?

Each of the organisations were asked how much they pay for blackwood and what influences the price. In addition they were asked what feature they would be most willing to pay more for. The results are listed in Table 4.

Table 4. Blackwood prices and variations

Price paid (\$ m ⁻³)	Variation on price	Feature prepared to pay extra for
Unknown	Size of order	Consistent colour
Unknown	None	Consistent colour, select grade
Unknown	None	Fiddleback
Not available	Dimensions of wood, fiddleback	Consistent quality
Not available	Irregular supplier (cheap)	Consistent colour
1500-3000	Dimensions of wood and the size of the order. Moisture content and defects.	Older wood, fiddleback and birds-eye. No knots
1950-4500	Size of order	Consistent colour
2200-3000	Fiddleback, quartersawn	Fiddleback
2300	Size of order	Suitable size for products
2500-3000	Dimensions of wood	Consistent colour

Variations in price from \$1500 to \$4500 m⁻³ are largely related to the quantity of wood ordered, the dimensions of the wood (in the case of fine furniture organisations) and, occasionally, the amount of fiddleback. Consistency in colour was found to be the feature organisations were most willing to pay a higher price for.

Demand for blackwood

The demand for blackwood varies considerably with the quality of the products being sold. Organisations

that sell only high-quality furnishings find blackwood in very high demand. Those organisations covering a broad range of high and low-value products find blackwood only a small fraction of their sales. The breakdown of demand for each of the organisation categories is as follows:

- Fine furniture (3 organisations) – all of these organisations listed blackwood as having the highest or equal highest demand from their entire range of timbers;
- Doors (1 organisation) – equal highest demand with Tasmanian oak;
- Flooring (1 organisation) – 5% of the market out of 23 options;
- General furniture (3 organisations) – two of these organisations only sell Victorian ash and blackwood. One listed blackwood as having 70% of its sales, the other 5%. The third organisation suggests that blackwood was second only to silver wattle in demand;
- Guitars (1 organisation) – Blackwood guitars have the highest demand although they are not the highest sales, due to price; and
- Rough sawn and value-added timber (1 organisation) – 85-90% of products were blackwood.

Eight of the organisations surveyed found the demand for blackwood stable over the last 5 y. The other two suggested blackwood demand had dramatically increased without explanation. All organisations predicted the demand for blackwood to remain stable or increase in the future.

Conclusions

Blackwood's unique appearance and traditional name have been the most important features in maintaining its long-standing presence in feature timber markets. Its value, like most timbers, is influenced by the quantity and quality of the wood although the price remains high even for small quantities.

The 'take home' message for growers is that there is currently a good market in Victoria for blackwood of any colour, as long as that colour is consistent. Harrison (1975), in his research in blackwood plantations in South Africa, found that uniformity in colour is linked to having a definite dormant period in the growing season. He also found that darkness in blackwood and the amounts of red and brown pigment decreased with height of the tree. Therefore, warmer, temperate climates may be less suitable to growing blackwood of consistent colour. Separate markets may be required for upper logs if consistency in colour is to be maintained.

Producing features such as fiddleback are an enigma for plantation growers, and this type of feature is likely to remain 'luck of the draw' in tree growth. There is some encouragement, however, in the fact that short, crooked logs are a frustration for many users. This suggests that growth manipulation through silvicultural management will be important in improving returns for growers. This is perhaps more important for blackwood than many other native timbers given the propensity for low feature-grade recoveries from native forest logs.

The outlook for the demand of blackwood is stable to increasing. Given its strong performance over many years and its increasing international recognition, blackwood remains a safe investment for growers. Blackwood's main native competitors – red gum and myrtle beech – have similar supply problems from native forest and issues with tree form, and are therefore unlikely to suddenly overrun blackwood. Problems with the consistent supply of teak have helped maintain blackwood as the preferred option when these two species compete. This is further confirmation of the investment security of blackwood.

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- Ken Luke – Melbourne Timber Flooring, Kensington
- Les Kennett – Black Forest Furniture, Macedon
- Melinda Andrew – Tudor Doors, Hallam
- Patrick Evans – Maton Guitars, North Bayswater
- Paul Simons – Lifestyle Furniture, Nunawading
- Peter Adams and Staff – Otway Hardwoods, Forrest

11

Blackwood Sawlog Sales in Tasmania

Nigel Foss

Private Forests Tasmania

Introduction

Tasmanian blackwood sawlogs have been harvested, sold and processed since the 1830s. What may have been initially viewed as an unlimited resource of high quality logs has gradually diminished over time through land clearing, sub optimal silvicultural practices and reservation processes.

Currently, many private landowners/farm foresters are prepared to speculate on what they perceive as an opportunity to produce blackwood sawlogs to meet future market demands.

However, any farm forester evaluating whether it is a commercially viable proposition to improve the silvicultural management of their native forest blackwood, or to establish plantations of this species, would quickly discover that based on current stumpages, returns may be greater from alternative land uses.

Apart from encouraging advances in blackwood silviculture there are also some positive signs that farm foresters could increase their stumpages to a point where this type of venture would be worthwhile.

State resource

Forestry Tasmania as the manager of State Forest is responsible for the State's largest resource of native blackwood. Processors source the majority their blackwood sawlogs from State Forest.

Under the Tasmanian Forest and Forest Industry Strategy (TFFIS) of 1989-90 the blackwood sawlog target to be made available to millers from Crown Land has been set at 10 000 m³ y⁻¹. The allocation amount has only been reached twice since 1989 (see Fig. 1).

It is estimated that blackwood sawlogs sourced from private property would not exceed 1000 m³ annually

(excluding Gunns Limited who process their own logs at their own mills).

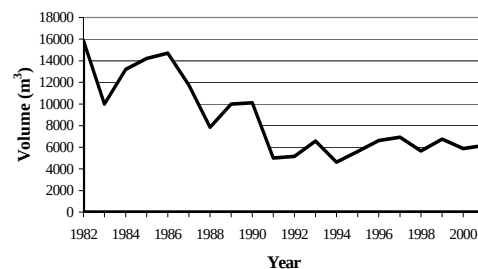


Figure 1. Volume of blackwood sawlog harvested from State Forest (Source – Forestry Tasmania)

Blackwood sawlogs currently processed by millers are mostly sourced from clear felling operations that are conducted in previously selectively harvested native forest from State Forest blackwood swamps in the Circular Head region of NW Tasmania. The remainder is located on both State Forest and private property in both mixed and wet sclerophyll forests found throughout Tasmania. Small volumes of sawlogs are sourced from selective harvesting conducted in Rainforest.

One of the last virgin stands of blackwood was harvested in 1979.

As one would expect and (current millers agree), the earlier selective harvested operations removed the best of the native forest resource, and has left a resource high in variability.

With an anticipated rotation of 70 y, and current silvicultural practices, Millers are hoping for a more consistent supply of high quality blackwood sawlogs in the future.

The annual allocation of 10 000 m³ from State Forest consists of both Category 4 and Utility grade sawlogs. Specifications for both categories are listed in Table 1.

Table 1. Blackwood sawlog Category 4 (Cat 4) and Utility Specifications (Source – Forestry Tasmania)

Property	Cat 4	Utility
Minimum length	3.1 m	2.5 m
Minimum small end diameter	30 cm	25 cm
Limbs and bumps 1	3 or 4 faces clear (in 3.1 m lengths)	2 of 4 faces clear (in 2.5 m lengths)
Spiral	1 in 8	1 in 8
Sweep	1 in 7	1 in 7
Scars 2	¼ face – 3.1 m in 3.1 m	½ face – 2.5 m in 2.5 m
Borers 2	Nil evident	No significant evidence
End defect	End-diameter 30-40 cm ub - Minimum of 10 cm radial ring clear of heart and sap End-diameter > 40 cm ub - As per Sawlog End Defect Limits Table	End-diameter < 30 cm ub – Nil End-diameter 30-40 cm ub - Minimum of 10cm radial ring clear of heart and sap End-diameter > 40cm ub - As per Sawlog End Defect Limits Table

A third category - Out-spec - is not included in the above target but is an optional grade that is available to the millers. This type of log does not meet either Cat 4 or Utility specifications. Out-spec logs that are not required by the millers are usually sold as pulp.

A sawlog can contain more than one category.

Millers who purchase sawlogs from private property normally apply these same specifications.

Privately-owned resource is not included in the TFFIS target.

Both private and State Forest native forest resource that is currently available for harvesting is secured by the Federal Regional Forest Agreement that is current to 2017.

Log buyers

The three major purchasers of blackwood sawlogs in Tasmania, in alphabetical order are-

- Britton Brothers
- Corinna Timbers
- Gunns Ltd.

There are many other sawmills, both stationary and portable, that also purchase smaller volumes.

Mechanisms of sale

Forestry Tasmania has Contracts of Sale for 5500 m³ y⁻¹ with Corinna Timbers and Britton Brothers.

The remainder of the annual blackwood sawlog resource from State Forest is sold by open tender in mixed category parcels of 100-500 m³ lots.

Most privately-owned blackwood are sold as part of fully utilised harvesting operation undertaken by a miller's own contractor. The grower normally enters into a sale agreement with the miller that covers all saleable timber of all species and grades.

Many landowners engage Farmwood Tasmania Treegrowers Co-operative to harvest and market their logs as an independent agent.

As portable sawmills have become more prevalent, smaller volumes and less accessible logs on private land have been sold. These trees are usually marketed by word of mouth.

Some landholders choose to contract a miller to process their own blackwood logs and sell the cut timber.

Portable sawmilling costs around \$50 m⁻³. Parcels of air-dried blackwood timber are often seen advertised in local papers for \$1500 - \$2000 m⁻³.

Returns

Figure 2 summarises the average annual blackwood royalties from State Forest since 1982.

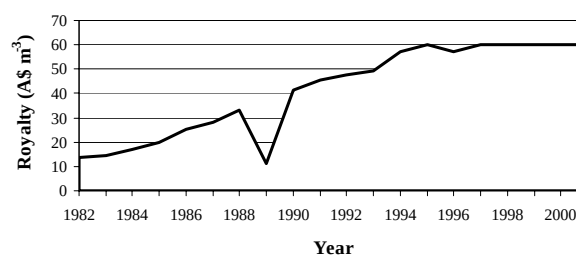


Figure 2. Royalty for blackwood sawlogs from State Forest (Source - Forestry Tasmania)

Royalty from Sate Forest has had an annual average increase of about 8% since 1982.

Table 2 lists the current approximate base royalties from State Forest for the three grades of blackwood sawlog.

Table 2. Base royalty for blackwood log grades in 2001

Category	Royalty (\$ m ³)
Category 4	60
Utility	30
Out-spec	15

The above base royalties have been at these levels for the past 5 y. Millers expect an increase in the near future.

Based on anecdotal evidence, the winning tender for State Forest tendered parcels has been up to 100% above the current base royalty rates.

Stumpages offered for privately-owned blackwood sawlogs are usually identical to the State Forest royalties.

As most blackwood sawlog sales from private property involves small volumes, the grower is usually not in a position to negotiate stumpages higher than State Forest base royalties.

Millers are currently achieving an average log recovery rate of around 25%.

Milled recovery rates of up to 40% can be achieved from logs of 50-60 cm in diameter with a uniform heart and no shake. Millers indicate that they could afford to offer higher returns to growers of logs meeting these preferred specifications.

Conclusion

Supply of blackwood sawlogs from State Forest, and base royalty rates have been consistent over recent years.

Growers need to aim to grow a sawlog that allows millers to increase their rates of sawn recovery.

Growers with smaller volumes of blackwood sawlog to sell, and who wish to improve their returns, should consider-

- Alternative marketing methods such as tendering.
- Joint marketing with other growers.
- Further downstream processing.

12

Farm-Level Blackwood Experience: Tasmanian Observations

Andy Warner

Private Forests Tasmania

‘Experience is the name everyone gives to their mistakes – life would be very dull without them.’
Oscar Wilde (Lady Windemere’s Fan)

Blackwood grows in native forest stands throughout many Tasmanian private property areas, with substantial areas having been harvested in the North West since early European settlement in the 1850s. Encouragement of private plantations of blackwood commenced only recently in the 1980s.

Experience in plantation blackwood management has increased exponentially over the past 20 y with major lessons for farm forestry highlighting the importance of:

- *A clear long term plan – including an understanding of the financial and revenue flow implications of rotations as long as 40 y or more.*
- *A recognition that eucalypt and radiata pine nurse crops may require sophisticated and expert management, while native blackwood silviculture may also not be an appropriate model.*
- *Understanding the financials – the Farm Forestry Toolbox developed by Private Forests Tasmania provides a practical aid to private growers in evaluating longer-term regime options and pricing structures.*
- *More sophisticated marketing – evolving a pricing parity that reflects the value of blackwood as a truly high-value ‘ specialty timber’.*

The major and enduring challenge for blackwood growers, harvesters, processors and manufacturers is not to claim a part of someone else’s piece of the blackwood value cake, but rather to continue to make the cake larger for everyone. This will involve the consumer willingly paying a premium price for quality blackwood products.

Early Tasmanian blackwood farm forestry

Tasmanian experience with blackwood (*Acacia melanoxylon*) as a farm forestry plantation species is relatively recent. The perceived slower growth rates and relative natural abundance of mature blackwood stands in the wetter coastal areas of the State meant that early plantation activity mostly involved eucalypt species for pulpwood and radiata pine for sawlog.

It was not until the early 1980s that blackwood establishment grants were offered as part of a broader scheme to encourage more private planting activity by the recently formed private forestry

division within the Forestry Commission. The grants provided direct assistance with site preparation and

planting for about 100 ha over a six-year period. Some enrichment planting in native forest following logging was also funded. Many of the plantations involved nurse crops of either eucalypts or radiata pine. Despite detailed plans of operations, active management of most these stands lapsed as there was only very limited on-ground assistance available for private landowners, especially in the north west.

The formation of Private Forests Tasmania (PFT) in 1994 as the first independent agency to facilitate sustainable and active forest management on private

land, in conjunction with successful applications for funding support under the Farm Forestry Program of the Natural Heritage Trust provided the impetus for the current revitalized interest in blackwood as a farm forestry option.

So what have we learnt from our limited dealings with blackwood over the past 20 y?

Blackwood farm forestry lessons learnt

1. **Native blackwood can be a misleading teacher** – Blackwood swamps with a natural nurse crop of native understory species encouraging good form for blackwood early in the rotation seemed simple to copy. However, in farm forestry plantations the rapid growth rates of young nurse crops such as *Eucalyptus nitens*, *E. globulus* or radiata pine can result in the blackwood being very quickly suppressed if the nurse crop is not kept in careful balance, especially if pulpwood returns are sought from the harvest of the nurse crop.
2. **Grower enthusiasm needs to be supported by expertise** – Without adequate support structures, especially for technical matters, mistakes can quickly become costly and the commitment wane!
3. **Grower commitment is required to a ‘marathon’, not a ‘sprint’ race** - Expenditure will be over a longer time (40 y plus) and involve more active management in the first decade than for pulp crops (12 y plus) or even most clearwood crops (25 y plus).
4. **Enthusiastic opinions need to be supported by appropriate research** - Acceleration of research on blackwood/nurse crop interactions, browsing management and the refinement of options for growers will help to encourage confidence regarding a range of silvicultural issues. Alternative nurse crops to the ‘big 3’ (*E. nitens*, *E. globulus* and radiata pine) need to be researched in a farm forestry context (small stands, high fertility sites, intensive browsing pressure, managing trees in and near watercourses).
5. **Uncertainty on the financial returns has discouraged some Tasmanian growers** – A lack of alternative market options to the limited domestic ones and the perceived low value for a ‘specialty species timber’ as reflected in the blackwood royalty from Crown native forests can make it all seem too hard!

Acting on these lessons

In Tasmania we have aimed to address the issues raised above through a concerted effort to empower growers, so they can take informed responsibility for their forestry decisions. In addition to field days, meetings and mailouts (such as the BIG newsletter), Tasmanian farm forestry experience over the past 5 y provides some innovations in this regard, utilising funding support from the Farm Forestry Program of the Natural Heritage Trust.

Providing growers with a road map to success –

In NW Tasmania the substantial presence of pulpwood and woodchip companies over the past 30 y has tended to promote shorter-term pulpwood opportunities, resulting in less focus or interest on potential longer-term clearwood options. With a time-frame extending over decades, landowners benefit from a written plan, detailing:

- Map displays of options for different parts of their land
- Their forestry options and their associated time and money inputs
- Expected returns predicted using the Farm Forestry Toolbox (see below) and appropriate warnings regarding assumptions made, and
- The sensitivity to changes in volume, price and interest rates.

PFT has a Farm Forestry Property Planning pilot project providing these outputs using maps, graphics and tables to present useful information to growers (see Fig. 1).

Market information regularly and widely available –

Unlike other farm crops where prices are often reported on a weekly basis in newspapers, timely regional forestry information in Australia is less accessible. A PFT pilot project has produced four market reports over the past 2 y. This has included data on product volumes, some pricing information and explanatory articles on other relevant issues including operational costs, log grades and farm forestry management case studies. Options for ongoing funding and distribution are being considered.



Developing more user-friendly technical information – The Farm Forestry Toolbox is a set of user-friendly Personal Computer tools that has been developed by PFT to help landowners better understand some of the technical issues associated with managing trees. The Inventory tool includes two blackwood tree volume equations - for New Zealand plantation and Tasmanian native blackwood. The Stand Manager tool (see Fig. 2) helps growers to quantify the financial implications of cash flows over time. Given the current Natural Resource Management emphasis in Australia, there may be increasing opportunities to include non-wood values in the analysis.

The aim of the scenario analysis below is to show trends rather than focus on the absolute values produced using these assumptions. Like all analysis, it is important to be familiar with the model and any assumptions, as GIGO – garbage in and garbage out – otherwise may apply!

Costs are based on recent trials in NW Tasmania involving current establishment and pruning costs applied in year 0 dollars. Additional later rotation

costs cover general maintenance, inventory and pre harvest planning costs and have been inflated at 4% every 4 y. (see Appendix 1).

Volumes are based on the Tasmanian tree equation, assuming a DBHob of 55 cm and height of 27 m, with Category 4 grade recovery from the pruned butt log of 6.1 m = 1.1 m³ and an additional Feature-grade length of 5 m from the unpruned section = 0.6 m³. (See Nigel Foss's paper presented earlier for details of the log grade specifications.)

Stumpages are ranged from \$50 to \$800 m⁻³ of Category 4 log. Feature-grade stumpage is assumed to be 40% of the Category 4 stumpage. No financial value has been allocated to craftwood, firewood or pulpwood from the balance of the tree, nor to non-wood values such as shelter, watercourse protection, etc.

Interest rates are set at 4% for this analysis, with the range in stumpage allowing for some sensitivity analysis.

Site productivity is based on rotation lengths of 40 y (MAI = 12), 60 (MAI = 8) and 80 (MAI = 6). MAI is the mean annual increment for Category 4 and Feature wood only.

Toolbox models cash flows as at 30 June in the year in which the costs/revenues occur.

The impact of the interest rate over time can be substantial for blackwood regimes. Table 1 shows that for an annual compounded interest rate of 2% it takes about 35 y to double the starting amount, but for an interest rate of 4% it takes only about 18 y.

Another way to demonstrate the impact is to consider the compounded cost from an expense at establishment over a 40-y rotation. If a 4% increase occurs every year until year 40 the original cost compounds by a factor of nearly 5.

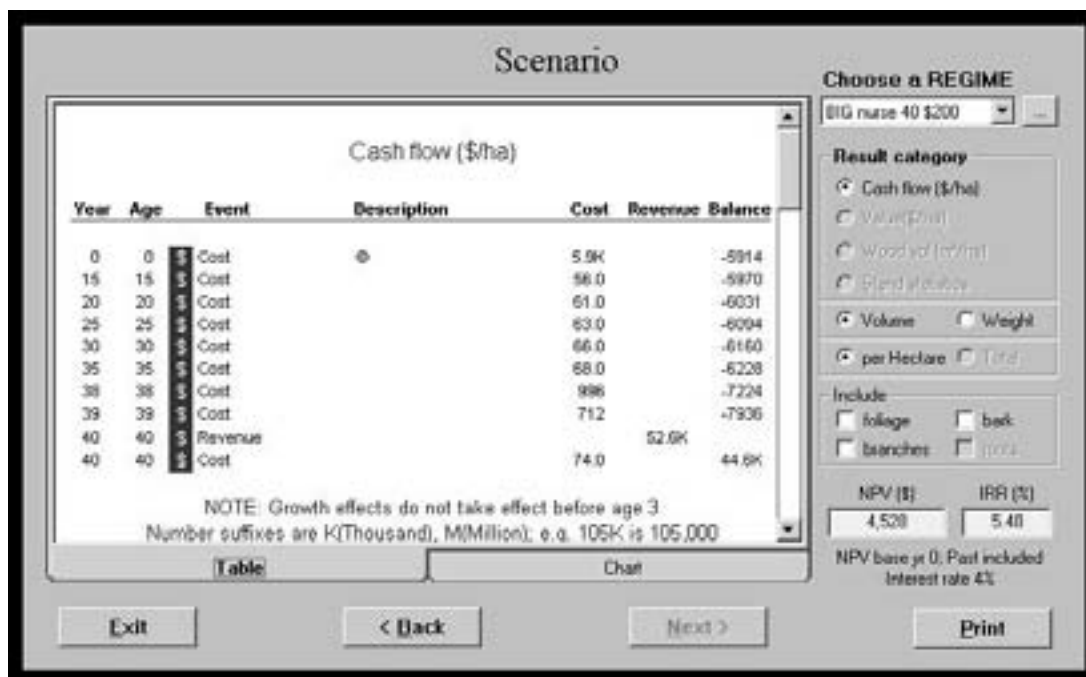


Figure 2. Farm Forestry Toolbox - Stand Manager output for \$200 stumpage

Table 1. Effect of interest rate on the time to double an original amount

Compound interest rate (%)	Time to double original capital (y)
1	70
2	35
3	24
4	18
5	15
6	12
7	11
8	9
9	9
10	8

For a 4% increase every second, third and fourth year, the increase over 40 y is 2.2, 1.7 and 1.5 times respectively.

The impact of rotation length (reflecting lower mean annual increment of products) is shown in Figure 3.

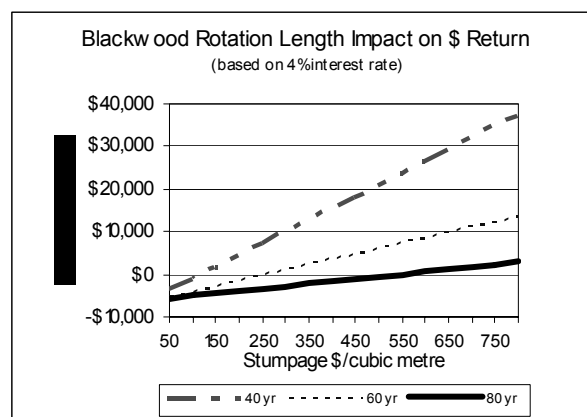


Figure 3. Impact of rotation length on net present value

Observations

1. Current Tasmanian ‘royalties’ (around \$60 m⁻³ for Category 4 native blackwood logs) produce an uneconomic return (NPV is negative at 4% interest rate) for all three rotation lengths.
2. The necessary Clearwood stumpage needed to break even (NPV = 0) is:
 - a. Between \$100 and \$150 m⁻³ for a 40 y rotation.
 - b. Between \$250 and \$300 m⁻³ for a 60 y rotation.

- c. Between \$500 and \$550 m⁻³ for an 80 y rotation.
3. Allowing for the current Category 4 stumpage of about \$60 m⁻³ to increase by relatively small amounts will achieve these stumpages for the 40 y scenario (see row 1 in Table 2).

Table 2 . Break-even stumpage interest rate increase required for the scenario rotation lengths

Rotation (y)	Breakeven stumpage interest rate (%) increase required-			
	Every y	Every 2 y	Every 3 y	Every 4 y
40	2	3	4	6
60	3	5	8	10
80	3	6	9	12

4. Using such analysis tools may also help provide impetus to the necessary marketing push to achieve the stumpage increases.
5. If we extend the scenario volume assumptions used above and allow a fallow period of one year to replant, the amount of plantation needed to provide a sustainable plantation supply of Clearwood blackwood can be estimated (see Table 3). Earlier papers have indicated that the current annual supply of native blackwood from Tasmania is about 8000 m⁻³ y⁻¹, so 500 ha of well-managed plantation over a 40-y period would provide an additional 2500 m⁻³ annually.

Table 3. Estimated plantation area for sustainable supply

Rotation length (y)	Area (ha) required to produce sustainable clearwood volume of-			
	2500 m ³	5000 m ³	7500 m ³	10 000 m ³
40	472	945	1417	1889
60	703	1406	2108	2811
80	933	1866	2800	3733

Conclusions

1. Plantation blackwood is an unproven product with both sustainable market quality and quantity still to be established. Native blackwood provides some confidence for the future since it has an established domestic market and reasonable export opportunities, albeit at current prices that seem to under value its ‘special species timber’ status.
2. In Tasmania, PFT has funded a blackwood planning officer position with seed funding for nine months to develop a regional plan for

blackwood opportunities and involve current and potential growers in a managed network. However, the major push for increased blackwood returns to growers and processors will require extra activity by more than the Tasmanian players!

3. While growing plantation blackwood is coming of age in terms of moving away from applying a traditional radiata or eucalypt silviculture to address its specific problems, there is still a shortage of published results of relevant, disciplined stand management outcomes that can be used in a farm forestry context. The Farm Forestry Toolbox offers the first public sourcing of blackwood volume equations in a farm forestry user-friendly context. Other national, trans-Tasman and international linkages associated with managing, modelling and marketing should be developed and promoted for mutual benefit.
4. Marketing opportunities will be enhanced by the gradual development of sufficient sustainable wood supply to meet a regular demand. This will require innovative developments for either logs or timber such as:
 - The collective sale of small amounts from farm forestry woodlots;
 - More refined segregation by quality and price;
 - Alternative marketing approaches such as woodyards and web-based sales;
 - International as well as domestic marketing;
 - Developing relevant certification appropriate to a high value commodity.
5. Future private plantings will result if there is good market demand that provides sufficient returns to the grower. We are reaching a critical stage if there is to be an expanding or even a sustainable supply of blackwood. A principal need is to empower growers so they can make more informed decisions towards greater future financial security – and get cracking on planting and managing their stands!

There is an important role for BIG and AMIGO initiatives in this process.

The major and enduring challenge for all of us involved with blackwood is not to claim a part of someone else’s piece of the blackwood value cake, but rather to continue to make the cake larger for everyone – grower, harvester, processor, and manufacturer. This will involve the consumer willingly paying a premium price for quality blackwood products.

Appendix 1 Costs and the year applied for the modelled scenarios

Item	Year	Cost ha ⁻¹ (\$)	Comments
1 Seedlings ordered - blackwood	-1	250	
2 Site clearing	-1	100	
3 Weed control 1 - preplant	-1	100	Roundup only
4 Fencing/guards/game control	-1	1900	\$1500 for blackwood + \$400 for shelter crop
5 Plantation layout	0	40	
6 Weed control 2 - preplant	0	150	Residual herbicide as well as Roundup
7 Planting blackwood	0	200	Planted in groups of 3 on grid layout
9 Seedlings ordered - shelter crop	0	75	Shelter crop
8 Weed control 1 - post plant	1	150	Blackwood
10 Weed control 1 - preplant	1	50	Shelter crop
11 Weed control 1 - post plant	1	75	Shelter crop
12 Form prune and maintenance	2	120	
13 Clearwood and form prune	3	240	
14 Form prune and maintenance	3	160	
15 Clearwood and form prune	4	240	
16 PSC lift 1	4	183	Immediately after clearwood and form prune
17 Form prune and maintenance	4	120	
18 Thin blackwood	5	80	Reduce to best 2 out of 3
19 Clearwood and form prune	5	200	
20 Form prune and maintenance	5	160	
21 Clearwood and form prune	6	200	
22 PSC lift 2	6	197	Immediately after clearwood and form prune
23 Form prune and maintenance	6	80	
24 Thin blackwood	7	100	Reduce to best 1 out of remaining 2 in group
25 Clearwood and form prune	7	140	
26 Clearwood and form prune	8	140	
27 PSC lift 3	8	210	Immediately after clearwood and form prune
28 Thin nurse crop	9	80	Done by stem injection
29 Thin remaining nurse crop	10	80	Done by stem injection
30 Inventory prior to harvest		700	Includes inventory 2 y prior to harvest age
31 FPP costs for harvest		500	Includes planning cost 1 y prior to harvest
32 Maintenance and some plot m'tment		50	Every 5 y from age 15 onwards

Regime based on:

750 blackwood ha⁻¹ planted in groups of 3
 250 *E. nitens* planted as nurse crop 1 y after blackwood
 Nurse crop is non commercially thinned in year 9 and 10
 Protectors or game proof fencing assumed at \$1900 ha⁻¹
 Form prune September and January linking in with clearwood pruning
 No site cultivation as too steep

Costs based on:

3 ha for Pruned Stand Certification (PSC) and browsing
 Assume \$20 hr⁻¹ for labour
 Costs to year 11 applied in year 0 as all in year 0 (current) values

13

Acacia melanoxylon Provenance and Layout Research in South-western Victoria

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Introduction

Acacia melanoxylon (blackwood) occurs naturally in south-western Victoria, Australia, but often as a small, slow-growing tree of poor form for timber production. On sites of marginal rainfall or poor soils, pruned blackwoods may also be particularly susceptible to borers. However, the relatively high value of quality blackwood timber means farm forestry for production of clearwood sawlogs may be feasible on optimal sites, particularly if value-adding by portable milling is possible. This research tested the performance of provenances of *A. melanoxylon* in SW Victoria. The effects, on blackwood growth and form, of planting alternate rows with *A. mearnsii* (black wattle), as a nurse crop, were also investigated.

Materials and methods

In spring 1993, *A. melanoxylon* provenance and layout trials were established at two sites near Hamilton in SW Victoria, Australia (Table 1).

Table 1: Sites of *Acacia melanoxylon* provenance trials in SW Victoria

Attribute	Location	
	Hensley Park	Vasey
Mean annual rainfall (mm)	680	650
Landzone	Basalt plains	Laterised tablelands
Altitude (m)	240	250

The main experimental factors were provenance (Table 2) and layout. Twenty provenances were included at each site, with 19 in common. The initial layout treatments were (i) *A. melanoxylon* (2222 trees ha⁻¹) and (ii) *A. melanoxylon* (1111 trees ha⁻¹)

with alternate rows of *A. mearnsii* (555 trees ha⁻¹) as a nurse crop. The rows were 3 m apart. The lattice design comprised two replicates at each site; the provenance unit being a line-plot of 10 trees.

At 5 y, every second nurse row at Hensley Park was removed (to waste) to reduce competition. At Vasey, a similar thinning of the nurse crop was carried out at 5.5 y.

Blackwood form was assessed at 6 y, according to a seven-point scale for acacias (Bird 2000), where scores 1-4 represent trees with potential to produce sawlogs, given pruning. Some form-pruning for clearwood production had been done already. The form scores were then grouped into the following three classes: Grade-1 sawlog (scores 1-2), grade-2 sawlog (scores 3-4) and non-sawlog (scores 5-7). The number of trees in each class, for individual sites, was analysed by ordinal logistic regression (Genstat 5 Committee 1997).

We measured height and diameter at breast height (DBH) of all blackwoods at 8 y. Clearbole pruning (Bird 2000) had not yet commenced. Following measurement, most of the remaining *A. mearnsii* was thinned to waste, and heavy pruning and thinning of blackwoods was carried out. Data from individual sites were analysed using residual maximum likelihood (REML) (Genstat 5 Committee 1997). The percentage of surviving trees was calculated. A previous collection of growth data occurred at 6 y.

Results and discussion

Overall performance

Results of growth, survival and form assessments are presented in Figure 1. Trees at Hensley Park performed better than did those at Vasey, probably due to higher rainfall and fertility. However, growth

was very slow at both sites. Overall, mean height and DBH of 8-y-old trees at Hensley Park were 5.1 m and 61 mm, respectively. At Vasey, the figures were 4.2 m and 53 mm, respectively. Growth was considerably slower than at sites in New Zealand (Nicholas *et al* 2001), Tasmania (Nielsen and Brown 1996; Nielsen and Brown 1997) and NE Victoria (Stackpole 2001).

Mean survival at 8 y was 91% at Hensley Park; some trees had died since age 6 y, when 97% of trees were alive. At Vasey survival at 8 y was only 68%. Losses since age 6 y, when survival was 81%, were also greater. This was probably due to greater competition for moisture at Vasey as a result of lower rainfall, northerly aspect and later thinning of the nurse crop. Trees at Vasey also suffered severe early damage from kangaroos and this probably increased variation in the data, particularly for survival and form.

At both sites, there were significant differences ($P<0.05$) in height, DBH and form among the provenances tested. Differences in growth and form between pure blackwood stands and nursed stands were also observed. There was no significant interaction between provenance and nurse crop treatments.

Provenance growth

The two Tasmanian provenances tested (A and B) ranked very highly for growth at both sites (Fig. 1).

There was a trend for provenances from lower altitude to grow faster. However, this trend was reversed amongst provenances from Central Victoria. High-altitude provenances from Yarrangobilly (T), Tallaganda SF (S) and Sassafras (R) in the Snowy Mountains of NSW showed very poor growth. Among low-altitude provenances, those from areas of higher rainfall often performed better. However, there is some danger, in relatively low-rainfall areas such as the trial locations, that higher-rainfall provenances could be susceptible to drought stress and infestation with borers.

Provenance rankings were different between sites. Provenances can be grouped according to region (Table 2). Rankings of these groups, in terms of growth, were similar for the two sites, except that the single provenance from NE NSW performed relatively badly at Vasey.

These trials had 13 provenances in common with provenance trials in NE Victoria (Stackpole 2001). Provenance groups from Tasmania and the Otway Ranges performed relatively better in SW Victoria than in a trial at Euroa (rainfall 954 mm, altitude 540 m). Conversely, Victorian Central Highlands provenances performed relatively better at Euroa. These differences were probably due to the higher altitude and more frequent frosts of the Euroa site.

Considerable provenance research has been done in Tasmania (Nielsen and Brown 1997), but mainly with Tasmanian provenances. Hence, few results can be compared with our trials.

Table 2. *Acacia melanoxylon* provenances trialled in SW Victoria

Prov	Provenance location	State	Region	Nursery/seedlot	Latitude (° ' S)	Longitude (° ' E)	Altitude (m)
A	Red Creek, Redpa	Tas	NW	ATSC 18084	40 55	144 46	50
B	'Fairfield', Cressy	Tas	N Midlands	TAS 1992	~41 40	~147 05	160
C	Carlisle River	Vic	Otways	D 04/92/A001	38 36	143 22	150
D	Pennyroyal Valley Rd	Vic	Otways	ATSC 17194	38 26	143 22	200
E	25 km SE Mount Gambier	SA	SE	ATSC 16526	37 57	140 56	40
F	Crawford River, W of Hotspur	Vic	SW	PVI 1992	37 56	141 30	150
G	Port Fairy Rd, Hamilton	Vic	SW	PVI 1992	37 52	141 58	175
H	Melville Forest (Koroite Ck)	Vic	SW	Larapinta	37 25	141 27	250
I	Melville Forest (Vasey Rd)	Vic	SW	Larapinta	37 23	141 50	250
J	Wando Dale, Satimer Rd Nth	Vic	SW	PVI 1992	37 27	141 36	300
K	13.2 km NNW of Welshpool	Vic	Gippsland	ATSC 16513	38 34	146 22	250
L	S of Traralgon	Vic	Gippsland	ATSC 15536	38 25	146 30	550
M	E of Seymour	Vic	Central	ATSC 17229	37 04	145 24	640
N	Lancefield	Vic	Central	ATSC 18021	37 14	144 46	500
O	Arthurs Ck Rd, Yan Yean	Vic	Central	ATSC 17230	37 34	145 08	215
P	Diggers Rest	Vic	Central	ATSC 17075	37 37	144 44	180
Q	15 km S of Bonang	Vic	E Gippsland	ATSC 16272	37 19	148 42	300
R	Sassafras	NSW	Snowy Mts	ATSC 17958	35 06	150 16	740

Prov	Provenance location	State	Region	Nursery/seedlot	Latitude (° ' S)	Longitude (° ' E)	Altitude (m)
S	Tallaganda SF	NSW	Snowy Mts	ATSC 18309	35 26	149 31	900
T	5 km E of Yarrangobilly	NSW	Snowy Mts	ATSC 16873	35 38	148 30	1000
U	Lawlers Ck, NNE of Stroud	NSW	NE	ATSC 16725	32 11	151 51	150

However, trials at Meunna (rainfall 1600 mm, altitude 250 m), NW Tasmania, included several mainland provenances. Growth of southern Victorian (Otway Ranges and Gippsland) provenances was comparable with that of Tasmanian provenances. The only southern NSW (Tallaganda) provenance to be tested ranked lower than most Tasmanian provenances, while provenances from Queensland performed poorly. The Tasmanian research resulted in the grouping of provenances according to similarities in climate, soil, altitude and location.

Provenance form

In general, provenances with good growth also had relatively good form (Fig. 1); there were no significant differences in form among faster-growing provenances. At Hensley Park, Mount Gambier (E) provenance ranked best for form, and was significantly ($P<0.05$) better than 9 provenances. Local provenances, particularly Melville Forest (I) and Wando Dale (J), also ranked well. There were similarities in results of this trial and the Euroa trial (Stackpole 2001). At both sites, Mt Gambier (E) and Red Creek (A) ranked highest among the shared provenances, while Lawlers Creek (U), Sassafras (R), Diggers Rest (P) and Tallaganda SF (S) ranked lowest of all provenances, with significantly ($P<0.05$) worse form than most other provenances. All NSW provenances had poor form and most of these came from high-altitude locations. This result was similar to that at Vasey. However, at Vasey, the Mount Gambier (E) provenance did not show good form; Pennyroyal Valley (D), Welshpool (K) and Seymour (M) provenances had the best rankings.

Nurse crops

Nurse crops of *A. mearnsii* had significant impact on blackwood growth and form (Table 3), with similar effects at the two sites. Nurse rows reduced height by more than 20% and DBH by around 40%, although we removed half of the nurse rows at 5-5.5 y.

Table 3. *A. melanoxylon* height, DBH, survival and stocking of grade-1 and grade-2 sawlogs, under *A. mearnsii* nurse crops in SW Victorian trials. Values are expressed as percentage difference in relation to pure blackwood stands.

Attribute	Location	
	Hensley Park	Vasey
Height	23	22
DBH	41	37
Survival (%)	4	16
Sawlog1 (No. ha ⁻¹)	31	30
Sawlog2 (No. ha ⁻¹)	47	36

Overall, only 15% of trees at Hensley Park were potential grade-1 sawlogs, and 5% of trees at Vasey. The use of *A. mearnsii* nurse crops increased the proportion of blackwoods rated sawlog-1 by 38% and 41% at the respective sites, however the proportion was still low (Fig. 1). In terms of stocking per hectare, there were more sawlog-1 trees in the pure blackwood treatments than under the nurse crops (Table 3).

Most blackwoods (mean 85% at Hensley Park and 69% at Vasey) were classed as sawlog grade 1 or 2. This represents the maximum proportion of potential sawlogs, given pruning. Using a nurse crop improved this percentage (Fig. 1), but again, in terms of sawlogs per hectare, nurse crops were detrimental (Table 3).

Across the Hensley Park site, there were enough blackwoods rated sawlog-1 to produce a final stocking of 200-300 grade-1 sawlogs ha⁻¹, given pruning. At Vasey, this would only be possible amongst provenances of the best form, such as Pennyroyal Valley provenance (D). At neither site would a suitable final stocking of sawlogs be feasible without pruning.

Conclusion

Blackwood growth in SW Victorian trials was poor. If blackwood is to be grown successfully in the area, optimal sites, probably of small area, with shelter and high moisture availability must be selected, and a long time until harvest anticipated. On the trial sites, southern Australian provenances of lower altitude and higher rainfall, including provenances from Tasmania, Otway Ranges and Crawford River,

generally ranked highest for growth. Some local SW Victorian provenances and higher-altitude Central Victorian provenances also performed relatively well. Faster-growing provenances generally had relatively good form.

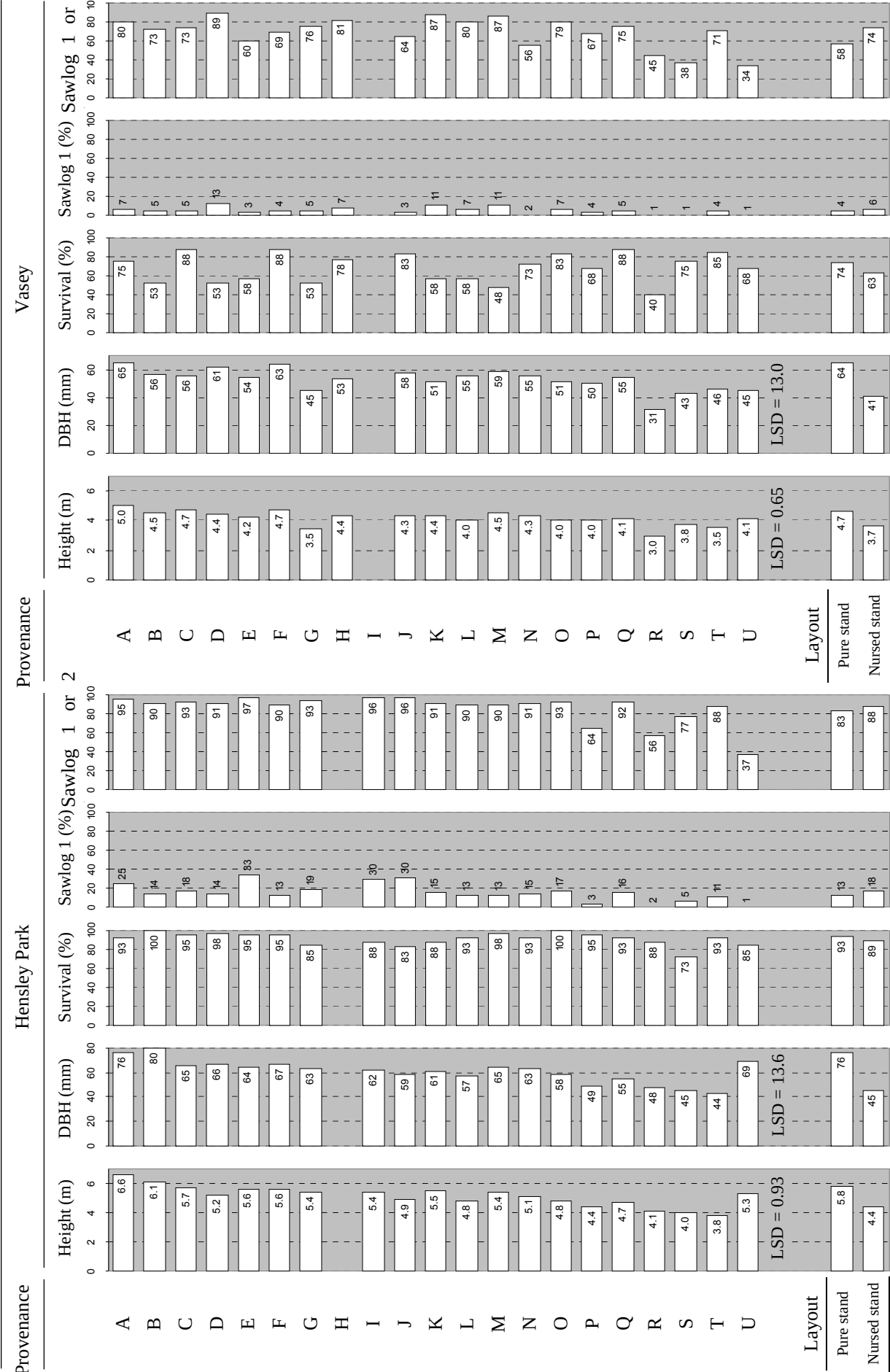
A. mearnsii nurse crops reduced blackwood growth considerably. The species was too competitive on the trial sites in SW Victoria and, if used as a nurse crop, *A. mearnsii* should be removed earlier than at 5 y. However, in terms of well-formed trees per hectare, black wattle as a nurse crop had a negative influence, and its use is questionable. Management by timely pruning and thinning is probably a better way to optimise growth and form. This intensive management may be best suited to small woodlots on farmland.

Management is probably also more important than provenance selection, as long as basic rules in provenance selection are followed, such as matching provenance to site according to altitude (frost tolerance) and general climate. Provenances from further north than southern NSW should not be planted in southern Victoria and Tasmania, and provenances from low altitude should not be planted at altitude, where heavy frosts are likely.

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Figure 1. (next page) Mean height, diameter at breast height (DBH) and survival at 8 y, and proportion of potential grade-1 and grade-1-or-2 sawlogs at 6 y, for *A. melanoxylon* provenances and planting layouts in trials in SW Victoria. The least significant difference (LSD) among provenances is indicated for height and DBH at each site.



14

***Acacia melanoxylon*– Provenance and Family Variation in Survival, Height and Stem Number at 14 Months in Guangdong Province China**

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*Genetic variation in survival, height and stem number between 35 provenances and 178 families of *Acacia melanoxylon* was investigated at 14 mo of age in a provenance/family trial in the tropics at Gudoushan Forest Farm, in Guangdong province, China. Significant variation in survival, height and stem number was found between provenances, and families within provenances. Provenance selection at the seedling stage in terms of growth was found to be unreliable. Within well-adapted provenances, variation in height and stem number between families was larger than between provenances. At 14 mo of age, five provenances from Queensland, four from New South Wales and one from Victoria, and 15 families were performing well.*

Introduction

Acacia melanoxylon R.Br. is world-renowned for its valuable timber that is used for veneer, furniture and cabinet making (Simmons 1981). It can reach over 35 m in height with diameters up to 1.3 m (Searle 2000). The natural distribution of this Australian species ranges between latitudes 16° and 43°S at altitudes from near sea level 40 m to 1500 m (Doran and Turnbull 1997).

Acacia melanoxylon was initially trialed in 1987 by The Research Institute of Tropical Forestry (RITF) on Hainan Island, with poor results. RITF researchers continued to test *A. melanoxylon* in the species trials, provenance trials, demonstration plantings and plantations in south-east China through the late 1980s and 1990s (Table 1). This acacia research was part of a highly successful collaboration (1986-1998) with Australian (CSIRO) scientists that was part-funded by the Australian Centre for International Agricultural Research (ACIAR).

The area of *A. melanoxylon* plantations in south-east China now exceeds 5000 ha. Currently the strong desire to expand the area of commercial plantations is severely limited by the lack of good seed and appropriate silvicultural knowledge.

With seed selected and supplied by CSIRO Forestry and Forest Products, a comprehensive provenance/family trial of *A. melanoxylon* was planted by RITF in Guangdong province China in 1996. The paper reports the survival, height growth and stem number of the trees in the trial at 14 mo of age.

Material and methods

The *A. melanoxylon* provenance/family trial was planted by the Research Institute of Tropical Forestry (RITF) at the National Gudoushan Forest Farm in Guangdong Province, China (about 112°52'E, 22°50'N, 350 m asl, mean annual temperature 21.7°; mean annual rainfall 2250 mm). The soil is a lateritic yellow soil derived from granite with a pH of 4.3. The previous vegetation on site was a secondary forest of *Pinus massoniana*.

All the open-pollinated seedlots in the trial were supplied by the Australian Tree Seed Centre (CSIRO Forestry and Forest Products). The seedlings were planted in May 1996 at a spacing of 2×3 m. A planting hole 50×40×30 cm was dug for each tree and 100 g of multiple fertilizer and 50 g of phosphate was placed in each hole. The 35 Australian provenances and 178 families (Table 2) were arranged in a randomised complete block (RCB) design with 8 replications and 3-tree line plots for each treatment.

Table 1. Summary of the introduction and genetic improvement of *Acacia melanoxylon* in China (1987–2002) by the Research Institute of Tropical Forestry

Year of planting	Type of planting	Genetic material	Area of planting (ha)	Location
1987	Species trial	2 provs	0.1	Shangyong forest farm, Hainan Island
1988	species trial	3 provs	0.1	Zhuhai, Guangdong
1989	Species trial	3 provs	0.3	Longtouxue forest farm, Guangdong
1990	Species trial	4 provs	0.3	Longtouxue forest farm, Guangdong
1991	Provenance trial	21 provs	12	2 sites: Hekou forest farm, Guangdong and Ruijin County, Jiangxi
1992	Species trial	6 provs	10	2 sites: Timian Huadu Guangdong Province, Longdong forest farm, Guangzhou, Guangdong
1994	Species trial	5 provs	0.3	2 sites: Shixing, Guangdong and Ganzhou, Jiangxi
1995	Species trial	5 provs	0.3	Shixing, Guangdong
1995	Plantation	4 provs	4000	4 sites: Conghua, Kaiping, Enping and Jiangmen, Guangdong
1996	Provenance/progeny trial	35 provs; (178 families)	18	3 sites: Gudoushan, Longdong, and Shunao forest farms, Guangdong
1996	Demonstration	1 prov	30	Dalingshan, Guangdong
1997	Seed orchard	20 families	4	Dongguan, Guangdong
1998	Demonstration	2 provs	50	Luofeng, Guangdong
1999	Demonstration	2 provs	50	Shantou, Guangdong
2000	Clonal seed orchard	35 clones	4	Jiangmen, Guangdong
2000	Plantation	1 prov	200	Meizhou, Guangdong
2001	Plantation	1 prov	300	Zhangzhou, Fujian
2002	Plantation	1 prov	50	Ganzhou, Jiangxi

Seedling performance for different families were measured at four months of age. Survival (S), height (H) and stem number (SN) were assessed in July 1997, 14 months after planting.

Data analysis

The raw data for survival (S) and stem number (SN) were transformed to $\log(1+x)$ before analysis. All of analyses were carried out by software produced by Nanjing Forestry University (Ye 1990).

Nested analysis of variance was used to evaluate the relative contribution of provenances and families-within-provenances to variance of the well-adapted provenances.

Q cluster analysis, using the centre of gravity method for Euclidean distance, was used to identify groups of provenances with like performance.

Results

Trial means

The means for survival, height and stem number of the 178 families studied are presented in Table 3 and provenance means for these traits are presented in Table 4.

Analyses of variance for survival, height and stem number

There were significant differences between *A. melanoxylon* provenances in mean survival (S), height (H) and stem number (SN) at 14 mo of age (Table 5). Seven provenances and 69 families had good survival ($S > 75\%$). Provenance differences in height and stem number accounted for 10.3% and 2.1% respectively of the variation. Differences within provenance and between families accounted for 18% of the total variation in height (Table 6) and 5.4% of the total variation in stem number (Table 7). The within-family variation plus error accounted for more than 70% of the total variation in height (Table 6).

Table 2. Geographic origin of *A. melanoxylon* provenances/families in trial

CSIRO Seedlot No. RITF trial code	Trial code of family	Individual tree collection numbers	Collection locality	State	Latitude (° ' E)	Longitude (° ' S)	Altitude (m)
14176--Q1	1--10	SDS00395--SDS00404	Atherton	QLD	17 17	145 26	1022
15821--Q2	11--20	BG004384--BG004394	Ravenshoe	QLD	17 35	145 32	1000
16513--V1	21--30	DFC00225--DFC00234	13.2 km NNW Welshpool	VIC	38 34	146 22	250
16526--S1	31--40	DFC00403--DFC00412	25 km SE Mount Gambier	SA	37 57	140 56	40
16725--N1	41--50	GJM00563--GJM00549	Lawlers Ck NNE Stroud	NSW	32 11	151 51	150
17263--Q3	51--60	MR0127/1--MRO127/10	Mt Mee-Sellins Rd	QLD	27 6	152 44	500
16873--N2	61--63	T0000215--T0000217	5 km NE Yarrangobilly	NSW	35 38	148 30	1000
17264--Q4	64--72	MR0104/1--5, 7-10	Springbrook	QLD	28 14	153 17	750
18980--V2	83--92	JSL993--JSL1002	Gellibrand River	VIC	38 43	143 15	50
19001--N3	93--102	DL955--DL964	Mt Lindsay State Forest	NSW	28 21	152 39	600
19002--N4	103--112	DL965--DL974	Wild Cattle Ck State Forest	NSW	30 13	152 49	600
19350--V3	113--122	JSL1683--JSL1694	Otways	VIC	38 41	143 33	300
19496--T1	123--129	1Q--1X	Queenstown district	TAS			0
19497--T2	130--144	2E--2M, 2T--2Y	South of Burnie	TAS			0
19498--T3	145--151	3E--3H, 3J-3L	W Launceston district	TAS			0
19499--T4	152--156	4D--4H	E Launceston district	TAS			0
19500--T5	157--161	5H, 5O, 5P ,5R ,5S	St Helens district	TAS			0
19501--T6	162--164	6C, 6D, 6H	Lake Echo district	TAS			0
19502--T7	165		Bathurst Harbour district	TAS			0
19503--T8	166--169	9D--9G	Maydena dist	TAS			0
19504--T9	170		Lake Sorrell	TAS			0
19505--T10	171--184	11F--11S	Cygnnet district	TAS			0
19506--T11	185--187	12D, 12E, 12G	King Island	TAS			0
16272--V4			15 km S Bonang	VIC	37 19	148 42	300
17010--Q5			17 km Woodford	QLD	26 50	152 50	400
17190--V5			Buckleys Swamp Rd	VIC	37 57	141 59	140
17230--V6			Arthurs Ck Rd Yanyean	VIC	37 34	145 8	214
17229--V7			Highlands	VIC	37 4	145 24	640
17075--V8			Diggers Rest	VIC	37 37	144 44	180
18021--V9			Lancefield	VIC	37 14	144 46	500
18344--A1			Mt Coree	ACT	35 18	148 49	1300
18309--N5			Tallaganda State Forest	NSW	35 26	149 31	900
19322--V10			Crawford River	VIC	37 56	141 30	0
19293--N6			Talbingo	NSW	35 31	148 18	400
19494--T12			Kannunah	TAS	0 0	0 0	0

Table 3. *A. melanoxydon* family means for survival, height and stem number at 14 months

Prov	Fam	S(%)	H (m)	SN	Prov	Fam	S(%)	H (m)	SN	Prov	Fam	S(%)	H (m)	SN
S1	31	29.2	0.89	1.8	T2	130	42.9	1.31	1.7	T6	162	8.3	0.88	1.5
S1	32	20.8	1.27	2	T2	131	50	1.5	1.7	T6	163	28.6	1.01	1.5
S1	33	25	0.91	2.3	T2	132	37.5	1.31	1.8	T6	164	50	1.16	1.9
S1	34	20.8	0.93	1.3	T2	133	54.2	1.52	2	T7	165	45.8	1.7	1.8
S1	35	12.5	2.42	1.7	T2	134	42.9	1.44	1.8	T8	166	55.6	1.14	1.6
S1	36	12.5	0.75	1.8	T2	135	25	0.73	1.9	T8	167	33.3	1.45	1.8
S1	37	33.3	1.29	1.6	T2	136	45.8	0.94	2.1	T8	168	20.8	1.7	1.7
S1	38	33.3	2.04	2.2	T2	137	41.7	0.95	1.6	T8	169	16.7	1.26	1.5
S1	39	16.7	1.53	1.3	T2	138	33.3	1.04	2	T9	170	25	1.33	1.9
S1	40	47.6	0.99	2.3	T2	139	41.7	1.33	2	T10	171	25	1.57	2.3
T1	123	37.5	1.94	1.6	T2	140	50	1.35	2.3	T10	172	47.6	1.14	1.4
T1	124	50	1.8	2.1	T2	141	62.5	1.59	1.9	T10	173	12.5	2.11	2.7
T1	125	29.2	1.94	1.7	T2	142	33.3	1.57	2	T10	174	61.1	1.53	2.3
T1	126	20.8	1.92	1.5	T2	143	23.8	1.59	2.5	T10	175	42.9	0.86	2.3
T1	127	41.7	1.39	2.1	T2	144	66.7	1.53	1.9	T10	176	75	1.61	1.7
T1	128	41.7	1.16	2.4	T4	152	41.7	1.43	2.4	T10	177	61.1	2.05	1.6
T1	129	25	1.12	1.5	T4	153	29.2	1.36	1.6	T10	178	50	1.39	1.9
T3	145	41.7	1.26	2.8	T4	154	41.7	1.06	1.6	T10	179	41.7	1.83	1.5
T3	146	20.8	1.69	2.3	T4	155	38.1	1.51	1.7	T10	180	41.7	2.19	1
T3	147	16.7	1.54	2.2	T4	156	45.8	1.25	1.3	T10	181	58.3	1.46	1.8
T3	148	45.8	1.21	1.9	T5	157	50	1.67	1.8	T10	182	4.2	0.5	2
T3	149	37.5	1.65	1.9	T5	158	66.7	1.43	1.9	T10	183	52.4	1.31	1.6
T3	150	37.5	1.35	1.8	T5	159	22.2	1.8	1	T10	184	29.2	1.85	1.7
T3	151	77.8	1.76	2.2	T5	160	58.3	1.88	2.1	T11	185	72.2	2.07	1.8
T12		37.5	1.52	2.3	T5	161	16.7	1.89	1.8	T11	186	16.7	1.67	2.3
										T11	187	9.5	1.25	2
Q1	1	91.7	1.88	2.5	N1	41	87.5	2.3	3	V1	21	41.7	1.69	1.8
Q1	2	100	1.95	2.5	N1	42	79.2	2.26	2.3	V1	22	54.2	1.9	2.1
Q1	3	100	1.97	2.6	N1	43	87.5	2.28	2.6	V1	23	33.3	1.87	2.2
Q1	4	91.7	2.02	2.4	N1	44	75	1.24	2.1	V1	24	33.3	1.8	1.9
Q1	5	100	2.08	2.2	N1	45	83.3	1.84	2.3	V1	25	54.2	1.67	2
Q1	6	91.7	1.68	2.8	N1	46	85.7	1.88	2.5	V1	26	16.7	1.73	2
Q1	7	87.5	1.7	2.6	N1	47	79.2	1.72	2.3	V1	27	54.2	1.4	1.8
Q1	8	100	2.06	2.8	N1	48	91.7	2.34	2.3	V1	28	41.7	1	1.4
Q1	9	83.3	1.63	2	N1	49	83.3	1.9	2.9	V1	29	25	2.04	1.8
Q1	10	100	1.83	2.5	N1	50	83.3	2.15	2.7	V1	30	58.3	1.8	1.8
Q2	11	100	1.71	2.5	N2	61	12.5	1.13	2.3	V2	83	41.7	1.6	2.2
Q2	12	87.5	1.66	2.1	N2	62	16.7	1.06	1.3	V2	84	20.8	1.44	2
Q2	13	95.8	1.8	3.1	N2	63	20.8	0.86	1.6	V2	85	33.3	1.35	1.2
Q2	14	91.7	1.73	2.7	N3	93	100	2.23	2.1	V2	86	37.5	1.7	1.7
Q2	15	95.8	1.78	2.4	N3	94	75	1.73	2.8	V2	87	45.8	1.63	1.6
Q2	16	95.8	1.87	2.4	N3	95	76.2	1.91	2.4	V2	88	45.8	1.5	1.6
Q2	17	70.8	1.78	2	N3	96	91.7	2.18	3.3	V2	89	45.8	1.5	1.6
Q2	18	75	1.81	2.4	N3	97	83.3	1.88	2.4	V2	90	29.2	1.56	1.9
Q2	19	66.7	1.6	1.8	N3	98	75	1.7	2	V2	91	54.2	1.76	1.8
Q2	20	83.3	1.78	2.5	N3	99	83.3	1.84	2.2	V2	92	66.7	1.25	1.8
Q3	51	95.8	2.12	2.7	N3	100	70.8	1.78	2.9	V3	113	54.2	1.36	1.6
Q3	52	91.7	1.89	2.4	N3	101	75	1.91	2.4	V3	114	25	1.57	1.7
Q3	53	95.8	2.32	4.3	N3	102	83.3	1.81	2.2	V3	115	29.2	1.56	2.4
Q3	54	87.5	1.91	2.6	N4	103	100	2.35	2.1	V3	116	25	1.41	1.9
Q3	55	95.8	2.15	2.1	N4	104	83.3	1.78	1.7	V3	117	33.3	1.12	1.2
Q3	56	87.5	2.06	2.5	N4	105	95.2	2.33	2	V3	118	62.5	1.07	1.7

Prov	Fam	S(%)	H (m)	SN	Prov	Fam	S(%)	H (m)	SN	Prov	Fam	S(%)	H (m)	SN
Q3	57	79.2	1.87	2.5	N4	106	91.7	2.26	2.1	V3	119	8.3	2.17	1.5
Q3	58	91.7	2.23	2.5	N4	107	87.5	2.03	2.2	V3	120	37.5	1.56	1.6
Q3	59	91.7	2.35	2.4	N4	108	95.8	2.13	2.2	V3	121	41.7	1.46	1.7
Q3	60	100	2.31	3	N4	109	70.8	1.89	2.1	V3	122	37.5	1.16	1.4
Q4	64	79.2	1.59	2.1	N4	110	87.5	2.07	1.9	V4		41.7	1.39	2.2
Q4	65	70.8	1.8	2.1	N4	111	87.5	2.03	2.4	V5		29.2	1.48	1.9
Q4	66	95.8	2.27	2.1	N4	112	70.8	2.03	2	V6		33.3	1.58	3
Q4	67	83.3	1.84	2.3	N5		6.7	0.5	1	V7		33.3	1.61	1.9
Q4	68	91.7	1.7	2.7	N6		60	1.73	2.5	V8		28.6	1.37	2.1
Q4	69	62.5	1.75	2.3	A1		16.7	0.76	1	V9		37.5	1.12	1.6
Q4	70	66.7	1.47	2.7						V10		54.2	1.84	1.9
Q4	71	81	1.92	2										
Q4	72	79.2	1.66	2.1										
Q5		66.7	1.59	2.5										
Average		56.6	1.64	2.1										
Stand error		27.6	0.39	0.5										

Table 4. Mean survival, height and branch number of *A. melanoxylon* provenances at 14 mo

Provenance	S (%)	H (m)	BN	Provenance	S (%)	H (M)	BN
QLD14176	94.6	1.88	2.5	VIC18980	42.1	1.53	1.7
QLD15821	86.2	1.75	2.4	VIC19322	54.2	1.84	1.9
QLD17010	66.7	1.59	2.5	VIC19350	35.4	1.44	1.7
QLD17263	91.7	2.12	2.7	ACT18344	16.7	0.76	1
QLD17264	78.9	1.78	2.3	SA16526	25.2	1.3	1.8
NSW16725	83.6	1.99	2.5	TAS19494	37.5	1.52	2.3
NSW16873	16.7	1.02	1.7	TAS19496	35.1	1.61	1.8
NSW18309	6.7	0.5	1	TAS19497	43.4	1.31	1.9
NSW19001	81.4	1.9	2.5	TAS19498	39.7	1.49	2.2
NSW19002	87	2.09	2.1	TAS19499	39.3	1.32	1.7
NSW19293	60	1.73	2.5	TAS19500	42.8	1.73	1.7
VIC16272	41.7	1.39	2.2	TAS19501	29	1.02	1.6
VIC16513	41.3	1.69	1.9	TAS19502	45.8	1.7	1.8
VIC17075	28.6	1.37	2.1	TAS19503	31.6	1.39	1.7
VIC17190	29.2	1.48	1.9	TAS19504	25	1.33	1.9
VIC17229	33.3	1.61	1.9	TAS19505	43.1	1.53	1.8
VIC17230	33.3	1.58	3	TAS19506	32.8	1.66	2
VIC18021	37.5	1.12	1.6	Average	46.2	1.52	2.0

Table 5. Results of analysis of variance of provenances

Source	df	Mean square			F		
		S	H	SN	S	H	SN
Replicate	7	0.0287	8338	0.0244	6.31**	1.61	4.16**
Provenance	34	0.0258	18341	0.0169	6.22**	3.73**	2.99**
Error	188	0.0042	4920	0.0057			

$F_{0.05}(7,188)=2.07$, $F_{0.01}(7,188)=2.75$, $F_{0.01}(34,188)=1.75$

Table 6. Nested analysis of variance for *A. melanoxylon* height at 14 mo

Source	df	MS	F	Variance	RD (%)	Expectation of mean squares
Replicate	7	16616	7.46	26	8.2	$Ve + 2.76Vf + 25.54Vp + 175.55Vr$
Provenance	48	11866	5.33	321	10.3	$Ve + 2.74Vf + 25.01Vp$
Family.	495	3709	1.66	586	18.5	$Ve + 2.53Vf$
Error	854	2228		2228	70.5	Ve

Table 7. Nested analysis of variance for *A. melanoxylon* stem number at 14 mo

Source	df	MS	F	Variation	RD (%)	Expectation of mean squares
Replicate	7	0.0705	5.51	0.000273	1.9	$Ve + 2.76Vc + 25.54Vb + 175.55Va$
Provenance	48	0.0224	1.76	0.000303	0.1	$Ve + 2.74Vc + 25.01Vb$
Family	495	0.0147	1.15	0.000758	5.4	$Ve + 2.528Vc$
Error	854		0.0128	0.0128	90.6	Ve

Height and height correlation

Seedling height for 178 families at 4 mo of age (in the nursery) and 14 mo of age (in the field) was measured. The best families in terms of height are listed in Table 8. The correlation between heights at 4 mo and 14 mo was also investigated and was found to be only 0.21 ($F=3.64 < F_{0.05}(1,178) = 3.99$) (Fig.1).

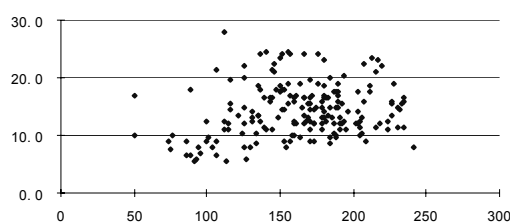


Figure 1. Scatter diagram showing heights (cm) of 178 *A. melanoxylon* families at 4 mo (vertical axis) and 14 mo (horizontal axis)

Q cluster analysis

A Q cluster analysis of the 35 provenances in trial was conducted (Table 9) for the traits of survival, height and stem number. This divided the provenances into three distinct groupings.

The Type I grouping had the best average survival (78%; ranging from 54 to 95%), and average height (1.9 m; ranging from 1.6 to 2.1 m) although the average number of stems (2.4 stems) was a little higher (ranging from 1.9 to 2.7).

The average survival and growth of the Type II grouping was 36% (ranging from 25 to 46%) and 1.5 m (ranging from 1.0 to 1.7 m) respectively. The worst provenances were in Type III with an average survival of 21% (ranging from 7 to 38%), and average height of 9 m (ranging from 0.5 to 1.1 m) and the average stem number was 1.4 stems.

Provenance selections

The seedlots grouped into the best category were: QLD17263 (Mt Mee-Sellins Rd), NSW19002 (Wild Cattle Ck State Forest), NSW16725 (Lawlers Ck NNE Stroud), NSW19001 (Mt Lindsay State Forest), QLD14176 (Atherton), VIC19322 (Crawford River), QLD17264 (Springbrook), QLD15821 (Ravenshoe), NSW19293 (Talbingo) and QLD17010 (Woodford) (Table 9).

Family selections

For commercial plantations, survival (S) is the most important factor followed by height (H) and then stem number (SN). On the basis of $S > \text{mean} + 1\sigma$, $H > \text{mean} + 1\sigma$, $SN < \text{mean} + 1\sigma$, 15 superior families from Queensland or NSW were selected as being the best for future plantations (Table 10). These have a mean survival of 93% and an average height of 2.2 m that exceed the trial average by 65% and 33% respectively. The average stem number of these selected families is 2.2— the same as the trial average.

Discussion and conclusions

Only 20% of best-growing families in the nursery performed well at 14 mo of age. The Victorian and Tasmanian provenances generally grew quickly in the nursery, but not in the field. On the other hand Queensland provenances, relatively slower growing in the nursery, performed better in the field. Early selection of superior provenances on the basis of height in the nursery does not appear to be reliable.

At this early age the adaptability and variability of *A. melanoxylon* provenances is evidenced by the range of *A. melanoxylon* provenances that performed well on this high-rainfall (on average 2250 mm y^{-1}) tropical site (22°50'N). The better performers ranged in origin from Atherton in north Queensland (17°17'S) to the Crawford River in Victoria (37°56'S).

Table 8. The best *A. melanoxylon* families for height at 4 mo and 14 mo of age

Best-growing families in field (H > H+1 σ , 14 months)			Best-growing families in nursery (H > H+1 σ , 4 months)			Best-growing families in field (H > H+1 σ , 14 months)			Best-growing families in nursery (H > H+1 σ , 4 months)		
Proven- ance code	Family code	Height (m)	Proven- ance code	Family code	Height (cm)	Proven- ance code	Family code	Height (m)	Proven- ance code	Family code	Height (cm)
Q1	5	2.08	V1	30	23	Q4	66	2.27	V3	118	21.5
Q1	8	2.06	N1	43	19	N3	93	2.23	V3	119	23
V1	29	2.04	N1	49	19	N3	96	2.18	V3	121	22.5
S1	35	2.42	N1	50	21	N4	103	2.35	V3	122	19.5
S1	38	2.04	V2	84	21.5	N4	105	2.33	T1	125	20.5
N1	41	2.3	V2	86	19.5	N4	106	2.26	T3	151	19
N1	42	2.26	V2	87	19	N4	107	2.03	T4	155	24
N1	43	2.28	V2	89	23.5	N4	108	2.13	T10	180	22
N1	48	2.34	V2	90	19	N4	110	2.07	T10	181	21
N1	50	2.15	V2	91	24	N4	111	2.03	T11	185	22.5
Q3	51	2.12	V2	92	20	N4	112	2.03	T11	186	24
Q3	53	2.32	N4	108	23.5	V3	119	2.17	T11	187	22
Q3	55	2.15	V3	113	24	T10	173	2.11	V10		20
Q3	56	2.06	V3	114	24	T10	177	2.05			
Q3	58	2.23	V3	115	24.5	T10	180	2.19			
Q3	59	2.35	V3	116	24.5	T11	185	2.07			
Q3	60	2.31	V3	117	28						

Table 9. Q cluster analysis for 35 *A. melanoxylon* provenances at 14 mo

Type	Provenance	Survival (%) Range/mean	Height (m) Range/mean	Stem no. Range/mean
I: Superior seedlots	QLD17263, NSW19002, NSW16725, NSW19001, QLD14176, VIC19322, QLD17264, QLD15821, NSW19293, QLD17010	54.2-94.6 / 78.4	1.59-2.12 / 1.87	1.9-2.7 / 2.4
II:	The rest	25-45.8 / 36.3	1.02-1.73 / 1.50	1.6-3 / 2.0
III	VIC18021, NSW16873, ACT18344, NSW18309	6.7-37.5 / 21.32	0.5-1.12 / 0.884	1-1.7 / 1.4

Table 10. Superior *A. melanoxylon* families at 14 mo

Seedlot code	Family code	Original family	Survival (%)	Height (m)	Number of stems
N4	103	DL965	100	2.35	2.1
Q3	59	MR0127/9	91.7	2.35	2.4
N1	48	GJM00547	91.7	2.34	2.3
N4	105	DL967	95.2	2.33	2
Q4	66	MR0104/3	95.8	2.27	2.1
N4	106	DL968	91.7	2.26	2.1
N3	93	DL955	100	2.23	2.1
Q3	58	MR0127/8	91.7	2.23	2.5
Q3	55	MR0127/5	95.8	2.15	2.1
N4	108	DL970	95.8	2.13	2.2
Q1	5	SDS00399	100	2.08	2.2
N4	110	DL972	87.5	2.07	1.9
Q3	56	MR0127/6	87.5	2.06	2.5
N4	107	DL969	87.5	2.03	2.2
N4	111	DL973	87.5	2.03	2.4
Mean of superior families			93.3	2.19	2.2

Provenance and family variation in *A. melanoxylon* for survival, height and stem number is significant. Variation for these traits was greatest within families, followed by that between families and then between provenances.

Genetic improvement of *A. melanoxylon* would be most rapidly progressed by the selection and cloning of superior individuals for a series of seed orchards. These and other *A. melanoxylon* breeding populations are urgently needed in China to satisfy the strong demand for quality seed for plantation establishment.

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Mixed-Species Plantings with Blackwood

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Introduction

Blackwood is a species that exhibits poor apical dominance. When grown in native forest, the sidelight suppression and protection from climatic extremes offered by surrounding vegetation produces trees with good apical dominance and hence stem form, resulting in straight, branch-free boles (Unwin *et al.* 2000). When grown in the open, however, poor apical dominance results in the development of large branches, relatively short trees and stems with unacceptable levels of kink, sweep and lean.

In Australia it is common to grow blackwood in plantations with a nurse crop species such as *Eucalyptus nitens*, *E. globulus* or *Pinus radiata*, to try and mimic conditions found in native forests. In order for a nurse crop to be effective in improving apical dominance and stem form, a number of factors need to be considered, such as the relative growth rates of the species, row spacings, methods of improving blackwood growth, and the optimal light environment for blackwood growth and form. This paper discusses appropriate management of mixed-species blackwood plantings based on research results and experience in Tasmania, and highlights some of the pros and cons of using a nurse crop system.

The importance of the light environment

What aspect of mixed-species plantings improves stem form? Research in native forest (Unwin *et al.* 2000) and with young plants in pots and plantations (Milton 1982; Medhurst *et al.* under review) suggests that, while protection from unfavourable climatic conditions might play a role, sidelight suppression is the major factor. Both apical dominance and height growth increase under low light conditions (Milton 1982; Medhurst *et al.* under

review). On sites exposed to frost and strong winds, but the protection aspect may be equally as important (Neilsen and Brown 1996).

In an artificial shading experiment where shade cloth was used to mimic nurse crops with heights of 50%, 100% and 150% of that of the blackwood, height growth of the blackwood was greatest with the 150% treatment. Daily light in this treatment was reduced by 50–60% in the lower two-thirds of the crown (Fig. 1). This suggests that there is an optimal nurse crop height for inducing favourable stem form.

There is a fine balance, however, between enough and too much shade. While blackwood is well adapted to growing under low-light conditions, if light levels are too low the blackwood becomes suppressed by neighbouring vegetation. The root:shoot ratio decreases and diameter growth does not occur (Milton 1982). The result is thin, relatively unstable trees that may be damaged easily or blow over during any operation to remove the nurse crop. Thus it is important to select nurse crop species carefully, and manage the nurse crop to ensure it does not suppress the blackwood.

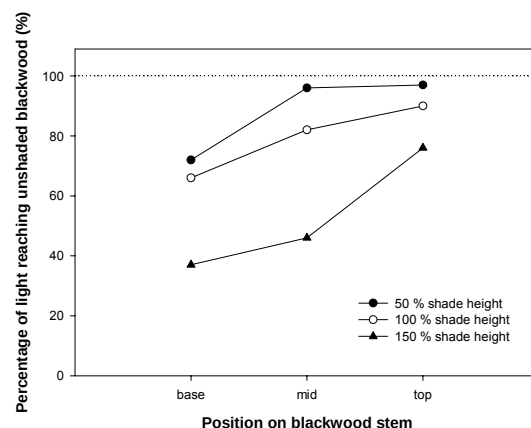


Figure 1. Percentage of light reaching three blackwood crown positions in a shading experiment where shade cloth was erected

Species

Species with dense crowns are ideal as nurse crops because they provide greater sidelight suppression. The species commonly used as nurse crops (*E. nitens*, *E. globulus*, *P. radiata*) have this characteristic. However, they tend to grow faster than blackwood, and thus suppression of the blackwood is likely without careful management. The eucalypts commonly grow faster than the *P. radiata*. These species may be more successful as nurse crops if planted 'off site' to reduce their growth rate.

An alternative that has been examined in small-scale plantings is to use tall shrubs such as *Pomaderris*, *Phebalium* and *Melaleuca* species. Many of these have a maximum height of 6–9 m (commonly the desired clearwood log length), and a growth rate comparable to that of the blackwood. If planted at close spacings (e.g. a 1 m grid) they should be able to promote good stem form up to their maximum height, after which the blackwood crowns can emerge above the nurse crop and drive blackwood diameter growth. The system mimics one of the successful native forest blackwood systems (Jennings *et al.* 2000), but as only a few young plantations currently exist the system remains largely untested. The negatives of the system are that (1) seedlings of these species tend to be expensive and a lot are required, and (2) the planting spacing makes access difficult for any management operations.

Crown shape may be an important consideration when selecting species for mixed-species plantings. Cylindrical crowns, such as those of *E. nitens* and *E. globulus*, shade a greater proportion of the blackwood crown for a given tree height than do conical crowns (such as *P. radiata*) (Fig. 2). Hence cylindrical crowns may provide effective 'nursing' from a younger age than conical ones, but also may suppress the blackwood earlier.

Managing the light environment

Effectively managing the light environment in a nurse crop system involves selecting a suitable spacing for planting, and imposing an appropriate nurse crop thinning regime. In order to reduce establishment costs and avoid access problems, nurse crops commonly are planted between 2.5 and 4 m from the blackwood rows. Observation and early research results from a nurse crop management experiment indicate that these spacings do not provide the blackwood with effective sidelight suppression for at least three years, depending on growth rates (Fig. 3). Significant form problems can

develop during this time and require remedial form pruning.

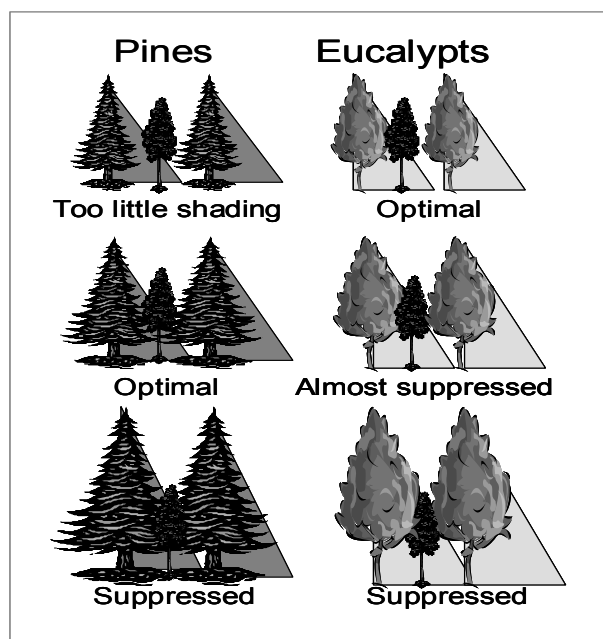


Figure 2. Shading of blackwood crowns from pine and eucalypt nurse crops

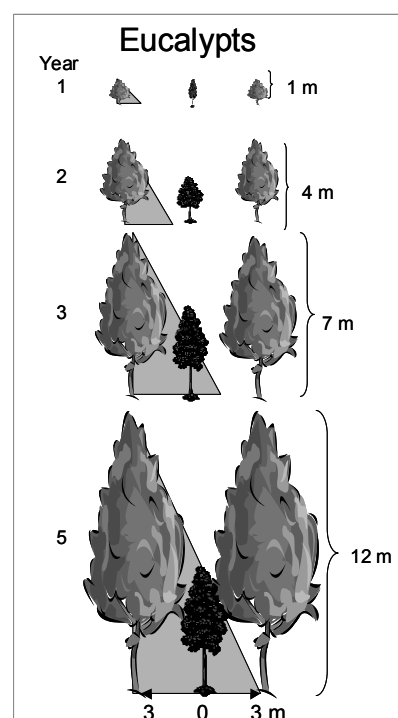


Figure 3. Illustration of the level of 'nursing' offered by a eucalypt nurse crop planted 3 m from blackwood rows, over the first three years of growth

An alternative is to establish the nurse crop prior to planting the blackwood, so that the blackwood is planted into 'light wells'. Operationally this system is difficult to manage, however, because it requires weed control and possible soil preparation immediately prior to planting the blackwood, and it is unclear how tall the nurse crop must be for optimal 'lightwelling'.

Another option is to reduce the spacing between planting rows. One system that is being examined in an experiment in Tasmania involves planting five rows of the nurse crop to every blackwood row. The spacing between rows is 2 m. The nurse crop will be removed progressively as the rows closest to the blackwood begin to suppress the blackwood, until only a single row of nurse crop (managed for clearwood) will remain between each blackwood row. The disadvantages of this system are that (1) a number of silvicultural interventions are required to thin the nurse crop, and (2) there is extra cost associated with the increased number of nurse crop trees.

Reducing row spacing may create problems when it comes to removing the nurse crop. If rows are too close together it may be impossible to remove the nurse crop without damaging the blackwood. Chemical stem injection can be used with eucalypts to overcome this problem, but this method has proven unsuccessful with *P. radiata*.

Row orientation can be important in optimizing sidelight suppression. North-south oriented rows will maximize sidelight suppression over a day.

In order to maximize volume growth of the blackwood, removal of the nurse crop is required at some stage in the rotation. The timing of this can be critical to avoid suppression of the blackwood by the nurse crop. Whether the nurse crop is removed in one operation or as a number of thinning events may be important in determining whether an optimal light environment is maintained for the blackwood. An experiment in northern Tasmania found that diameter growth of 7-yr-old blackwood responded rapidly to removal of between 33% and 100% of a *P. radiata* nurse crop (Fig. 4), with greatest increases following 66% or 100% removal.

However, removal of 66% or 100% of the nurse crop significantly reduced height growth and increased the number of trees with large branches or multiple leaders two years after treatment. It was concluded that heavy thinning or total removal of the nurse crop was not appropriate unless it was combined with form pruning or the desired log length had developed. Light thinning, however, can reduce the likelihood of the blackwood becoming suppressed, and can improve stem form at least in the short term. The remainder of the nurse crop can

then be removed when the desired log length has been achieved.

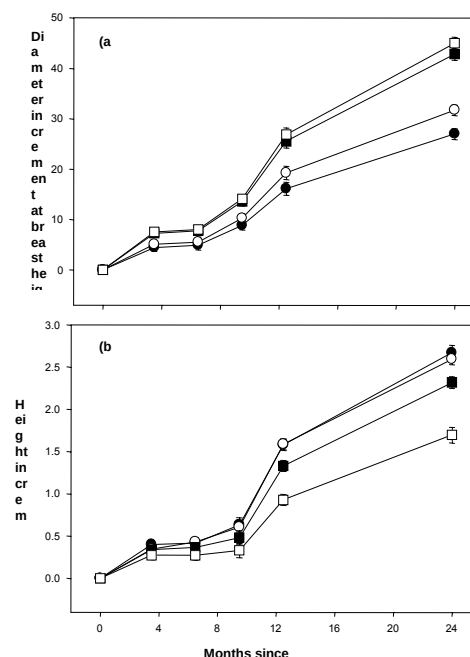


Figure 4. (a) Mean height increment and (b) mean diameter increment of blackwood after removal of *Pinus radiata* nurse crop. (● = unthinned control; ○ = 33% of nurse crop removed; ■ = 66% of nurse crop removed; □ = 100% of nurse crop removed.) Error bars show mean standard error.

Effects of silvicultural treatments

Silvicultural treatments such as fertilising and pruning can affect the relative growth rates of the blackwood and nurse crop, and it is important to understand the response of both species when determining appropriate silvicultural management. For example, in a blackwood/*P. radiata* system in northern Tasmania, the blackwood responded strongly to applications of phosphorus fertilizer (Fig. 5). While the *P. radiata* grew faster than the blackwood over the period of the experiment, the *P. radiata* responded more strongly to magnesium or the combination of nitrogen and phosphorus. Hence fertilizing with phosphorus gave the blackwood an advantage, and resulted in a more favourable blackwood:*P. radiata* height ratio than was recorded in unfertilized plots.

Similarly, the most appropriate pruning regime is one that does not reduce blackwood growth. If height growth in particular is reduced by pruning, then a less favourable blackwood/nurse crop height ratio could lead to earlier suppression of the blackwood.

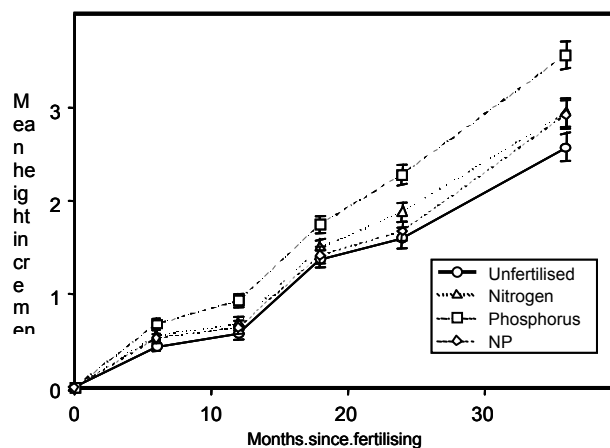


Figure 5. Mean height increment of blackwood following applications of nitrogen and phosphorus fertiliser

Conclusions

With careful management nurse crops can improve stem form and apical dominance, and reduce the need for form pruning. Often management will be a compromise between improving stem form and maximizing blackwood growth. While some of the systems discussed above are unsuitable for large-scale plantations because of the costs involved and operational constraints, they may be an option for smaller-scale plantations.

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16

Stand Management in Fenced-Intensive-Blackwood Regeneration

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Forestry Tasmania

Forestry Tasmania has been fencing eucalypt coupes for blackwood regeneration for more than 15 y. The oldest coupes have reached the target age for pre-commercial thinning (PCT). Release trials and PCT trials have shown that if eucalypt competition is removed, blackwood diameter growth rates increase. However, this can be at the expense of good form, so timing of treatment is important. Economic analysis of eucalypt stand management regimes shows that the best net present values are reached where a commercial thinning is included in the regime. There may be damage issues associated with commercial removal of the eucalypt overstorey in these mixed stands. A trial is currently being established which will compare growth responses and operational suitability of a standard 50% eucalypt basal area reduction which will then be scheduled for future commercial thinning, with a treatment which will thin the eucalypts down to final crop stocking at age 13 y.

Introduction

Tasmania now has over 750 ha of eucalypt regeneration that has been fenced to protect the natural blackwood regeneration from browsing. These areas previously carried blackwood as a sub-canopy species and are intended to be managed primarily for future blackwood production. This treatment is known as fenced-intensive-blackwood (FIB). The fenced areas contain varying densities of both blackwood and eucalypt saplings, although most coupes are adequately stocked with both (Jennings and Dawson 1998).

The fenced coupes span about 15 y in age and the oldest coupes have started to reach the target age of 10-25 y for pre-commercial thinning. If the areas of fenced regeneration are allowed to grow on untended, they become dominated by the eucalypts within the stand. The blackwood stems are nursed by a *Pomaderris apetala* understorey and show excellent form, but the blackwood growth is suppressed by competition from both the eucalypts and the *Pomaderris*.

Stand management trials

In 1995, a trial was established, in Togari Forest Block, to assess the effects of competition between the blackwoods and the eucalypts, the effect of competition from the understorey species and the effect of removal of competition on the growth and form of blackwood saplings. The eucalypt and

Pomaderris apetala competition were removed at different rates from around single tree plots. The details of this trial are described in Jennings *et. al.* (in press). A diagrammatic representation of the release treatments is shown in Figure 1.

The trial has shown that if the competition is reduced, blackwood diameter growth increases in proportion to the available light (Jennings *et. al.* in press).

By age 9 y there was a significant difference between all treatments and these growth trends have continued (Fig. 2). At age 12 the controls showed a steady PAI (diameter) of 0.8 cm y⁻¹ over the 6 years since treatment. In comparison, the PAI (diameter) for the no gap treatment was 1.4 cm y⁻¹, 1.6 cm y⁻¹ for the small gap treatment and 2.1 cm y⁻¹ for the large gap treatment.

This increase in diameter growth, however, did come at a cost to form, with more and bigger branches being retained where more light was available. Figure 3 shows the mean number of live branches in 2 cm diameter classes in the lowest 6 m of blackwood stem for each treatment after 5 y.

The no-gap treatment had the fewest branches in the lowest 6 m of stem as the *Pomaderris* also responded to the eucalypts being removed and was leafier than in the controls. As the gap treatments resulted in progressively more light, both the number and size of branches increased in response to treatment. The large-gap treatment had significantly more branches of all sizes than all other treatments.

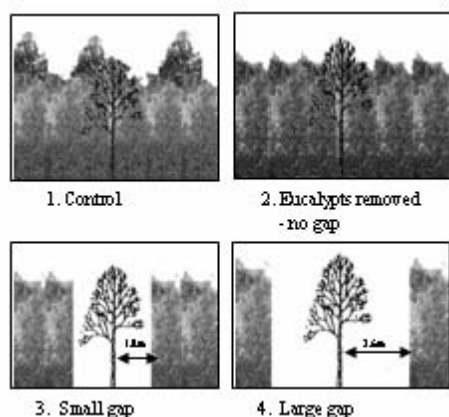


Figure 1. Treatments applied at Togari release trial at age 6 ($n = 27$)

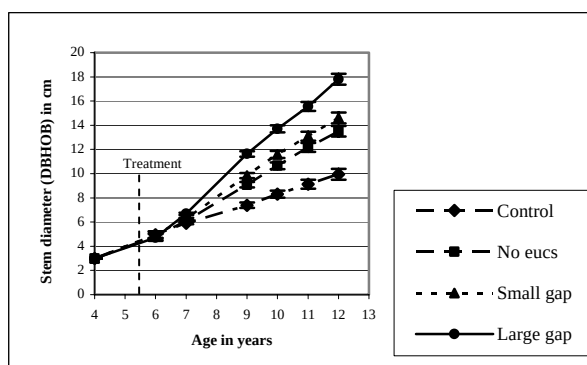


Figure 2. Mean blackwood diameter growth for each treatment (error bars show least significant differences at $P = 0.05$, $n = 27$)

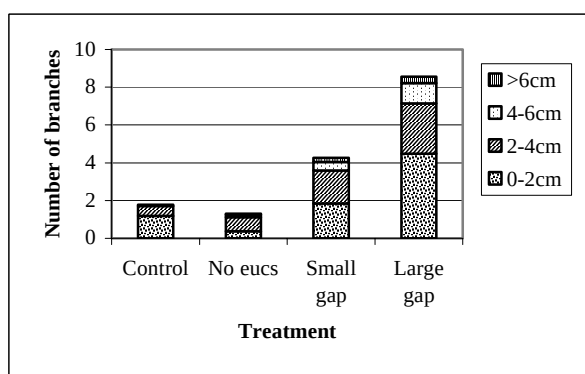


Figure 3. Mean number of branches in lowest 6 m of blackwood stems. (Legend shows branch diameter classes.)

A pre-commercial thinning (PCT) trial was also established in the same coupe at Togari in 1999. Two levels of thinning (50% and 75% BA removal) were carried out on the eucalypts while all blackwoods were retained. Measurements over the last 3 y have shown that mean diameters of eucalypt retainers in both thinned treatments are significantly larger than those in the control treatment although the two thinned treatments do not differ significantly. The blackwood stem diameters were also enhanced by removing the eucalypt competition with the heavier thinning treatment resulting in a significantly larger mean blackwood diameter.

These stand management treatments have been applied to a small area in one coupe. There is now a requirement for an operational stand management prescription to be developed and applied to a number of coupes. The aim is to increase the blackwood sawlog production of these stands as the investment in fencing has already been made, but to keep the total return from the coupe as high as possible.

Economic overview of stand management treatments

Intensive native forest regimes are generally combinations of pre-commercial thinning (PCT) using manual stem injection of glyphosate herbicide at about 15 y of age, and commercial thinning (CT) at 25-40 y. Commercial thinning is carried out using both ground-based and cable harvesting systems with thinning yields consisting almost entirely of pulpwood (LaSala *et al.* 2001).

A financial analysis of stand management regimes for wet eucalypt forests with rotations of 65 y (LaSala *et al.* 2001) has ranked various regimes by net present value and eucalypt sawlog volume (see Table 1). A ranking of 1 is most profitable or productive. The analysis was based on eucalypts and did not consider understorey trees such as blackwood.

The regimes which have the greatest NPVs are those that contain at least one commercial thinning in the regime. However, commercial thinning of the eucalypts at in fenced coupes may not be operationally viable, because of damage to the blackwood sawlog stems growing as an understorey beneath them. This is unfortunate as it reduces the economic viability of the regime as the revenue from mid-rotation sales of pulpwood is foregone (LaSala *et al.* 2001). The alternative, pre-commercial thinning only (PRE), was shown to increase sawlog volume at harvesting, while resulting in no operational damage to the stand.

These results are important priorities for blackwood stand management and may justify a prescription of PRE where it would not normally be recommended because of its low NPV.

Table 1. Net Present Value (NPV) and eucalypt sawlog volume rankings for various stand management regimes (from LaSala et al. 2001)

Regime	Retention rate (stems ha ⁻¹)	Average. treatment age (y)	NPV rank- ing	Euc. sawlog volume ranking
No thinning	All stems		5	4
PCT only (PRE)	500	15	6	2
CT1 only	250	30	2	3
PCT + CT1	500, 200	15, 30	4	1
CT1 + CT2	250, 100	30, 45	1	6
PCT+CT1+CT2	500, 200, 80	15, 30, 45	3	5

Developing new regimes for blackwood stand management

The PCT trial at Togari showed that 75% eucalypt basal area (BA) removal enhanced diameter growth for both blackwood and eucalypt retainers, although it reduced eucalypt stand productivity. In the absence of a commercial thinning of the eucalypts at a later date, this level of PRE is probably required in order to open up the stand sufficiently to produce a long-lasting advantage to the blackwood stems. Although information on blackwood growth and volume production from these fenced coupes is not yet available (as the coupes are all less than 15 y old) there is a potential to produce blackwood and eucalypt sawlogs on about 60-y rotations by applying a single heavy pre-commercial thinning.

The logistical problems of commercially thinning the eucalypt overstorey in these fenced coupes needs to be resolved, especially if FIB is to be an attractive investment option. A trial of two regimes in 13-y-old FIB is currently underway with the

thinning scheduled for spring 2002. These regimes will be:

- A PCT treatment to the usual 50% eucalypt BA retention rule, retaining all blackwoods except those with very poor form, with the area scheduled for commercial thinning at a later date, and
- A heavy PRE treatment retaining only 250 eucalypt stems ha⁻¹, removing directly competing vegetation from a selected 250 blackwood stems ha⁻¹ and removing blackwoods of very poor form.

Commercial thinning of the first area will not be possible for at least ten years, but the success of these prescriptions at an operational implementation level will be assessed before the next coupe is considered for treatment.

Acknowledgments

Thanks to Ann LaSala for Togari PCT trial results.

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17

Mixtures: Planting Blackwood in New Zealand Indigenous Vegetation

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A number of trials have been established in New Zealand since the early 1960s where the performance of Acacia melanoxylon has been tested as an enrichment species. Plantings have been located either within an existing indigenous high forest structure, where previous logging had removed the softwood canopy, or as a new forestry crop within developed or developing indigenous scrub cover on reverting hill country farmland. Results of the older trials identified blackwood as the best performing of a range of exotic species within a high forest, although blackwood on this site has lost vigour after 30 y. New trials on the East Coast of the North Island within developing indigenous scrub dominated by kanuka (Kunzea ericoides) and manuka (Leptospermum scoparium) indicate the potential of a scrub cover to significantly reduce the amount of form pruning required to achieve a clear bole. Early results from these trials show that blackwood planted in narrow lanes (<2 m wide) cut in young developing scrub have a significantly longer clear bole without pruning than those planted in wide lanes (>4 m wide) or in open sites. Four years after planting at Poroporo, blackwood within lanes 1 m wide had clear boles over twice the length of those of those of trees planted in an open site. Further results are the continued need for pruning to maintain the development of a clear bole once blackwood emerges from the surrounding scrub cover and the preferable siting of plantings within a young vigorous scrub cover.

Introduction

The interest in blackwood in New Zealand developed because of its success in planting in mixture with indigenous vegetation throughout the country (FRI 1978, 1982, 1983; Nicholas 1979).

This support came from two main areas:

- (i) Blackwood was one of the most successful species trialed in a multi-species enrichment trial established in 1960-61 testing hand-cut and tractor-cleared canopy gaps in logged native forest on the Mamaku Plateau near Rotorua.
- (ii) The North Island survey of blackwood plantings identified enrichment plantings as some of the most successful (FRI 1978).

Blackwood has several advantages over other species when planting in mixture with indigenous species. These are:

- The shade tolerance of blackwood along with its commercial potential provides an alternative to complete land clearing, and exposing a vulnerable site to soil loss, to establish traditional forest crops.
- The influence of the existing vegetation helps to improve form and reduce intensive pruning requirements.

- Blackwood has a minimal landscape impact when interplanted with indigenous species because its colour and form mixes readily with most shade-tolerant indigenous species.

It may be considered, however, that there are some disadvantages in using blackwood in mixture with indigenous vegetation. These are:

- It is a non-corporate species and lacks large resource awareness.
- It produces seed which remain viable for many years in the ground.
- It is a low-volume producing species on an individual tree basis.

While information on managing blackwood as a single-species plantation is becoming more common (Nicholas and Brown 2002), there are many successful examples of blackwood established in mixture with indigenous vegetation. The forest manager, however, needs to understand the principles of planting in mixtures with indigenous vegetation: that is to create an environment with sufficient light and shade to minimise management input, improve form and maintain growth. It must also be recognised that the form control exercised by the accompanying vegetation extends only to the height of the surrounding scrub. Experience and research in New Zealand have helped to understand the management of mixtures with indigenous vegetation.

Mamaku trial

Mamaku Forest is located on the Mamaku plateau at 550 m asl; in 1960 and 1961 the rainfall was 2030 and 2160 mm respectively.

In 1904 Mamaku Forest was selectively logged for podocarps by Steele Bros. In 1947 intensive podocarp logging was undertaken by Arahiwi Sawmilling Co., and the best tawa was removed as well. These operations left the forest with a scattered stocking of native hardwoods tawa (*Beilschmiedia tawa*), kamahi (*Weinmannia racemosa*), tawari (*Ixerba brexioides*), hinau (*Elaeocarpus dentatus*) and pokaka (*Elaeocarpus hookerianus*). Regeneration (poles and saplings) was mostly tawa and hinau, with larger trees on the knolls and low ridges. Where logging had been more intensive, a 5-7 m cover of scrub hardwoods including coprosma (*Coprosma* sp.), mahoe (*Melicytus ramiflorus*), pate (*Schefflera digitata*) and fuchsia (*Fuchsia excorticata*) had developed.

As the forest carried some potentially-merchantable residual trees, land clearing and conversion was not considered to be appropriate. Thus Forest Research established trials to test various methods of enriching second-growth indigenous forest in Mamaku Forest and to determine the suitability of different exotic species for this purpose. (Comparable trials were established in podocarp/beechness forest at Rangatau Forest on the southern slopes of Mt Ruapehu, and to a lesser extent in manuka scrub at Te Wera Forest in Taranaki). Enrichment plantings were also established in Rotoehu Forest.

The trial, established in 1959-61, covered 54 ha, and tested 18 exotic and one indigenous species. In an adjacent area to the Mamaku trial an enrichment trial with native species was also established.

Site preparation methods tested for the exotic species included:

- Hand - cut clearings
- Bulldozer clearings
- Bulldozer - crushed lanes
- Bulldozer - cleared lanes
- Total clearing by windrowing
- Gaps formed by poisoning scrub hardwoods.

Regular measurements were collected from 1961 to 1982 (Table 1). A full trial report was completed in 1984 (B. Moberly unpublished data).

Table 1. 1982 Height and diameter summary of best performing species

Species	Height (m)		Diameter (cm)	
	Untended	Tended	Untended	Tended
<i>Acacia melanoxylon</i>	17.9	17	17.9	25.5
<i>Cryptomaria japonica</i>	12.3	11.1	12.3	18.1
<i>Cupressus macrocarpa</i>	13.7	14.3	13.7	22.4
<i>Cupressus lusitanica</i>	14	12.8	14	24.3
<i>Picea sitchensis</i>	11.8	10.2	11.8	11.27
<i>Thuja plicata</i>	10.1	9.3	10.1	18.7
<i>Eucalyptus fastigata</i>	23.3	-	23.3	na
<i>Sequoia sempervirens</i>	10.1	10.5	10.1	21.3

This report concluded that the most successful species was *Acacia melanoxylon*, followed by *Cupressus macrocarpa* and *Cupressus lusitanica*. *Cryptomaria japonica*, *Picea*, *Sequoia* and *Thuja* also performed well in places.

Despite some impressive growth rates, the *E. fastigata* was not considered a success because of potential damage from native pin-hole borer.

In the last five years, the health of crowns of the *Acacia melanoxylon* has declined, and significant mortality has occurred. Insect attack by sap suckers is a possible cause of the poor health.

Hand-cut groups

An area of 22 ha was divided up by 36 grid lines about 20 m apart. Along each lane 6-12 groups of 25 trees were planted. The centres of the groups were about 20 m apart. Groups were 14.6 m in diameter, large enough to accommodate the 25 trees at a spacing of 1.8 x 1.8 m in a cruciform formation.

One of the lanes was tended (pruned and thinned) while the other was untended. Where only one lane was planted half the groups were tended. Other areas were prepared by bulldozer to establish lane and group plantings.

The species planted in the hand-cut groups are listed in Table 2.

Table 2. Species tested in hand-cut groups

<i>Abies concolour</i>	<i>Larix</i> spp
<i>Abies grandis</i>	<i>Libocedrus decurrens</i>
<i>Acacia melanoxylon</i>	<i>Nothofagus obliqua</i>
<i>Cryptomaria japonica</i>	<i>Picea sitchensis</i>
<i>Cupressus macrocarpa</i>	<i>Pseudotsuga menziesii</i>
<i>Cupressus lusitanica</i>	<i>Thuja plicata</i>
<i>Eucalyptus delegatensis</i>	<i>Tsuga heterophylla</i>
<i>Eucalyptus fastigata</i>	<i>Sequoia sempervirens</i>
<i>Eucalyptus obliqua</i>	<i>Dacrydium cupressinum</i> *
<i>Eucalyptus regnans</i>	

* indigenous species

In January 1998, diameters of all live trees located in the hand-cut groups were measured (Table 3).

Table 3. Diameters from 1998 assessment of hand-cut groups

Species	Diameter bh (cm)	
	Tended	Untended
<i>Acacia melanoxylon</i>	35.5	26.1
<i>Cryptomaria japonica</i>	33.1	23.5
<i>Cupressus macrocarpa</i>	37.8	na
<i>Cupressus lusitanica</i>	35.8	na
<i>Picea sitchensis</i>	17.6	19.6
<i>Thuja plicata</i>	32.5	29.4
<i>Eucalyptus fastigata</i>		57.6
<i>Sequoia sempervirens</i>	30.2	18.6

The trial block has extremely variable site characteristics, resulting in several plots per species that have performed well in terms of diameter growth and survival, while adjacent plots have either fared poorly or failed. Overall, the size of the lightwell and the numbers of adjacent dominant tawa also appear to have had a major effect on species performance.

The better-performing species were *A. melanoxylon*, *C. lusitanica*, *C. macrocarpa*, *S. sempervirens* and *Thuja plicata* from a list similar to that of the 1984 assessment. Perhaps *C. japonica* should also be included because of its fair diameter growth, but there were many trees of poor form and the species appeared prone to wind damage, even on trees with single leaders (not only those with double or multiple leaders).

The treated plots (pruned and thinned), as expected, performed better than untended plots.

Of the eucalypts, *E. fastigata* had performed the best, but only as individual trees, often attaining a large diameter, but with heavy branching.

The native species tested, *Dacrydium cupressinum* (rimu), had often survived well, but had either been suppressed by more vigorous *C. japonica* or surrounding native species.

North Island survey

Interest by the NZFS in identifying higher-value species for planting resulted in a survey of North Island blackwood plantings in 1978. Blackwood plantations, mixed species stands and shelterbelts were assessed at 69 locations (FRI 1978). This work showed that shelter and growing conditions (mixtures, plantations, etc.) had the greatest influence on growth and form of blackwood. A later survey of South Island stands reached a similar conclusion (B. Cosslett, *pers. comm.* 1985).

Of the 69 locations assessed as part of the 1978 survey, four were mixed with indigenous vegetation (Table 4).

Table 4. Summary of 1978 sample locations where blackwood was mixed with indigenous vegetation

Site	Age (y)	Crop trees assessed (n)	DBH (cm)	Ht (m)	Bole ht (m)
Rotoehu	18	6	25.7	18.6	4.5
Te Wera	17	6	24.4	23.2	5.5
Mamaku	18	8	22.8	13.5	5.5
Wairarap	12	10	13.6	7.6	3.1
a					

Westland

Early plantings in Westland showed the potential of blackwood when established in regenerating or logged-over native areas. It could tolerate shade and weed competition from native regeneration, and did not require significant fertiliser inputs. These attributes placed blackwood in front of pine as an afforestation species for parts of the region.

The initial plantings, established on well drained areas, were so impressive that blackwood was selected by the NZFS as the main species other than pine for planting in South Westland. As reported by Gifford *et al.* (2002) in these proceedings, a significant resource was established. Growth, however, reflected site attributes, with performances varying widely (Table 5).

While blackwood was established in many areas as a plantation forest, because of native regeneration the system was in reality a mixture with regenerating indigenous forest.

These sample plots show the variability in performance of blackwood in Westland. In particular, height growth is considerably less than

that seen on many North Island sites, but diameter growth has been reasonable ($>1 \text{ cm y}^{-1}$).

Table 5. Summary of Westland sample plots established as mixtures with indigenous vegetation

Site	Age (y)	Stocking (stems ha^{-1})	MTD (cm)	MTH (m)	BA ($\text{m}^2 \text{ ha}^{-1}$)	Vol ($\text{m}^3 \text{ ha}^{-1}$)
Wanganui	20	767	27.2	14.2	23.7	127
Ianthe	19	190	31.4	15.1	11.3	63.7
Ianthe-1/1	16	423	23.7	13.1	9.6	48.1
Ianthe-1/4	16	492	21.5	12.1	9	41.9
Granville*	31	250	33.8	18.4	15.5	107.6

*Mixed with *Nothofagus fusca* at 120 stems ha^{-1}

East Coast trials

Trials by Forest Research on the East Coast of New Zealand's North Island have investigated the effect of lane width and other management practices on form and performance of blackwood planted in various indigenous scrub cover (Herbert 1994). Analysis of one of the trials planted in cut lanes in a scrub cover dominated by kanuka (*Kunzea ericoides*) showed blackwood had reached a height of about 4.5-6 m. At age 4 y the overall incidence of multi-leadering was 25% on blackwood trees averaging 4.9 m in height, an excellent result considering no form pruning had been carried out.

Figure 1 clearly shows the form control from narrow lane widths, while the lanes 6 and 9 m wide, despite having been planted with double rows of blackwood, have done little to improve form and are performing similarly to the controls. In all plantings of blackwood the natural, unpruned clear bole length (single leader, lightly branched) has been monitored since planting. At Poroporo the blackwood planted in lanes 1 m wide have achieved a mean clear bole length exceeding 4 m, a gain of over 2 m from blackwood planted without a competing trainer species (Fig. 2).

Height growth in the lane plantings also reflect the influence of the associated mixtures (Fig. 3). At Rangitukia, growth was excellent in the first six years, but once the blackwood emerged from the scrub, height growth slowed as apical dominance was lost and the crown spread out. The trend is the same in the Poroporo trial, although the differences in total mean height between the control and the lane plantings are slight. These trials, despite their close proximity, are demonstrating varying responses to differing soil types and vegetative scrub behaviour. In the older trial at Rangitukia lanes were cut into young (less than 10 years old) and dynamically growing scrub. Consequently the acacia had to compete for height with an actively growing surround. At Poroporo the scrub at planting was older (>20 years), shorter and beginning to

naturally thin prior to lane cutting. Gaps in the cover were already being invaded by indigenous conifer species and in hindsight the scrub cover was weak and in decline. Therefore in combination with heavier and wetter soils than at Rangitukia height growth and the length of the unpruned clear bole is shorter.

The attempt to improve form by encouraging competition between blackwood in wide lanes (>6 m wide) by planting double rows did not succeed and on these sites form has been similar to that of blackwood planted in open, non-scrub plantings. At both Rangitukia and Poroporo the length of the lightly branched and single leader bole was developed in the first 3-4 y after planting. However, once blackwood emerged from and dominated surrounding scrub the form of stems rapidly deteriorated as crown break and persistent heavy branching occurred.

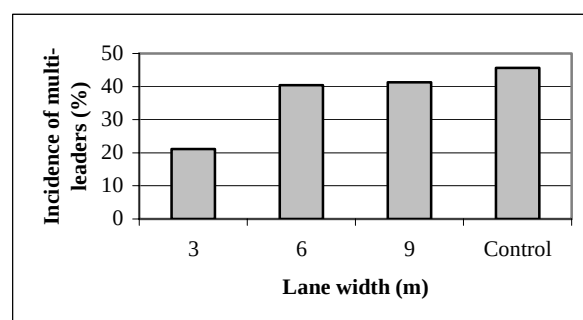


Figure 1. Effect of lane width on form of 4-y-old trees at Poroporo

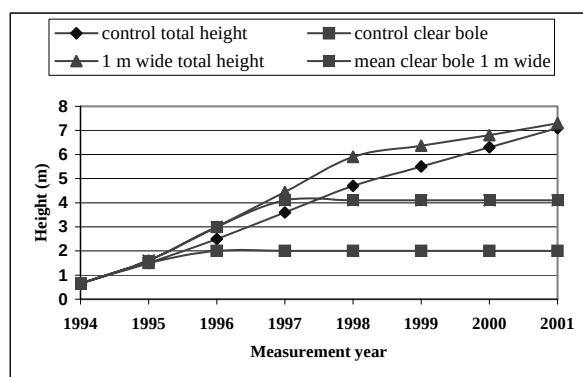


Figure 2. Effect of lane width on form and growth at East Coast trials, age 7 y

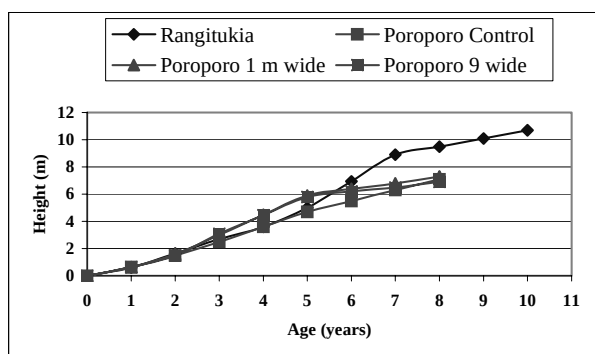


Figure 3. Performance of blackwood at age 8 and 10 y planted in varying lane widths at Rangitukia and Poroporo

These East Coast trials have successfully demonstrated the potential of planting blackwood in mixtures with indigenous vegetation, but those contemplating planting blackwood in a scrub-covered site need to take into account lane width and form pruning as part of the management process.

Other locations

Other successful examples of blackwood planted in mixture with indigenous vegetation exist in other South Island locations, i.e., Southland and Canterbury, as well as in North Island forests from Waitangi to Gisbourne. These indicate that the system has been successful throughout New Zealand.

Regeneration concerns

Although early plantings of blackwood to enrich native forest have been quite successful, at times in New Zealand the concept of replacing indigenous forest or scrub with an exotic species was not acceptable. More recently, concern has been raised on the potential of blackwood to regenerate into native reserves adjacent to current plantings, and create an exotic weed problem. Many protagonists of this argument tend to concentrate on the potential for blackwood regeneration, rather than the actual ability of blackwood to invade natural vegetation in NZ. There is little argument that either through seed drop or root suckering blackwood has the ability to regenerate on a site, but has not shown an invasive tendency. A survey of 15 regional councils by Forest Research in 1999 found that although other acacia species are considered to have weed status in many regions, blackwood does not. The only respondent to the survey suggesting blackwood had weed characteristics was the Department of Conservation.

Blackwood is considered a weed species in South Africa, where it is spread by birds and there are no seed predators. The situation is different in New Zealand; there is no evidence of bird spread in New Zealand and preliminary tests show that in the North Island up to 50% of seed can be damaged by insects. From limited studies conducted in both 1980 and 2001, South Island seed appears to be healthier than North Island seed. This may be an artifact of sampling and should be tested with wider collections of fresh seed in the future.

Evaluations of Forest Research regeneration plots established in 1984 and reassessed in 2001 showed a reduction in surviving regeneration; where seedlings were noted on disturbed sites, these have developed into saplings. No invasion of native forest has occurred on these monitored sites which include enrichment planting from 1960.

The recent field study has reinforced the conclusions from a 1984 study which stated 'It was considered that these studies confirmed the ability of blackwood to regenerate well in open, disturbed conditions (after logging), but no significant spread is likely to occur in shaded, undisturbed conditions within indigenous forest' (B. Moberly unpublished report).

Further field studies by Forest Research to assess blackwood regeneration on other sites included stands ranging from 95 to 17 y old. This concluded that a consistent pattern emerged from field assessments of blackwood stands in Westland and in the North Island. There was no evidence that blackwood would become a weed species invading native vegetation outside of planted areas without localised changes in soil and light conditions.

Regeneration was occurring within existing plantings and was likely to move out of these only if light and soil disturbance occurred within rooting distance and if seed was available. Even where regeneration was occurring, the active native vegetation was often-outcompeting the young blackwood regeneration.

Blackwood has shown an ability to colonise road edges, from both root suckers and seed dispersal onto disturbed road edges, but as described above is not expected to move into native vegetation unless light and soil conditions are favourable. Roadside colonisation occurs with a myriad of species in all forest areas of New Zealand because of the combination of light and soil disturbance. Because of ease of access, such colonisation can be managed by appropriate forest management, either through roadside trimming or the use of herbicides, and in determining grading direction near existing seed sources.

This species which has been in the country for over a century and planted widely, providing sufficient opportunity to demonstrate any capacity to seriously invade native ecosystems. Blackwood has had ample opportunity to colonise and invade farmland, native and exotic forest but only does so if associated with soil disturbance or if the seed is carried by man, especially with road machinery. There is no doubt that in the future regeneration will occur at harvesting time if soil disturbance occurs. Forest managers will have the opportunity to control or manage such regeneration at that time.

The likelihood of blackwood becoming a biosecurity risk in the future is no less or more than it has been over the last century. Assessment of stands from Harihari to Hunua indicates that, under New Zealand conditions, there is no evidence of blackwood becoming a significant biosecurity risk in the future. It is likely that its continued planting as a specialty timber species will see it become even more common in the landscape as a plantation species.

Economics

Several studies have evaluated blackwood planted in mixture with existing vegetation (Table 6).

Table 6. Examples of economic analysis incorporating planting in mixtures

Reference	Date	IRR (%)	System
Cavanna & Glass	1985	5.3-8	Group planting
Herbert	1994	6.5-6.8	Groups & lane planting
Unpublished	1994	6	Lane planting

These analyses, using old timber prices, are now well out of date, but they all showed a positive return of similar magnitude. Herbert used a stumpage value of \$50 m⁻³ and he stated that if the Sydney timber prices were used, returns for blackwood could be of the order of 10-12%. As current prices for blackwood logs are now around \$200 m⁻³, these higher returns appear quite possible.

Discussion

The research studies and other forest and farm plantings all show that blackwood interplanted in scrub is an excellent system. Key aspects are:

- Manuka/kanuka is an effective trainer for blackwood, as it is for native species.

- Broadleaf species are more difficult to manage because their more vigorous growth causes greater shading.
- Site selection is important in growing blackwood, it must have sufficient soil moisture.
- Gap size or lane width should be about half the height of the surrounding vegetation.
- Lanes are preferred for planting because they make it easy to locate trees at future visits; when planting in lanes or holes it is imperative that seedlings be planted directly under the canopy gap, which does not always occur in the centre of the lane or hole.

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18

Physiological Responses to Pruning in Mixed Species Plantings

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Introduction

Pruning of live branches, both form and lift pruning, is used extensively in blackwood plantations to manage the formation of a high-quality and straight, branch-free bole. Green pruning inevitably reduces growth potential because of the loss of leaf area, but is associated with physiological responses that provide the tree with a means of compensating for this lost potential. In this paper we address these responses in the context of a five- to six-year-old mixed species planting of blackwood with *Pinus radiata* as the nurse crop. The *P. radiata* was planted at 5.0 x 2.5 m between and within row spacings (800 trees ha⁻¹); the blackwood was planted between every second row of *P. radiata* at 10.0 m x 2.0 m spacings (500 trees ha⁻¹). The nurse-crop was planted to provide sidelight suppression. Such competition for light will clearly affect the ability of the blackwood to maximise growth responses through compensatory mechanisms, and thinning of the nurse-crop may be required.

Severity of pruning and photosynthesis

Physiological responses to green pruning occur at two levels. The first is related directly to the photosynthetic process and is observed as an increase in single-leaf net photosynthesis (Reich *et al.* 1993; Pinkard *et al.* 1998); the second is observed as an increase in the rate of leaf development and increase in leaf longevity of existing leaves (Pinkard and Beadle 1998a). The magnitude and duration of these physiological responses is, most importantly, related to the severity of pruning though also appears to be a function of species (Pinkard and Beadle 2000).

Changes in photosynthesis and canopy development were investigated in one of four treatments that combined three levels of form pruning of the blackwood (viz. 0%, 25% and 50% removal of total foliage area), and four levels of thinning of the *P. radiata* (viz. 0%, 33%, 66% and 100% removal of stand basal area). The 66% thinning treatment was used where every second and third nurse-crop tree in the row was removed. This was the minimum requirement to achieve a measurable increase in the level of incident light at the base of the canopy (1.3 m) at a point equidistant between the blackwood and nurse-crop (Fig. 1). To mimic selective pruning, the central blackwood in each of the three replicates was an unpruned control. The 25% and 50% pruning treatments were randomly assigned to the trees on each side of this control. Average blackwood and nurse-crop height and diameter at breast height just prior to treatment in January 2000 were 5.4 m and 63 mm, and 6.9 m and 112 mm, respectively.

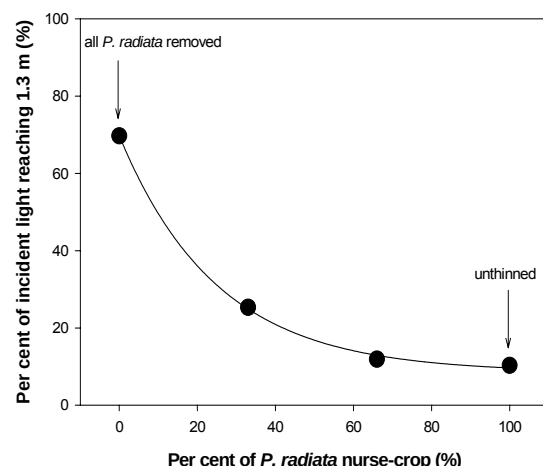


Figure 1. The level of light reaching 1.3 m at the base of the canopy between blackwood and *Pinus radiata*

The 50% pruning treatment led to an increase in photosynthetic capacity ($A_{\max}$) over the whole crown ($p < 0.05$) compared to the unpruned treatment, two weeks after pruning (Fig. 2). Differences in $A_{\max}$ between these treatments were sustained for at least 40 weeks but primarily in the upper and middle parts of the canopy. In general, differences in $A_{\max}$ between the 25% pruning treatment and unpruned treatment were not significant though there was an immediate response to the pruning and the overall effect of pruning treatment was significant ($p < 0.10$) six weeks after pruning.

Crown development was estimated from an allometric relationship between branch diameter and branch leaf area (Pinkard, unpublished data), and measurements of branch diameter at pruning, and on five more occasions over a 12-month period. Changes in relative crown leaf area following pruning indicated a recovery to pre-pruning levels within two months in the 25% pruning treatment and within 12 months in the 50% pruning treatment (Fig. 3). Thus the period of time required to replace lost foliage coincided with the increases in $A_{\max}$ in both pruning treatments.

Linking physiology with growth

It can be seen from the above observations that blackwood has compensatory mechanisms that can lead to the tree's recovery to the pre-pruning condition. In both pruning treatments this was associated with no significant effect on height increment or on diameter increment in the 25% pruning treatment. However, in the 50% pruning treatment, there was a significant reduction in diameter growth two years after treatment (Fig. 4).

In a *Eucalyptus nitens* plantation that had 55% of its crown area removed in a single-lift pruning from below, crown recovery was also completed in around one year (Pinkard *et al.* 1999), but this was not associated with any significant reduction in growth compared to an unpruned control (Pinkard and Beadle 1998b). In *E. nitens*, significant increases in $A_{\max}$ occurred also in response to this level of pruning.

The underlying reason for this apparent difference between species in response to similar levels of pruning is not clear, but the most likely explanation is the effect of the nurse crop on the total levels of radiation incident on the blackwood. This was investigated by measuring average incident light at three levels within the blackwood canopy and four levels within the nurse-crop canopy in the 66% (same plots as used for the photosynthetic measurements described above) and 100% thinning treatments (Fig. 5).

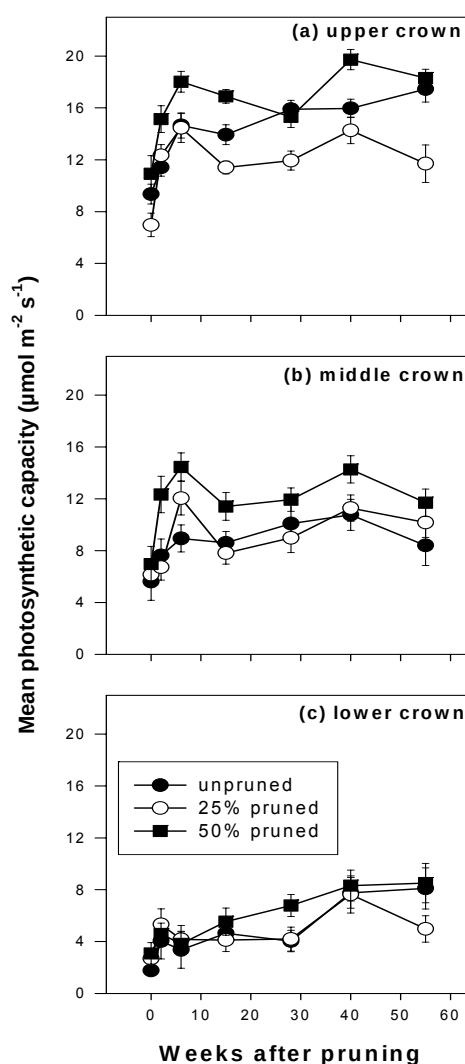


Figure 2. Photosynthetic capacity and pruning severity at three levels - (a) upper, (b) middle and (c) lower - in the blackwood canopy

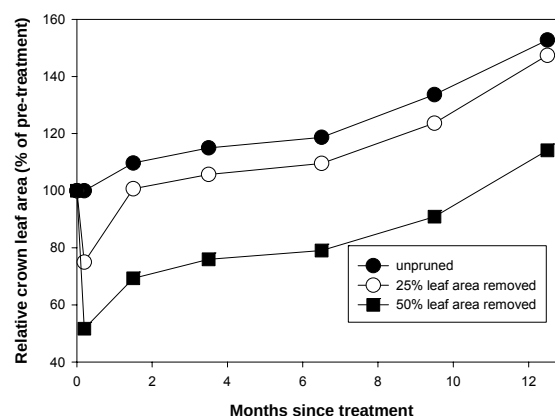


Figure 3. Changes in relative crown area and pruning severity

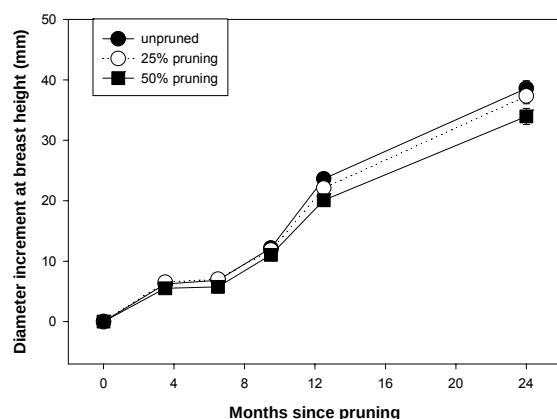


Figure 4. Changes in diameter increment and pruning severity

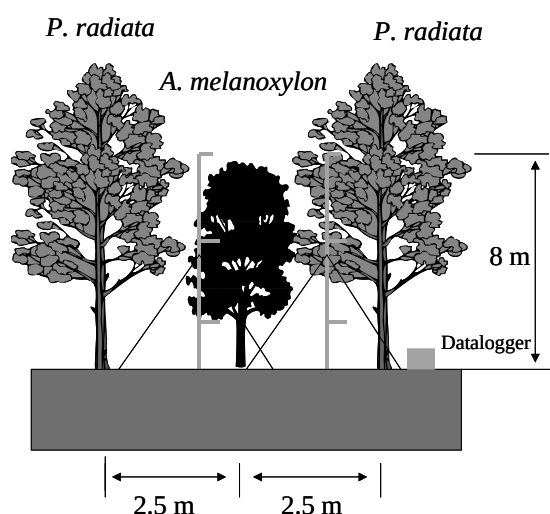


Figure 5. The location of light sensors in the blackwood and *Pinus radiata* canopies. Levels of light incident at the top of the pine canopy were measured in an open area adjacent to the plantation.

At the time of sampling in April 2002, average blackwood heights were 7.7 m and 7.1 m respectively in these treatments. Average height of the nurse crop in the 66% thinning treatment was 12.5 m. The effect of this difference in height was to reduce the levels of light incident at the top of the blackwood canopy to 70% of incident radiation (Fig. 6). The high leaf area density of blackwood resulted in there being no differences between treatments at the mid-point and directly beneath the blackwood canopy, though this measure was highly variable in the 100% thinning treatment. It is interesting to note that the measurements at the same heights in the *P. radiata* canopy show that it is a species with a lower leaf area density, which imposes moderate levels of sidelight suppression (see Pinkard *et al.*, this volume).

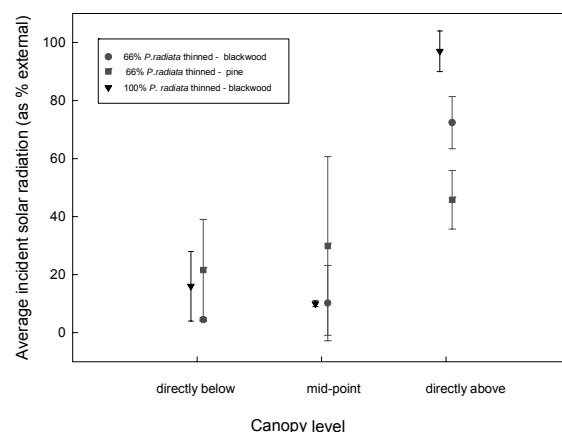


Figure 6. Light profiles in the 66% and 100% removal of *Pinus radiata* canopy treatments

What can we learn from these physiological measurements? In summary, blackwood has a capacity to recover its crown leaf area from severe levels (50%) of form pruning. This is related to an increase in A_{max} . This observed increase in photosynthetic capacity, however, is not fully realised because of the presence of the nurse crop and this can lead to a significant reduction in diameter growth. This conclusion was supported from measurements that showed that the effect of the 50% pruning treatment on diameter growth was greater in the low compared to the high intensity thinning treatments (data not shown). Thus crown responses to a given level of pruning will be slower, and the ability of the recovering crown to photosynthesise will be less, than the values measured here when thinning removes less than 66% of the nurse crop. The rapid recovery from less severe levels (25%) of form pruning was probably associated with the transient increase in photosynthetic capacity that occurred in the first few weeks after pruning. Increasing severity of form pruning is also associated with the removal of a greater proportion of branches in the middle and upper levels of the canopy. These branches contribute a much greater proportion of the carbon gain to the tree than those in the lower level of the crown. Thus, while the increase in photosynthetic capacity at the leaf level was observed only in the upper and middle parts of the crown, levels of canopy photosynthesis at these levels would have been more compromised in the 50% compared to the 25% pruning treatment. In addition, the reduced levels of incident light caused by the presence of the nurse-crop would have meant less than full expression of these enhanced levels of photosynthesis. Taken together, these factors would have contributed to the very large difference (around 8 months in the time for canopy recovery between the two treatments).

Pruning and form

Form pruning by definition targets branches that have already fallen behind the criteria that define good form, or are expected to do so in the period between the current form pruning and a subsequent silvicultural intervention, for example lift pruning. In this experiment, the form just before the treatments were established was poor. Across all treatments, only 41% of the trees had a single leader and 22% had one or more branches >30 mm diameter. Table 1 shows that form pruning increased ($p<0.05$) the number of trees with single leaders and that increasing severity of pruning was related to decreasing numbers of large branches. Two years after pruning these effects were not evident. The reason for this poor result is partly related to the absence of any form pruning prior to the start of the experiment when the blackwood was age 5.5 years. While it remains uncertain whether an earlier form pruning would have led to better outcomes, a greater reduction in the number of apical leaders is likely. Earlier form pruning would also be undertaken before canopy closure, so the recovery of the canopy from a given level of pruning will be faster.

Table 1. The number of large branches per *Acacia melanoxylon* stem and the number of competing leaders per stem immediately and two years after pruning. Mean standard errors are in parentheses.

Time of observation and form pruning treatment ^a	Mean number of leaders per tree	Mean number of branches >30 mm diameter per tree
<i>Immediately after treatment</i>		
0	2.40 (0.10)	1.39 (0.08)
25	1.58 (0.09)	1.22 (0.05)
50	1.58 (0.09)	1.14 (0.05)
<i>Two years after treatment</i>		
0	1.83 (0.09)	4.29 (0.33)
25	1.71 (0.09)	3.61 (0.33)
50	1.79 (0.09)	2.99 (0.25)

^aFraction of *A. melanoxylon* leaf area removed (%)

Conclusions

The logic for using nurse-crop systems is to minimise the need for intervention, particularly pruning. The reality is that some pruning is still required in these systems. The faster growth of the nurse crop compared to the blackwood leads to the intensification of shading of the blackwood with time (Pinkard *et al.*, this volume). This means that any form pruning should be light to minimise reduction in growth of the blackwood. If pruning is initiated early, branching patterns that are likely to lead to poor form can often be managed (Brown 1997). In blackwood plantings without nurse crops in New Zealand, the greatest improvement in form occurs with annual pruning (Nicholas *et al.* 1994). Such frequent pruning should not be necessary with nurse crops but should be used as required at least until good form has been established in the first 6 m of the stem. In the blackwood-*P.radiata* system used here, the last form pruning rather than the first form pruning would have occurred at around the beginning of the experiment. Judicious thinning of the nurse crop can then be undertaken without experiencing the prejudicial effects on form that could not be managed through form pruning at this stage in the stand's development. The slower growth of blackwood during winter suggests that compensatory responses to green pruning will be maximised and period of crown recovery minimised if green pruning is undertaken in spring to coincide with an acceleration in the rate of growth.

Acknowledgement

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Modelling Response to Pruning and Nurse Crop Competition: A Work in Progress

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A simple model based on plausible assumptions governing light interception, biomass partitioning, canopy development, and stem height and diameter growth is developed to model the growth of blackwood (Acacia melanoxylon) in response to form pruning and nurse crop thinning. The response to form pruning postulates a pruning response that decays with time and affects one or more of light use efficiency, the ratio of foliage:stem biomass partitioning, and leaf litterfall. A model for partitioning intercepted radiation in a multi-species canopy takes into account effects of the nurse crop. The full model 'does the right things', but has not yet been applied to blackwood. Progress is promising, but the model is definitely 'a work in progress' rather than a definitive model! This paper summarises the basic elements of the model, and compares its qualitative behaviour to observed growth data from both blue gum (Eucalyptus globulus) and blackwood.

Introduction

Experiments on how form pruning and nurse-crop thinning affect blackwood (*Acacia melanoxylon*) growth and physiology provide general qualitative guidelines for silvicultural management of blackwood (Medhurst *et al.* 2002). However, much of this data came from experiments conducted under quite specific conditions. The actual response to an intervention will depend on factors such as stand age and site conditions. To provide support for management that is neither site- nor age-specific it is necessary to develop a model consistent with both general stand growth and specific physiological responses of blackwood. In this project I develop the basics of such a model.

I used the stand growth model described by McMurtrie and Wolf (1983) as the starting point for such a model. Their model takes into account light interception and photosynthetic production, respiration, allocation to various biomass pools, and litterfall and root turnover. Each of these was represented by simple empirical relationships with constant parameters. The model I use here has biomass pools for foliage, stem wood, branches and bark, and roots, and I generalised some of the basic relationships in the original model. I added relationships for the affects of form pruning on canopy growth and photosynthetic

capacity, and for the affect of the nurse crop on the radiation available to the blackwood.

The emphasis is on simplicity, perhaps at the risk of over simplification, but detail can be readily added as needed. I describe the assumptions of the simple model, and then indicate how a more rigorous approach could be adopted.

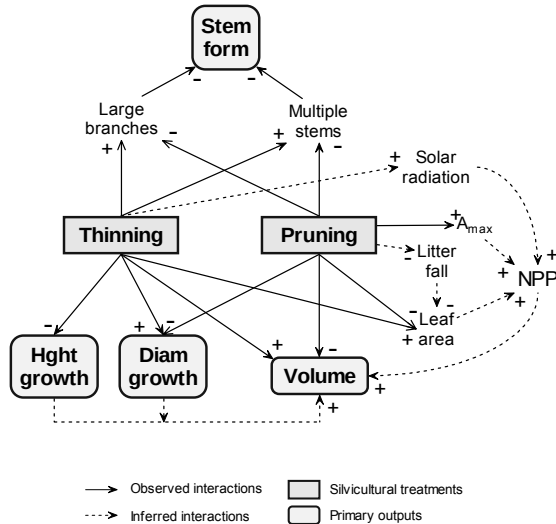
Effects of blackwood silviculture

Figure 1 summarises the observed effects of nurse-crop thinning and form-pruning on the growth and physiology of blackwood. This is based on data from experiments by Medhurst *et al.* (2002) at Beulah in NW Tasmania, which are typical of responses observed elsewhere and for other species. In Figure 1 factor A affects B *positively* if an increase in A leads to an increase in B, or *negatively* if an increase in A leads to a decrease in B. Figure 1 also differentiates responses observed directly from blackwood from those inferred from other experiments or generic responses.

For example, nurse-crop thinning increases the number of large branches and multiple stems in the blackwood. It also increases solar radiation impinging on the blackwood, and hence leads to an increase in NPP and volume. Blackwood form-pruning has been shown to increase

photo-synthetic rates, and as pruning is mainly from below it decreases litter fall. These two effects enhance the immediate recovery of the canopy.

Figure 1. Influence of nurse-crop thinning and



form-pruning on blackwood growth and stem-form

Analyses such as those in Figure 1 are the basis for incorporating silvicultural effects into the growth model. For example, NPP (G , $\text{kg}_{\text{DM}} \text{m}^{-2} \text{yr}^{-1}$) is proportional to intercepted radiation, which is determined from canopy LAI (L , $\text{m}_{\text{leaf}}^2 \text{m}_{\text{ground}}^{-2}$) using Beer's Law, i.e.

$$G = \varepsilon Y (1 - e^{-kL}) Q_0$$

where ε ($\text{kg}_{\text{DM}} \text{MJ}^{-1}$) is a measure of the efficiency of conversion of light into dry matter, Y takes into account respiration, k is the canopy extinction coefficient, and Q_0 ($\text{MJ m}^{-2} \text{yr}^{-1}$) is the radiation incident on the canopy. Nurse-crop thinning:

- immediately allows more light to reach the blackwood canopy, which increases Q_0 , and
- opens space for the blackwood canopy to develop, which allows L to increase.

The result is an increase in growth rate. (The improved light environment, however, reduces height growth, and increases diameter growth, relative to an unthinned stand.) Form pruning immediately reduces L , and so reduces growth rate, but induces a pruning response that:

- increases light saturated photosynthetic rate A_{max} , and hence increases ε ,
- decreases leaf litter fall, and
- increases biomass partitioning to foliage at the expense of stemwood.

The result is an immediate increase in photosynthetic rate per unit leaf area, together

with a recovery over time of L , but at the expense of stem diameter growth.

Modelling growth and silvicultural effects

Figure 2 is a schematic diagram of the full model. It shows the flow of carbon through the McMurtrie and Wolf (1983) model, and submodels for height and diameter growth, and for the effects of pruning and of nurse-crop stocking on blackwood growth. It also shows various influences and feedbacks. These components are discussed in more detail below.

Light interception, photosynthetic production, and respiration

Light interception by the canopy is determined using Beer's law and requires canopy LAI (L). Total production is assumed to be proportional to intercepted solar radiation since above-ground dry matter production is observed to be so (e.g. Linder 1985), and the light use efficiency (ε) is the slope of this relationship.

The simplest way to take respiration into account is to assume that G is a fixed fraction ($Y \approx 47\%$) of gross production (e.g. Waring *et al.* 1998).

Biomass allocation, litterfall, root turnover and mortality

In McMurtrie and Wolf (1983) the biomass partitioning ratios were constant parameters. I assume that: partitioning to roots is a constant parameter (η_R) with a higher value on nutrient-poor or water-stressed sites, the ratio (η_{FS}) of foliage:stem biomass partitioning declines as stem height increases, and partitioning to branches and bark (η_{BB}) declines with age.

I assume leaf litterfall and root turnover rates (γ_F and γ_R) are proportional to the current leaf and root biomass pools. Mortality assumes a constant death rate.

Height growth

I assume that tree canopies are ellipsoids with a uniform leaf area density, and that foliage is added at the top of the canopy and litterfall confined to the base. In a closed canopy the rate of height growth is proportional to the rate of production of foliage and inversely proportional to canopy leaf area density, and the rate of canopy lift is determined by the rate of litterfall.

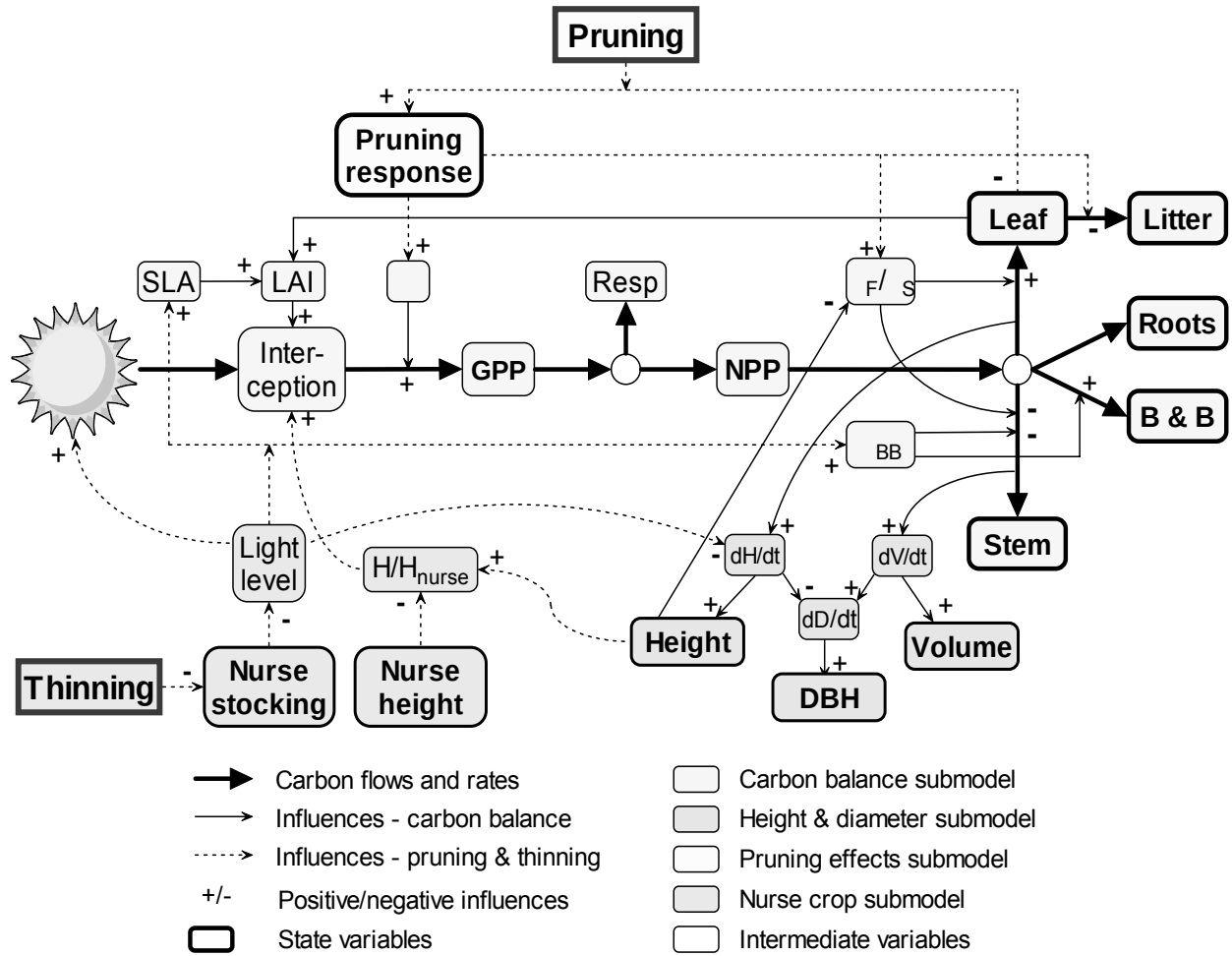


Figure 2. Schematic diagram of tree growth model including potential effects of a nurse crop and pruning

Stem diameter growth

I assume a conical stem with a constant shape factor, so increments in stem biomass, height and diameter are constrained by a simple volume formula. As biomass is added to the stem it increases stem volume, and this is accompanied by an increase in one or both of stem height or diameter. I also assume the ratio (η_{HD}) of height and diameter growth rates is under environmental control; so, for example, nurse crop thinning reduces competition for light which reduces height growth.

Response to pruning

I use a simple mechanistic approach to represent the pruning response. Data from blackwood (e.g. Medhurst *et al.* 2002) and for *E. nitens* (e.g. Pinkard *et al.* 1998) show responses in both growth and physiology were maintained over a significant period of time. For example, for several months following pruning, light-saturated photosynthetic rate A_{max}

was higher than in un-pruned trees, and canopy growth rate was enhanced.

I assume pruning initiates a pruning response (P) that affects one or more of photosynthesis, partitioning to foliage, and litterfall. P is a dimensionless quantity whose value declines with time and reflects the current strength of the pruning response. At pruning P is set equal to the fraction of foliage biomass removed, but then declines exponentially with a time constant of the order of 6-12 mo. I make no attempt to provide a physiological basis for P .

Pruning initiates an increase in the efficiency with which the remaining leaves produce assimilates, so A_{max} , and hence also the light use efficiency ϵ , increase with P . I assume the increase in the rate of canopy development is mediated by an increase in the ratio η_{FS} and/or a decrease γ_F . So ϵ and η_{FS} are modelled as increasing functions of P , and γ_F as a decreasing function of P . As P declines towards 0, these parameters return to their values in the absence of pruning. The strength of the response of these various parameters (say τ) is expressed as

the percent change (P_{τ}) in the parameter when $P=1$. Thus the change in τ induced by pruning depends both on the value of P_{τ} and the pruning intensity.

This simple model has a potentially rich repertoire of behaviour and can be parameterised from data on assimilation and stand development at several times following pruning.

Light interception in a mixed-species canopy

Since the blackwood/nurse-crop system is a two-species stand, light interception by each species is required to drive the tree growth model. I use the ERIN model (Wallace and Verhoef 2000) to partition intercepted light between the nurse crop and blackwood. ERIN requires the heights and leaf areas of each canopy. Blackwood height and leaf area were predicted using the tree growth model. The nurse crop top height was assumed to be 90% of mean dominant height predicted by a simple empirical model (Candy 1989), and nurse crop leaf area was assumed to be proportional to its canopy depth.

In the ERIN model, a species is said to be *dominant* if its canopy completely over-tops that of the second, or *suppressed* if its canopy is completely below that of the second. In these cases, Beer's law applies to each canopy, and the light incident upon the suppressed canopy is that transmitted by the dominant canopy. If the canopies intermingle the light intercepted by one species is a weighted average of interception assuming it is in turn dominant or suppressed, and the weighting factor is proportional to the square of the ratio of the canopy top heights.

Effect of a nurse crop

The nurse crop reduces the radiation available to the blackwood for growth, and I quantify this effect by the ratio Λ of radiation incident at the

top of the blackwood canopy to that incident on the top of the nurse crop, with $0 \leq \Lambda \leq 1$. High light levels ($\Lambda \rightarrow 1$) tend to increase branch production and reduce height growth, as demonstrated by the response to nurse crop thinning (see Fig. 1). In the model I represent this by making partitioning to branch and bark (η_{BB}) an increasing function of Λ , and the height growth rate a decreasing function of Λ .

Application of the model

I have not yet rigorously tested the full model on data from a nurse-crop/blackwood trial, but its major elements have been verified in various ways as shown here.

Application of the tree growth model to blue gum

The tree growth model was tested by applying it to a blue gum plantation that was neither water nor nutrient limited, and for which nine years of growth data are available. Some parameters were assigned values based on data from other blue gum stands, but a few were estimated by fitting model output to observed mean tree height, stem volume, and canopy LAI. This was not a rigorous validation, but Figure 3 shows the model can reproduce observed data and provide plausible long-term trends. Although the model is intended for use with real daily or monthly climatic data, it was applied here with no seasonal variation in radiation.

Application to the pruning submodel

The ability of the pruning submodel to reproduce observed effects was tested by using it to prune a notional stand and then comparing the responses with those shown by Beadle et al. (this Conference).

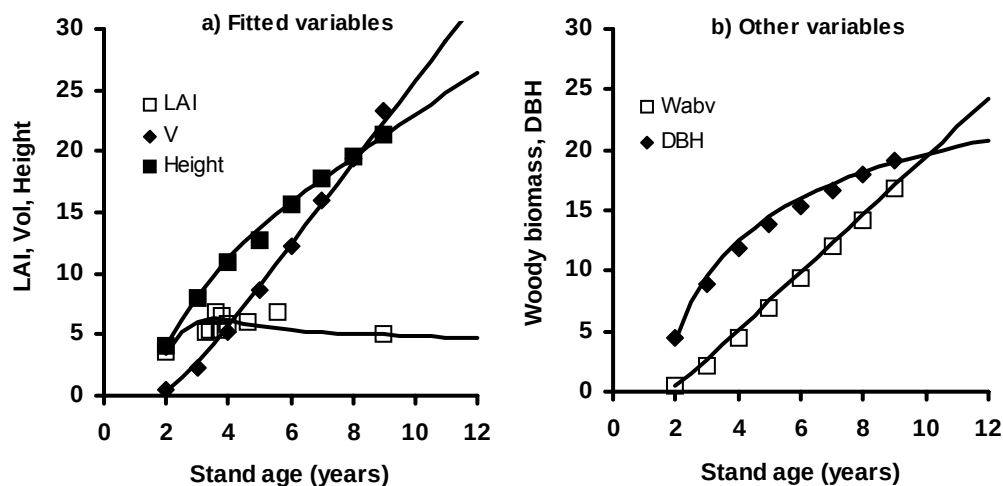


Figure 3. Comparison of observed stand development (symbols) of irrigated blue gum with predictions (lines) from the tree growth model

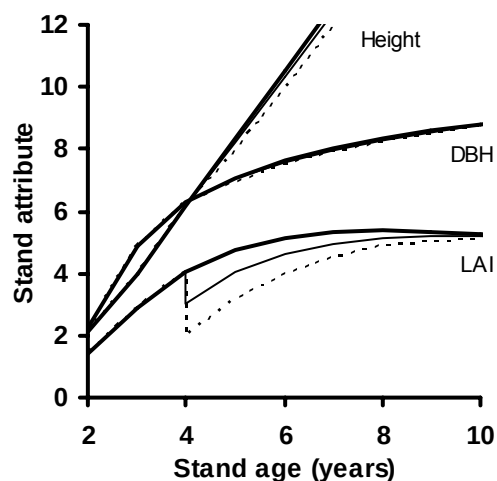


Figure 4. Effect of pruning at age 4 y on subsequent growth of a notional stand: unpruned (—), 25% pruned (---), 50% pruned (----)

Figure 4 illustrates response of canopy LAI, stem height and DBH to two levels of pruning as predicted by the tree growth model with no pruning response (i.e. $P=0$). Over time the canopy recovers, but height and diameter always lag the unpruned stand.

A pruning response was then assumed such that

- P is initially the fraction of foliage removed and decays exponentially with a rate constant of 1 yr^{-1} ,
- γ_F is decreased, and ε and η_{FS} are increased by 50% for unit P (i.e. $P_\tau=50\%$). The magnitude of these effects is arbitrary.

Figure 5 shows post-pruning growth increments in LAI, DBH and height over a three-year period as predicted using the pruning submodel. Figure 5a shows LAI growth with and without

the pruning response, and canopy recovery is enhanced by the pruning response. The qualitative nature of canopy recovery is consistent with Figure 3 of Beadle *et al.* Figure 5b shows that DBH growth with the pruning response is qualitatively consistent with Figure 4 of Beadle *et al.* Figure 5c shows the height growth with the pruning response. In this case the result obtained differs from that observed in blackwood, e.g. Figure 4b of Medhurst (2002) shows no effect of pruning on height growth.

Application of ERIN model

Application of the ERIN model requires the top height and canopy LAI of the nurse crop and of the blackwood. These were obtained for May 2000 and 2002 from the Beulah experiments (Medhurst *et al.* 2002) and from unpublished data of Cherry and Worledge. Top heights had been measured directly, blackwood canopy leaf area was inferred from an allometric relationship between leaf area and stem diameter, and stand leaf areas were measured for the four thinning treatments at Beulah. I assume that as canopy lift had not occurred for the nurse crop, its LAI was proportional to tree height, and found $5.5\text{--}5.6 \text{ m}^2 \text{ leaf m}^{-1} \text{ height}$.

The light transmitted to breast height in the blackwood-nurse crop stand in May 2000 was calculated using Beer's law and is compared in Figure 6a with observed data (Fig. 1 of Beadle *et al.*, this Conference) as a function of nurse-crop stem number. Figure 6b shows the fraction of incoming radiation intercepted by both the blackwood and the nurse crop.

Application to nurse crop thinning

This is part of the work in progress – watch this space!

Discussion

The model has three distinct components: a tree growth model, a model for the response to pruning, and a model for effects of a nurse crop on the light environment and growth of the blackwood. The tree growth and nurse-crop models are based on existing models. The pruning model is a simple, novel mechanism that captures observed physiological responses. The complete model has yet to be tested using data from a blackwood/nurse-crop plantation, but its individual components give generally plausible responses. The tree growth model reproduces observed growth of a blue gum plantation, the pruning submodel produces a range of plausible responses, as does the submodel for the influence of the nurse crop.

The growth model

I made significant simplifying assumptions on how the environment impacts tree growth – basically by subsuming these impacts into model parameters. However, these can be readily generalised in proven ways, e.g. as follows.

Light use efficiency varies in response to factors such as temperature or water availability. These effects can be modelled using the approach adopted in GROWEST (Fitzpatrick and Nix 1970) or 3-PG (Landsberg and Waring 1997), or photosynthetic production can be calculated using a process-based model (e.g. Sands 1995, 1996). Beer's law applies to a closed canopy, but it can be generalised for partial canopies (e.g. Jackson and Palmer 1979), and explicit expressions for light intercepted by individual trees are available (e.g. Charles-Edwards and Thornley 1973; West and Wells 1992).

A process-based approach to modelling respiration can be based on dark respiration, tissue maintenance respiration, and construction respiration.

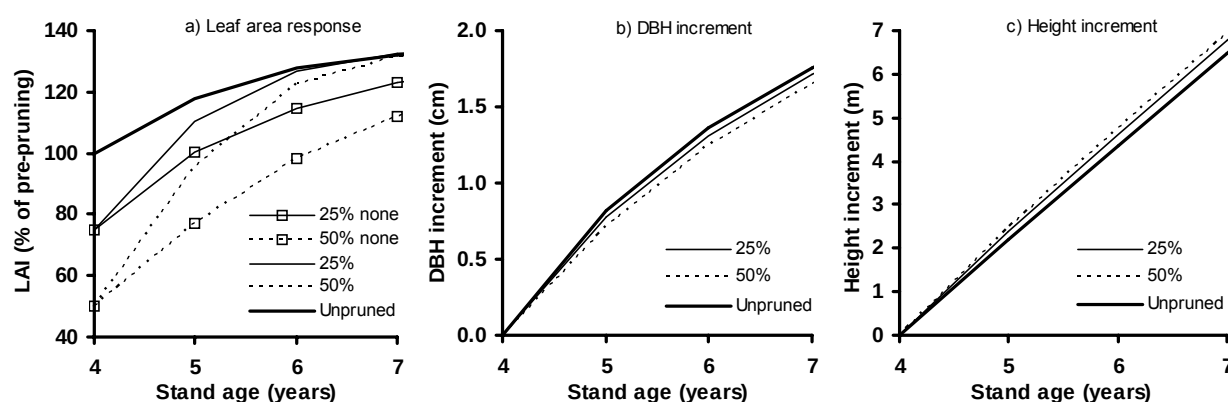


Figure 5. Post-pruning growth of (a) LAI, (b) DBH and (c) height of a notional stand: unpruned (—), 25% pruned (—), 50% pruned (---); symbols (□) indicate growth in the absence of a pruning response ($P = 0$)

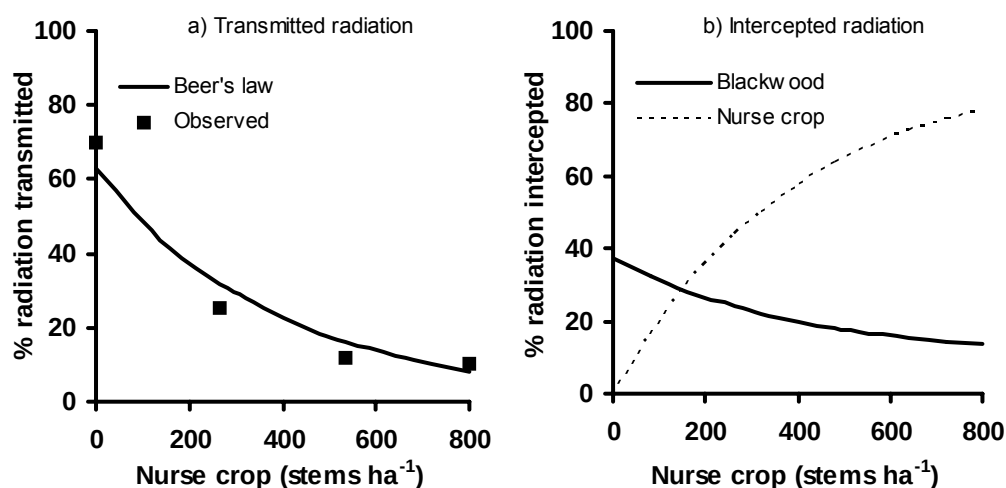


Figure 6. Transmitted (a) and intercepted (b) incoming solar radiation by a blackwood-nurse crop stand in response to nurse-crop stem number. Transmission was determined by applying Beers law to the combined stand, and interception was calculated using the ERIN model.

Dark respiration is proportional to leaf biomass, maintenance respiration is proportional to tissue biomass, and construction respiration is a constant fraction of the biomass synthesised. The specific respiration rates depend on factors such as tissue nitrogen concentration and temperature.

West (1993) modelled biomass partitioning in the McMurtrie and Wolf model as the solution to a linear programming problem that maximises leaf production subject to biological and mechanical constraints. However, this approach is too detailed for the simple model applied here. In general, γ_F and γ_R are affected by environmental factors, e.g. water stress, and can be made to vary with long-term conditions. Mortality of suppressed trees can be modelled in response to competition for light (e.g. West 1987), and density-dependent mortality can be introduced via the self-thinning rule (e.g. Landsberg and Waring 1997).

The model for canopy development assumes the canopy is closed so there is strong coupling between addition of new foliage and height growth rate. Prior to closure, addition of new foliage will be through branch elongation as well as height growth. Although the model does take enhanced branch growth in young stands into account because η_{BB} declines as stands age, it is still necessary to take into account reduced height growth rate in open stands.

Applications

The basic tree growth model provides a good fit to observed stand development provided the

model is initialised with observed data, e.g. at age 2 yr, and the predicted long-term trends also appear to be very plausible. However, it was difficult to obtain a good simulation of stem diameter growth when the stand was initialised at an earlier age. (This problem is not unique to this model!) This might be because the model does not properly determine radiation intercepted by an open stand, nor properly simulate canopy development prior to closure.

The growth in canopy LAI and DBH following pruning as predicted by the pruning model were qualitatively in agreement with the observed responses. However, height growth was predicted to be enhanced slightly following pruning, which was not observed by Medhurst *et al.* (2002). In the model height growth is tied to the production of new foliage and the leaf area density was assumed constant, so the enhanced production of foliage drove increased height growth. In reality, the blackwood canopy was not closed, and new foliage would be accommodated through branch elongation. Over the first year following pruning, leaf area density declined slightly (from 1.35 to 1.26 (± 0.8) m⁻¹, not statistically significant), although the canopy leaf area increased markedly.

The tree growth model can in principle be applied to the nurse crop. However, I calculated nurse-crop height using a simple empirical model (Candy 1989), and assumed that nurse-crop canopy leaf area is proportional to canopy height prior to canopy lift. (Comparison of observed nurse-crop heights at ages 6 and 8 yr

with output from the empirical model suggested a site index of about 33 m at age 20 yr.

Beers law and the ERIN model were applied to predict light interception by the blackwood and nurse crop in May 2000. Figure 6a suggests total stand interception declines more rapidly than might be inferred from Beers law. Figure 6b shows that less than 40% of the incoming radiation is intercepted by the blackwood, and this declined markedly with increased nurse-crop stem number. This is largely because the stand-level LAI of blackwood was less than 1. Data collected in May 2002 can be used to validate application of the ERIN model.

Conclusions

The work I presented here is very much 'a work in progress'. There are several distinct aspects to future work:

- a) The tree growth model must be made responsive to the environment. In particular, effects of temperature on light use efficiency, and of soil nutrition and water availability on biomass partitioning to roots must be re-instated.
- b) The manner in which canopy development (and hence height growth) is modelled must be modified to take into account lateral growth prior to canopy closure.
- c) The nurse-crop model must be verified, especially the prediction of the light environment of the blackwood, e.g. using data on light interception collected by Worledge, Cherry and Beadle at Beulah.
- d) The model must be explicitly parameterised for blackwood and tested using data from a realistic blackwood/nurse-crop system. This requires acquisition of suitable data sets covering the long-term growth of blackwood, and preferably including measures of canopy leaf area, height and diameter.
- e) The model must be implemented in a standard environment. I suggest MS Excel might be a suitable platform as it allows the user to work in a familiar environment and makes all the power of spreadsheets available.

Acknowledgements

I thank Chris Beadle and Ian Nicholas for their patience over the interminable delays due to time-consuming other business that has caused this project to remain a work in progress!

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Blackwood Growth Model and Final Crop Stocking

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Current suggestions for final-crop stocking of blackwood plantations in New Zealand indicate that at 200 stems ha⁻¹ a mean tree diameter of 60 cm should be achievable in 35 y. Analysis of preliminary growth model runs support this, provided site conditions are conducive to reasonable growth rates. The model indicates that stockings lower than 200 stems ha⁻¹ (between 150 – 200) provide faster diameter growth, but not as much volume as the higher stocking.

Data from a 15-y-old regime trial series on five sites also suggest that stockings of 200 stems or lower are required to give the mean annual diameter increment required to achieve the target of 60 cm in 35 y.

Sample plot assessments reveal the need for careful siting of blackwood. Shelter and adequate summer moisture are required to provide growing conditions suitable for blackwood to be considered a commercial crop.

The above final-crop stocking level, although some data suggest it is conservative, is considered suitable to cover for within-stand mortality and tree loss through crown breakage. Such a regime should provide trees of 60 cm diameter on sites selected as suitable for blackwood plantations. As more data become available for analysis, the suggested regime may be refined in time.

Introduction

One of the big issues in blackwood management is what final crop stocking to aim for. With a suitable target in mind managers can work backwards to the initial stocking for either pure or as mixed stands.

Several attempts have been made to resolve this issue. The original blackwood survey, using a crown-to-stem ratio, suggested that final-crop stocking of 100 stems ha⁻¹ would provide a tree 60 cm in diameter before strong crown competition was encountered. The target diameter of 60 cm DBH is based on the requirement to produce a sawlog of sufficient size to obtain a reasonable conversion rate, especially of heartwood. This is supported by analysis of sawing trials (Cavanna and Glass 1985). There is no doubt that larger logs are preferred by sawmillers, and smaller logs give a much lower output (Nicholas and Brown 2002). A more detailed analysis of the ratios of stem to crown also suggested a stocking of about 100 stems ha⁻¹ (Law 1986). South African papers have suggested a final-crop stocking of about 395 stems ha⁻¹ (de Zwaan 1982). While unlimited diameter growth may be a laudable target, when economic factors - especially crop revenue - are considered, the volume production from 100 stems ha⁻¹ is quite low. This raises the 64 million dollar question: how high can you push final-crop stocking and stand volume production without significantly compromising individual-tree diameter growth?

The largest barrier to answering this question for New Zealand forestry has been the lack of suitable stands for evaluation. While we have some older

stands, they have not been managed to provide silvicultural information. Two stands, planted in 1967, which had thinning treatments applied, helped provide early information, but small plot size created some problems in interpreting the data with any confidence. To overcome these problems Forest Research, from the 1980s, established a number of permanent sample plots (PSPs) throughout the country to cover a range of climatic and soil conditions. These were regularly measured to develop a reasonable time series of data for each stand. The second major effort was the establishment of silvicultural regime trials in 1987 on five sites in the North Island to test pruning and thinning options. A Westland trial was established, but abandoned because of poor survival and variable growth. The regime trials were measured annually from 1990- 2002, with the exception of 2000.

The combination of the PSPs and the regime trial data provided sufficient information to develop a preliminary growth model (Berrill *et al.* 2002).

Current thinking suggests that managers should aim for a blackwood stand with a mean tree DBH of 60 cm by age 35 y and a final crop stocking of 200 stems ha⁻¹ (Nicholas and Brown 2002). This scenario was reached from interpretation of stand data and field visits to appropriate stands, but is not regarded as the definitive answer. Like all preliminary conclusions, these values can be expected to change as better information becomes available.

To explore options in final crop stocking three aspects will be discussed in this paper.

I	Growth model
II	Regime trial
III	Sample plots

I Growth model

Using a range of starting data, the preliminary growth model clearly indicates improved diameter growth with stockings below 200 stems ha^{-1} . In the example used by Nicholas and Brown (2002), the sample plots at 160 stems ha^{-1} were predicted to achieve a 62 cm tree by age 34 y (the recommended limit for the model), while at 200 stems ha^{-1} they would be under 60 cm, with a mean DBH of 57 cm at age 34 y. This suggests either a lower stocking (<200 stems ha^{-1}) or a longer rotation would be required to achieve the 60 cm mean tree DBH on this site. Higher stockings, however, should yield more sawlog/veneer material.

The growth model also includes a mortality function: in the example used above, the model predicts stockings of 128 and 158 stems ha^{-1} at age 34 y for age-5 starting values of 160 and 200 respectively.

II Regime trial

Diameter growth in the regime trials at age 11 y was analysed, but showed no significant stocking trends (Nicholas *et al.* 2000). The latest analysis with age 15 y data shows a very different picture (Kimberley *et al.* 2002). Current diameters now reflect stocking differences with statistical differences between high (425 stems ha^{-1}) and lower stockings (125 or 200 stems ha^{-1}). Perhaps even more significant are the differences in the age 14-15 diameter increments. These indicate a strong stocking effect (Fig. 1).

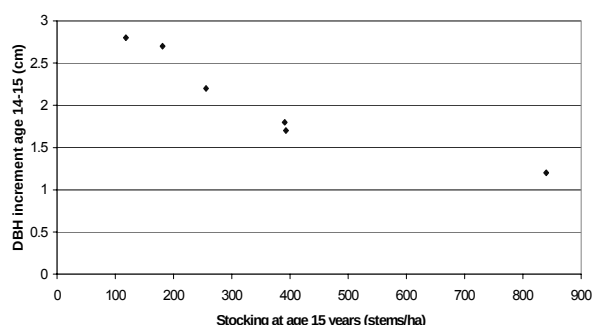


Figure 1. Regime trial diameter increment age 14-15 y

With 20 y growth until expected rotation age of 35 y and a required diameter MAI of 1.7 cm yr^{-1} , it would appear from this data that stockings over 250 stems ha^{-1} are unlikely to attain a DBH of 60 cm in 35 y.

The reduction in diameter increment is also closely related to the crown size of trees within the more heavily stocked plots. In recent years the crown has risen from 6 to 12 m in the highly stocked stands.

The regime trial is starting to provide very important data on blackwood management, especially the influence of stocking on growth rate. Continued measurement of these trials is important to track stand dynamics for both diameter and changes in green crown movement.

Data from the regime trial at age 15 y is certainly supporting a final crop stocking of 200 stems ha^{-1} or less to produce stems of 60 cm DBH at a harvest age of about 35 y.

III Sample plots

The PSP data is reflected in the growth model, but inspection of individual plots, plot data and growth model runs from individual plot data certainly support the final-crop stocking values suggested. What is strongly evident from sample plots is the effect of site on long-term growth rate. This aspect cannot be stressed enough: blackwood require sheltered sites with adequate moisture to meet the target values. While the species is tolerant of a wide range of site conditions and will survive and grow in some atrocious soil conditions, it cannot be expected to perform as a profitable commercial crop on all sites.

Conclusion

The suggested final crop stocking of 200 stems ha^{-1} is supported by analysis of results of growth model runs, analysis of data from the regime trials and evaluations of individual sample plots. There are indications, however, that this may be a slightly conservative regime, with stocking slightly on the high side. Nevertheless, given the mortality in some stands and the need for extra crop trees because of crown breakage, for the current level of knowledge, a regime with a final crop stocking of 200 stems ha^{-1} to achieve a mean stand diameter of 60 cm in 35 y is still suggested. This is, of course, provided the blackwood is on a reasonable site that will support required growth rates.

Recommendations on final-crop stocking should be determined by detailed analyses of log types, log values, silvicultural costs and a range of rotation lengths. There is insufficient data in New Zealand to conduct such analyses. When such data becomes available in the future from further PSP observations and the regime trials, however, the conclusions made in 2002 with the data now available may be amended.

Acknowledgements

The assistance of the many Forest Research team members in measuring trials and sample plots is appreciated. We would especially like to acknowledge the patience and assistance of the PSP data management team of Judy Hayes, Carolyn Anderson and Joanne Butt for their help.

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21

The Future of the Blackwood Industry Group

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Lorne 1996

The first blackwood meeting was held in Lorne, in November 1996, largely through the efforts of Rowan Reid from Melbourne University, with strong CSIRO support from Alan Brown and Suzette Searle.

Participants

Many states were represented at this conference of 48 participants. Ian Nicholas was the sole non-Australian attending.

Outcomes

The meeting was supported by JVAP (Joint Venture Agroforestry Program), the Blackwood Industry Group (BIG) was formed and the production of a newsletter followed. This was distributed in winter 1998. This was a successful meeting, although no full proceedings were published.

Smithton 2000

This second meeting was well organised by Chris Beadle (CRC) and Andy Warner (Private Forest Tasmania), ably supported by their respective teams.

Participants

Several states were represented among the 37 participants, although most attending were Tasmanian-based. Ian Nicholas and Ian Brown, from New Zealand, attended and offered to host the next meeting. It was felt that the four years between previous meetings was too long, so the next was set for 2002.

Outcomes

The meeting was supported by JVAP. Before the meeting, the newsletter was resurrected by Chris Beadle, with mailings in 2000 and 2001. It currently has a distribution list of 70.

This was a very successful meeting, with a formal proceedings published, thanks to the efforts of Alan Brown the editor, and the organisers. There was little opportunity, however, to discuss the future of BIG.

Rotorua 2002

This meeting is also supported by JVAP, as well as BIG, AMIGO (NZ Farm Forestry Acacia Action Group) and Forest Research.

This third blackwood meeting seeks to learn from previous meetings. Proceedings will be pre-published, thanks again to the efforts of Alan Brown. It has also successfully gained a wider international input with papers from Chile, China and South Africa. A pre-conference tour has also been included, and a session to discuss the future of BIG has been scheduled.

BIG: what direction?

As a six-year-old organisation, where does BIG need to go? We currently have a 'membership' of about 70 (newsletter distribution), but do we have a focus, do we know who we are?

I believe that to move forward a working group is required. This should be formed from people involved in the wider industry across countries, especially those that have the opportunity to invest time into thinking through blackwood issues.

I believe this core group should be sought from those who have attended at least two BIG meetings, with key people co-opted as required.

Issues can then be discussed by this team and conclusions disseminated through the newsletter.

Issues for this committee could be:

- Communication (newsletter and workshops)
- Research
- Marketing

- Utilisation
- Management
- Policy
- Certification
- Funding

There will be overlap in some of these issues, but let's have some healthy debate on what are seen as the important aspects.

My wish-list for this meeting is:

- Input of new people into a more formal committee
- Defined outputs from BIG (one or two discussion papers annually, resulting in a summary paper for the newsletter with input from countries interested?).

- An agreed workshop program; I suggest every three of four years
- Development of better yield predictions (volume tables, merchantable yields and growth model)
- Better genetic summary for each country or state
- Better resource and market data
- Identification of funding opportunities
- Development of a web page, possibly through Forest Research

BIG has a history of key individual people being active, that is often the best way to make progress, but after six years we should be mature enough to have a team that can help us move the blackwood industry forward.

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Future Directions of the Blackwood Industry Group

Don Britton

Britton Brothers Pty Ltd, Smithton, Tasmania

Key considerations

- There needs to be a forum for investigating means of gaining maximum benefit for all players, from growers to end users.
- Special focus is needed on gaining greater market acceptance of blackwood of all grades, and so gaining a greater return in stumpage, timber and finished product prices.
- Efforts must be made to secure funding for research from all available sources and to reach consensus on the projects to be undertaken.
- Conferences may need to be less frequent, smaller and less formal. It is difficult for companies such as Brittons to develop new themes for papers, but not so hard to be involved in discussion of specific issues and provide answers to questions that relate to our area of expertise.
- Blackwood needs to be perceived as unique and desirable by buyers of high quality furniture, so commanding prices similar those obtained for teak and cherry. Appropriate strategies need to be formulated to achieve this goal.

Suggested priorities for extra research

- Genetic/provenance research to target medium/dark-coloured wood of good density.
- Silvicultural regimes to maximise growth without sacrificing density.
- Pruning techniques to quickly establish trees of good form with at least 6.0 m of clear stem.
- Immunisation of sapwood and an associated means of darkening sapwood to increase recovery and specifications of sawn timber as well as meeting quarantine requirements.
- A means of eliminating staining in veneer flitches prior to slicing.

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Blackwood Industry Group Conferences: Then, Now and into the Future

Sue Jennings

Forestry Tasmania

I can only describe myself as naive as I bustled off to Lorne for the first Blackwood Industry Group (BIG) conference. Full of importance at representing Forestry Tasmania (Native Forests) I was keen to learn all that the Victorians had to offer on native forest blackwood silviculture. Imagine my disappointment to find that blackwood is not specifically managed as a natural part of in the State forests in Victoria. Their mountain ash forests are managed to produce high quality mountain ash, with any blackwood, satinwood etc. thrown up as a by-product. With the increase in browsing problems in native forest regeneration, it is unlikely that the blackwood component of these forest will increase.

My disappointment was partially off-set by the interesting things Rowan Reid had to show, the realisation that people like Suzette Searle were doing all sorts of things that I had never heard of, and meeting people in widespread and diverse fields who were all focussed on blackwood. But I think the great awakening for me was to learn that I was actually part of the 'blackwood industry'. I had really only thought of myself previously as a grower – with my job to produce blackwood on State forest. I hadn't thought about the whole marketing – growing – harvesting – processing – and selling the final products - process. I had thought only in terms of growing as much good quality blackwood as I could, as quickly as I could, without thinking about how much was actually needed and that our high quality blackwood furniture industry could actually fall victim to furniture fashions for blonde wood, etc. I was also interested that Victorians in general did not rate their own home-grown blackwood very highly (described often as 'just a wattle') while 'Tasmanian blackwood' (the very same species) was a sought-after product. There's a lot in the name!

The second BIG conference held in NW Tasmania was on my own patch, so I was much more familiar with the sites and the issues. The perennial question of plantations versus native forest got an airing, along with some interesting spacing and pruning, and growth information from New Zealand. We visited the much-publicised site of the 'Blackwood Release Trial' at Togari and looked at the great form of native forest blackwood and the diameter growth rates that can be achieved if blackwood is released from competition... but at the end of the conference we posed the questions – 'Is this really what industry wants?' Do we lose wood quality if we grow blackwood too fast? What is it about good quality that makes it good? We need some feedback from the sawmilling and furniture-making industry on these points.

Forestry Tasmania and the Cooperative Research Centre have put together a joint proposal for a project to explore these issues. The aim is to talk to industry stakeholders to determine what qualities (colour, density, figure, consistency etc) are important for good quality in blackwood, and then to sample natural blackwood regeneration, FIB blackwood regeneration and plantation blackwood to see how they perform for these qualities. However, this project will not go ahead unless it is partially funded by the industry stakeholders. It's time industry realised that they're also part of the growing process. As we gain more confidence in the products that we can produce, we really need more information from industry in what they **want us to produce**. It's not quite designer blackwood.... but it's not far away.

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Future Directions of the Blackwood Industry Group (BIG)

Andy Warner¹ and Chris Beadle²

¹Private Forests Tasmania

²Cooperative Research Centre for Sustainable Production Forestry and CSIRO Forestry and Forest Products

From Lorne, Victoria in November 1996 to Smithton, Tasmania in November 2000 and now to Rotorua, New Zealand, November 2002 represents the six years of total growth of BIG (discounting the gestation period for the first meeting)!

A six-year-old blackwood plantation represents an investment of a lot of time and money in establishment and some pruning, but without further management this investment will be mostly wasted.

Without stretching the analogy too far, BIG has also had considerable effort invested in it to date. But this too will be largely wasted without an ongoing plan and commitment. At the Lorne meeting, an attempt was made to make BIG a more formal structure which has resulted in more active coordination, newsletters, an impetus to maintain a level of research activity in Australia for the species and further plantings as well as the Workshops. While these have been satisfying outcomes, the 'Future Directions' of BIG may become clearer if we can address the following:

1. **Marketing** – How do we increase the profile of blackwood regionally, nationally, trans-Tasman and internationally? What effective role can a web-based information service on blackwood play? Is it possible to make the returns from blackwood larger and in such a way that everyone benefits? Can we start promoting products based on plantation blackwood before we have a secure resource based on plantations? Do we need to differentiate between products based on native forest blackwood and market them differently from those based on plantations?
2. **Silviculture** – How do we collate information based on trials in plantations and farm forestry so that it can be referenced by others? What

information is available on blackwood other than the published papers from the 3 BIG Workshops? Is there a case for a blackwood database? How do we fund ongoing and new blackwood research?

3. **Processing opportunities** – What options are there for quantifying the outcomes of blackwood rotations under different environmental conditions, e.g. high vs low productivity? What options are there for on-farm vs mill processing?
4. **Economics** - Can we introduce non-wood benefits into the cash-flow analysis? Can we provide better financial information to encourage growers to invest in blackwood plantations by showing the impact of stumpage, growth and product changes?
5. **Survey of blackwood growers, researchers and processors** – What can we collectively contribute to help fund actions and projects to fill the gaps in our blackwood knowledge? What are the perceived needs from each sector?
6. **Working competitively but working together** – How do we best facilitate contributions to the common blackwood good, without surrendering perceived competitive advantage at an individual and regional level?
7. **Distilling the essence and finding the money and time** - What are some realistic goals and objectives we can set ourselves? What are the priorities and how do we address funding to achieve outcomes? Is it time for a levy to fund knowledge generation for the industry?

Summary of meeting of Blackwood Industry Group (BIG) and *Acacia melanoxylon* Interest Group Organisation (AMIGO)

23 November 2002

Chris Beadle, Andy Warner and Ian Nicholas

Introduction

The following summary, based on the meeting at the Workshop, has been added to this final publication, but it did not appear in the printed proceedings distributed at the workshop.

The meeting considered a range of issues.

Committee

A core group to initiate and coordinate activities will consist of Andy Warner, Ian Nicholas and Chris Beadle, and others as necessary. The committee will seek wider membership embracing China, South Africa, Chile and Vietnam. The possibility of more-structured meetings will be pursued. A fourth workshop, possibly in Victoria, in two to three years time, that considered issues related to wood quality, wood processing, value adding and marketing will be considered. The production of information packages that promote blackwood will be examined.

Blackwood website

A proposal for a stand-alone website with useful links will be developed. Financial support will be sought from the Joint Venture Agroforestry Program (JVAP) and other interested funding organisations. The site will be a repository for reference material and for downloaded summaries and abstracts. The site could also be used for a self-funded chat group. A project will be developed to prepare material for the website.

BIG Newsletter

The newsletter will continue. There will be one issue per year, available in hard copy and electronic form. Besides news items, feature articles will be sought. Chris Beadle will continue as editor.

AMIGO Newsletter

This will continue as usual for NZ Farm Forestry members of the action group; AMIGO currently produce two issues per year.

Research

A list of research projects with some consensus on priorities was required. The most likely sources of research funding will continue to be JVAP (RIRDC), NHT(2) and possibly FWPRDC. FRNZ may also continue to support research in blackwood. A call was made for researchers to provide help in the design of demonstration trials. Researchers should also be willing to capture information that could be provided by landowners. A more uniform approach is required to the scoring and evaluation of trials, and consideration should be given to embracing acacias other than blackwood.

It was proposed that a 'coffee-table' book promoting blackwood as a high-quality timber should be written.

Blackwood workshop — possible research and further action ideas

Research suggested by attendees is summarised below; bracketed figures indicate multiple suggestions covering generally the same topic. The proposals have been sorted by general topic and then by most frequent suggestions and then alphabetically.

Genetics

1. (9) Clonal trial (of elite trees) to determine most suitable clones for different regions — evaluation to include wood colour, density etc. Identify heritability of characteristics. The benefits are that such work has not been undertaken previously, and it would extend our knowledge whilst involving growers. Use regional clones in any such a trial in Australia to avoid genetic pollution.
2. (2) Range-wide seed collection from individual trees from Australia — as the basis for provenance trials and seed orchards — applying the discipline to start with a range of seed sources as broad as possible.
3. Clonal variation — check soil properties at Ian Brown's clonal area to identify possible causes of differences in growth and form.
4. Review clonal propagation techniques.
5. Fingerprinting key seedlots so that if material is re-imported to Australia genetic pollution might be managed. High Australian interest!
6. Genetic summary — bring together the diverse information and collate it into a more useful reference list.
7. Genetic pollution may be an issue in the future in Australia after rotations of >30 y— use regional cloning to avoid this.

Silviculture

8. (4) Impact of higher pruning and final stocking — volume per tree vs more trees of smaller volume. What do you lose in diameter growth if you let trees grow tall without pruning?

9. (2) Understanding how the nurse crop grows and identifying when the blackwood is being suppressed. Focus on encouraging height growth via shelter.
10. Forest Research regime trial — thinning options; identify density, colour and rot parameters.
11. Growing other species with blackwood — not just as a nurse crop.
12. Predicting sapwood transformation to heartwood — the age at which it occurs and the impact of pruning on this.
13. Regulatory options to provide security of harvest for blackwood.
14. Understanding juvenile foliage growth and its impact on apical dominance as a means of influencing form etc.
15. Using natural regeneration for second-rotation crops (future project).
16. What's causing the prolonged diameter increment compared to eucalypts?
17. Work on branch diameter as a surrogate for leaf/photosynthetic production?

Utilisation

18. (7) Formation and colour of heartwood plus density — determining what produces consistent colour and density. Check the inherited characteristics of plantation-grown blackwood vs material from natural stands, including techniques to describe the colour and the role of genetic factors. There is a Tasmanian project proposal with the ARC (Forestry Tasmania and Forest and Forest Industry Council) but the question needs more industry support.
19. (3) Promotion of uses other than furniture — look for markets for smaller logs ex thinnings.
20. (2) Identifying market needs — help growers to decide what to manage their trees for.
21. Furniture design and using variability in colour.
22. How is wood quality affected by growth rates and silvicultural methods, e.g. by a nurse crop vs no nurse crop?
23. Impact of growth rate on appearance in furniture.

24. Incorporate furniture and retailing into BIG as an important part of the total cycle.
25. Marketing — getting high-value product recognised with variability considered a plus, not a minus.
26. Pruned stand certification as a means of improving marketability.
27. Recognition of blackwood as a lifestyle — not just the products.
28. Wood quality — consider pathogen impact on recovered volume/value.

Miscellaneous

29. Database on seed source, planting information, regime planned, nature and timing of silvicultural activity undertaken, etc. Provide a standard format to encourage record keeping (free on website).
30. Emphasise the need for scientific method to underpin any work done.
31. Incorporating ‘Promod’ type blackwood growth models into the

(Tasmanian) Toolbox to help landowners understand some of the interactions between site and growth.

32. Non-wood factors associated with blackwood — water quality improvement, nitrogen fixation, carbon sequestration, site amelioration?
33. Invasion issues.
34. Link future plantings to natural resource management agenda for funding — link with water quality and riparian plantings — Australian funding may be facilitated.
35. Review the ‘soft’ results from various experiments done by farm foresters.

Future actions

The meeting concluded with the recommendation that the committee coordinate activities on both future meetings and research activities, when and as appropriate, reporting back via the BIG newsletter.

Program

22 November 8.15 am

Introduction

Managing Blackwood at the Forest Level

Morning tea

Utilising and Marketing Blackwood

Lunch

Blackwood Experiences

Blackwood Silviculture

Afternoon tea

Blackwood Responses

Dinner

23 November 3pm

The Future of the Blackwood Industry Group

23 November 8.30 am

Field Trip

Depart from Rydges Hotel

1987 Regime trial (6 ha)

Trial background (Ian Nicholas; Forest Research)

Regime trial studies (Ian Nicholas, Ham Gifford and Mark Kimberley; Forest Research)

Growth patterns
Nutrition patterns
Pruning results
Thinning results
Stocking effects

1984 Provenance trial

New Zealand seed source trials (Charlie Low and Ian Nicholas; Forest Research)

Lunch in grounds of Forest Information Centre 12.45 pm

1906 plantation

History and measurements (Ham Gifford and Ian Nicholas; Forest Research)

1987 Regime trial

Measurement summary (Ham Gifford and Ian Nicholas; Forest Research)

Agroforestry research (Ian Power, AgResearch)

Completion of AMIGO field day, workshop participants return to Rydges Hotel for final session, 3 pm

Blackwood Industry Group

Panel session: Warner, Beadle, Nicholas, Jennings and Britton

Five-minute presentation on future directions of BIG, followed by open discussion for 30 minutes

Formal close of Workshop

Participants¹

Name Country			Name Country		
1	M.W. Allardice	New Zealand	37	Allan Levett	New Zealand
2	Cynthia Barnard	New Zealand	38	Neil MacKintosh	New Zealand
3	B.G. Barrack	New Zealand	39	Fay MacKintosh	New Zealand
4	Chris Beadle	Australia	40	Tariq Mahmood	Pakistan
5	Geoff Brann	New Zealand	41	Neville Martyn	New Zealand
6	Don Britton	Australia	42	Glenyss McQueen	New Zealand
7	Ian Brown	New Zealand	43	Neill McQueen	New Zealand
8	Stuart Brown	New Zealand	44	John Millett	New Zealand
9	Maria Cherry	Australia	45	Graham Milligan	New Zealand
10	Wade Cornell	New Zealand	46	Logan Negus	New Zealand
11	Mike Crow	New Zealand	47	Ian Nicholas	New Zealand
12	Kalev Crossland	New Zealand	48	Juan Carlos Pinilla Suarez	Chile
13	John Fairweather	New Zealand	49	Libby Pinkhard	Australia
14	Robyn Fairweather	New Zealand	50	Grahame Pole	New Zealand
15	Allan Fleming	New Zealand	51	Nolene Pole	New Zealand
16	Ian Forster	New Zealand	52	Rowan Reid	Australia
17	Nigel Foss	Australia	53	Tom Riddell	New Zealand
18	Coert Geldenhuys	South Africa	54	Jane Riddell	New Zealand
19	Ham Gifford	New Zealand	55	Chris Robb	Australia
20	Angus Gordon	New Zealand	56	John Roper	New Zealand
21	John Goy	Australia	57	Tim Rose	New Zealand
22	Peter Harrington	New Zealand	58	Peter Sands	Australia
23	Libby Goy	Australia	59	Suzette Searle	Australia
24	Vern Harris	New Zealand	60	David Soar	New Zealand
25	Michael Hay	New Zealand	61	Stuart Swanson	Australia
26	Audrey Hay	New Zealand	62	John Tasker	New Zealand
27	Denis Hocking	New Zealand	63	A.J. Van Veen	New Zealand
28	Tim Jackson	Australia	64	Andy Warner	Australia
29	Ross Jackson	New Zealand	65	Jay Weeks	New Zealand
30	Sue Jennings	Australia	66	Kees Weytmans	New Zealand
31	Peter King	New Zealand	67	Eric Williams	New Zealand
32	Liz Kingsford	New Zealand	68	Adrian Williams	New Zealand
33	Jon Lambert	Australia	69	Dale Worledge	Australia
34	Stephanie Lambert	Australia	70	Zhang Fangqiu	China
35	Ross Larcombe	New Zealand			
36	Brian Lee-Jones	New Zealand			

¹ As at 15 November 2002