Growth and silviculture of *Acacia melanoxylon* plantations in Tasmania

W.A. Neilsen and D.R. Brown
Forestry Tasmania

Abstract

Research into silviculture, seedling protection, provenance performance and seed treatment was undertaken between 1990 and 1995 to support the establishment of 780 ha of Acacia melanoxylon *(blackwood) plantations. Growth of 1 cm/yr DBH and 1 m/yr height have been obtained, allowing pruning to 4.6 m by age nine years. Good establishment on mild sites should allow rotation objectives of around 45 years to be achieved for* A. melanoxylon *sawlogs. However, in research plantings on frosty sites, growth has been severely restricted, with a mean height of only 3 m at age six years. On a frosty site, nurse crops significantly improved both survival and growth.*

Regimes currently recommended for growing A. melanoxylon *use either a* Pinus radiata *nurse crop, managed for pruned sawlog production, or a eucalypt nurse crop managed for pulpwood. Pruning regimes have been developed because plantation-grown* A. melanoxylon, *even with a nurse crop, requires pruning to correct and produce quality sawlogs.*

Systems have been developed to minimise potential problems such as suppression of A. melanoxylon *by the nurse crop, or the potential damage to* A. melanoxylon *on removal of the nurse crop. Information on the success of these systems is incomplete at this stage. However, the utilisation of nurse crops is expected to improve the overall economics of growing* A. melanoxylon.

One of the biggest problems in successful establishment of A. melanoxylon *is protection of young seedlings from browsing by native and introduced animals. Seedlings were browsed preferentially by ground-dwelling animals such as rabbits and wallabies, and 1080 poisoning alone has not provided adequate control. Fencing has been used routinely for large-scale plantation establishment, but individual protection of the plants using various grow-tubes has been successful in several research plantings. A narrow grow-tube, requiring one stake only, proved to be a cost-effective means of providing protection for seedlings, with the costs being comparable to fencing. Other protectors were also effective but more expensive.*

Significant differences between Tasmanian provenances for height and survival have been found in most trials. Frosting effects were found to be consistently worse for far north-western provenances and high-altitude, north-eastern provenances. High-altitude, north-western provenances were generally less affected by frosting, but were also slower growing in the established trials. Provenances from Tasmania, Victoria and southern New South Wales should be considered in selecting provenances for testing in Tasmania. Provenances from northern Australia failed due to poor frost resistance.

Following variable results from pre-treating seed with hot water to assist germination, a number of trials were carried out to determine the most effective practical means of obtaining even germination of A. melanoxylon. *Scarification of seed was recommended as a suitable method of treatment.*

Introduction

Acacia melanoxylon R.Br. (blackwood) occurs over most of south-eastern Australia and north to Queensland, but the main occurrence is in Victoria and Tasmania. Its altitude range is from sea-level to 1000 m and it grows on a wide range of soils. It develops best as an understorey in moister eucalypt forests, in association with rainforest or in swamps (Forestry and Timber Bureau 1957).

Blackwood produces high quality timber and veneer for the fine furniture industry, and is much in demand in Australia and overseas. In Australia, substantial quantities are also being used for wall lining and craft items. Timber colour varies from a golden brown to darker brown. The desirability of the timber and the potential to grow veneer and sawlog-sized trees in a reasonable time give it the potential to be a good plantation species. It has been planted extensively, though sporadically, in various parts of the world (Allen 1992).

Research into blackwood plantations has been carried out over a number of years by Forestry Tasmania, with funding from various sources. The blackwood plantation programme undertaken as part of the National Rainforest Conservation Program gave some impetus to the research between 1989 and 1991. Following an evaluation of the status of the blackwood industry, it was recommended that a minimum of 1200 ha of blackwood plantations should be established in Tasmania over the next 30 years (Allen 1992). Following the Helsham Inquiry (DEST 1988), $1.8 million of Federal Government funds were allocated for the establishment of blackwood plantations under the Intensive Forest Management (IFM) Program, for the purposes of increasing forest productivity in Tasmania. Most of these funds have been spent in the Beulah and Castra plantations, south of Devonport, with smaller areas being planted in the south and far north-west of Tasmania.

Under the IFM Program, 695 ha of blackwood plantations were established between 1990 and 1995. In addition, 85 ha of research trials had been established, bringing the total area of blackwood plantations to 780 ha. Plantations have been established on good sites with adequate rainfall, with an emphasis on mild environments where frost frequencies are low. Despite this, there have been some losses of blackwood due to frost. Care in fencing has minimised losses due to browsing animals. Along with the plantation establishment programme, research was undertaken to further evaluate (a) silviculture and growth, (b) seedling protection, (c) provenance selection and performance, and (d) seed treatment.

A. Silviculture and growth

Several silvicultural options are available for growing blackwood. These include the use of various nurse crops which may or may not have commercial value.

Blackwood plantations have been grown successfully but, in Tasmania, pure plantings have shown poor form, with multiple branching and poor apical dominance. Overseas, pure plantings have needed frequent pruning to restrict branching and improve form (Nicholas 1988).

The tendency of blackwood to have poor form has led to experimentation with nurse crops (Barr 1981; Nicholas 1981, 1988; Hickey 1988). Nurse crops are fast-growing species co-established with blackwood. Ideally, they create a 'light-well' effect that draws the blackwood up towards the light, encouraging a tall, straight tree with a minimum of branch development. The main problem with using nurse crops is the need to manage the two species so that the blackwood does not become over-topped and, thus, suppressed by the nurse crop. The problem is overcome by careful selection of nurse-crop species and by careful thinning.

The use of dense nurse crops, which would produce the best form and suppress branching in blackwood, is uneconomic, with a high cost of plants, reduced growth on crop trees and high cost of thinning. There is little hope of early commercial thinnings from such nurse crops.

Acacia melanoxylon plantations established with commercial nurse crops

The restriction of side light alone has been noted to reduce branching in blackwood and so improve form (J. Lake, pers. comm.). A combination of nurse crop and pruning is proposed for plantations for two main reasons:

- Some improvement in blackwood form resulting from the use of a nurse crop will allow pruning on an economic schedule.
- The nurse crop can be utilised to improve the economic return of the regime.

1. *Pinus radiata* D. Don nurse crop

Pinus radiata offers the potential to provide a nurse crop and grow a profitable pruned sawlog as an interim crop. One of the main problems in growing blackwood with a nurse crop will be the removal of the nurse crop as a commercial harvest without damaging the blackwood. In growing a clearwood *P. radiata* crop, protection is afforded by planting rows of *P. radiata* at 5 m row spacing, with blackwood inter-planted between each second row. At felling, with two adjacent rows of *P. radiata* (Photo 1), the blackwood should be afforded sufficient protection to minimise damage.

In commercial plantations, *P. radiata* was planted at 800 stems/ha and blackwood was planted at 500 stems/ha. The blackwood and the pine nurse crop will be thinned and pruned to provide clearwood sawlogs. Clearwood pine sawlogs will be removed at about 20 to 25 years, with the final blackwood harvest estimated to be at 40 to 45 years.

Although greater numbers of blackwood, in the range of 1500 stems/ha, have been advocated by some authors (Barr 1981; Nicholas 1988; Bishop *et al.* 1985), sufficient final-crop trees can be obtained from a much lower stocking, with suitable pruning.

Photo 1. Silvicultural arrangement for growing blackwood, seen at age three years, with a row of A. melanoxylon *between every second row of the* Pinus radiata *nurse crop.*

Table 1. Pruning regime for A. melanoxylon.

Mean dominant height (m)	Age (years)	Pruning
5	5	Form prune to 2.7 m
7	7	1st prune to 2.7 m and form prune to 4.6 m
9	9	2nd prune to 4.6 m and form prune to 6.4 m
11	11	3rd prune to 6.4 m

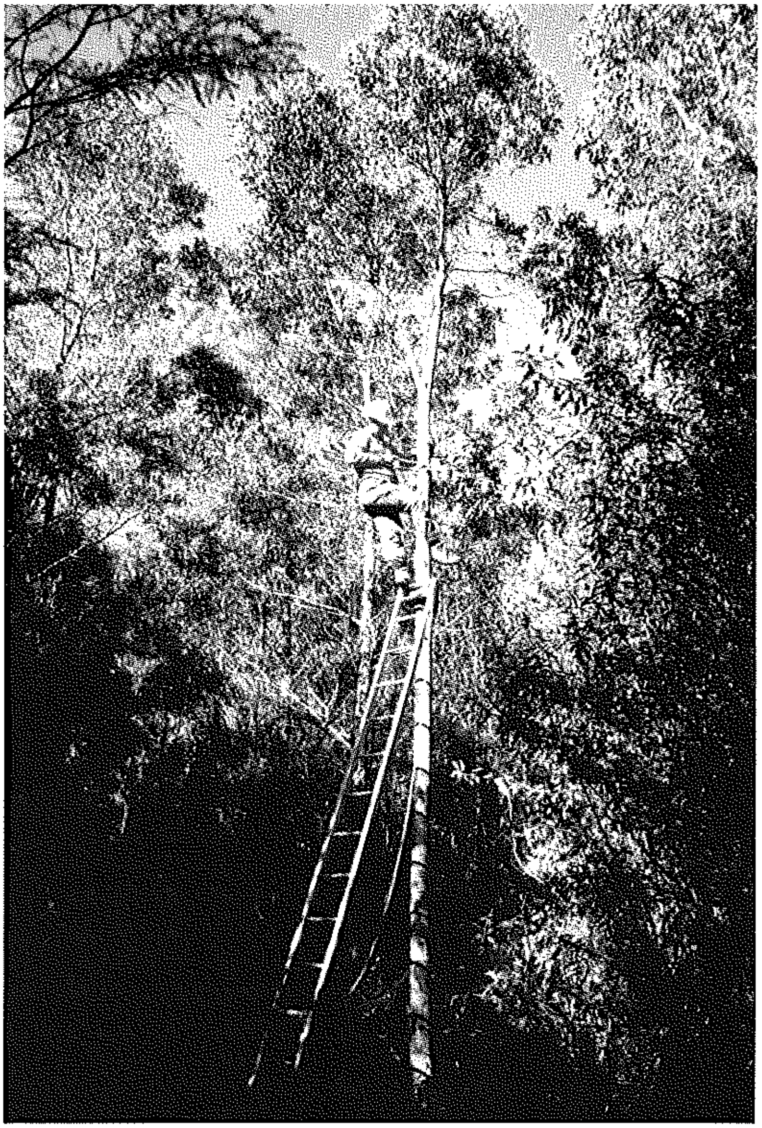

Photo 2. Pruning A. melanoxylon *to 6.4 m at age 11 years at Goulds Country. Excellent form of final-crop stems has been obtained by a combination of cover crops and pruning.*

2. *Eucalyptus nitens* (Dean & Maiden) Maiden or *E. globulus* Labill. nurse crops

With an *E. nitens* or *E. globulus* nurse crop, the recommended planting arrangement is alternate rows of blackwood and eucalypt. Row spacing of 3.5 m, and spacing within the rows of 2.8 m, gives a stocking of 500 stems/ha for each species. It is anticipated that the eucalypts can be felled for pulpwood without serious damage to the blackwood.

Pruning regime

Plantation-grown blackwood requires pruning to correct form and produce quality sawlogs (Barr 1981; Nicholas 1988). A regime of one form-pruning and a three-lift pruning to 6.4 m is proposed for routine plantations in Tasmania (Table 1; Photos 2 and 3).

With a *P. radiata* nurse crop being managed for clearwood production, first-form pruning and first- and second-lift pruning of the blackwood should correspond with first, second and third pruning of the *P. radiata* respectively.

Photo 3. Acacia melanoxylon *at age seven years, pruned to contain the defect core to a maximum of 15 cm.*

Growth of *Acacia melanoxylon* compared to that of other species

A research trial was established to compare the performance of blackwood, with and without nurse crops, in relation to various other potential plantation species.

The planting site was located in north-eastern Tasmania at 120 m altitude and has been described by Wilkinson and Neilsen (1990). Soils were yellow podsolic soils formed on adamellite granites. The upper horizon generally comprised a coarse, free-draining, dark-grey, gravelly quartz soil to 20–30 cm in depth, overlying a deep, yellow clay with high quartz content. The climate was temperate, with annual precipitation of approximately 980 mm with a winter peak and periods of summer moisture deficit. The site formerly carried *E. regnans* F. Muell. forest of 34–41 m mean dominant height (MDH).

Species and combinations were:

1. *E. nitens* (Toorongo)
2. *E. globulus* (Moogara)
3. *P. radiata* (Upper Castra S.O.)
4. *A. melanoxylon* (Smithton)
5. *P. radiata/A. melanoxylon* (as above)
6. *E. nitens/A. melanoxylon* (as above)
7. *E. regnans* (Moogara)
8. *E. delegatensis* R.T. Baker (F1O)
9. *E. obliqua* L'Hérit. (F8)

Each treatment was planted as a 40-tree plot, consisting of 4 rows x 10 trees. Plots with *A. melanoxylon* under a nurse crop of *P. radiata* or *E. nitens* were planted in alternate rows, with two rows of each species in a 4-row plot. Treatments were replicated in three blocks.

All plots have been pruned and thinned as appropriate, with all species being grown for sawlogs. By age nine years, the blackwood

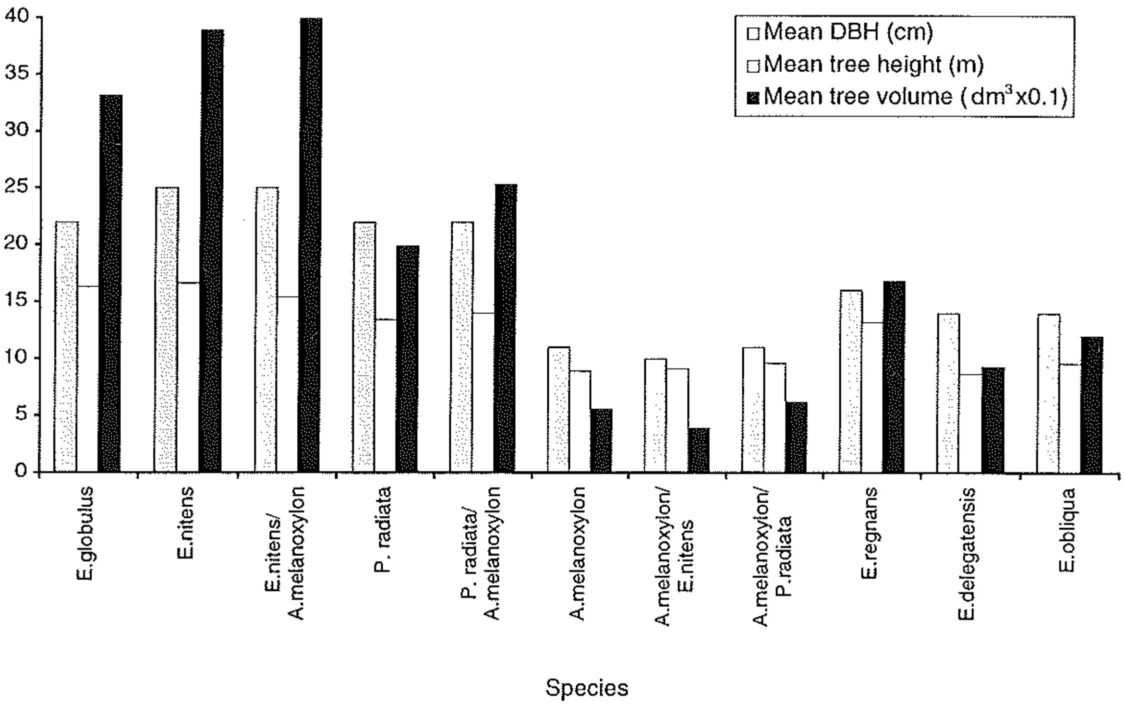

Figure 1. Mean DBH, height and tree volume at age nine years for species established in north-eastern Tasmania.

had reached a height of about 9 m and had been second-lift pruned. High pruning to about 6.4 m had been carried out on the *P. radiata, E. globulus* and *E. nitens*, which had reached heights of between 13 and 16 m. High pruning of the blackwood should be completed by age 11 years, at which time the plots will be thinned to final stocking.

With a mean diameter of 11 cm at age nine years, the blackwood was well established and had maintained steady diameter growth since planting (Figures 1 and 2). Both the volume and diameter of the blackwood under the *E. nitens* nurse crop were falling behind that of the other blackwood treatments and, although not significant at age nine, it may have indicated greater competition for blackwood using the *E. nitens* nurse crop (Figure 2).

The mean tree volume at age nine years varied from 39 dm^3 for the blackwood under *E. nitens* to 399 dm^3 for the *E. nitens* on the same plots. All species except *E. delegatensis* and *E. obliqua* had significantly greater tree volume than the blackwood (Figure 1). The *P. radiata* trees had about four times the volume of the blackwood while *E. nitens* and *E. globulus* had about seven times the average blackwood volume. Volume growth of the blackwood has always lagged somewhat behind other species to age nine years (Figure 2).

Survival was over 95% for all treatments and the form of the blackwood showed an improvement under the nurse crops.

Acacia melanoxylon development under various nurse crops

A research trial covering 20 ha has been established to determine the potential of blackwood as a plantation species when grown alone and in combination with commercial nurse crops of *P. radiata, E. nitens* or *E. globulus*. Various combinations of spacing, thinning and pruning were used. The area was fenced to restrict animal browsing.

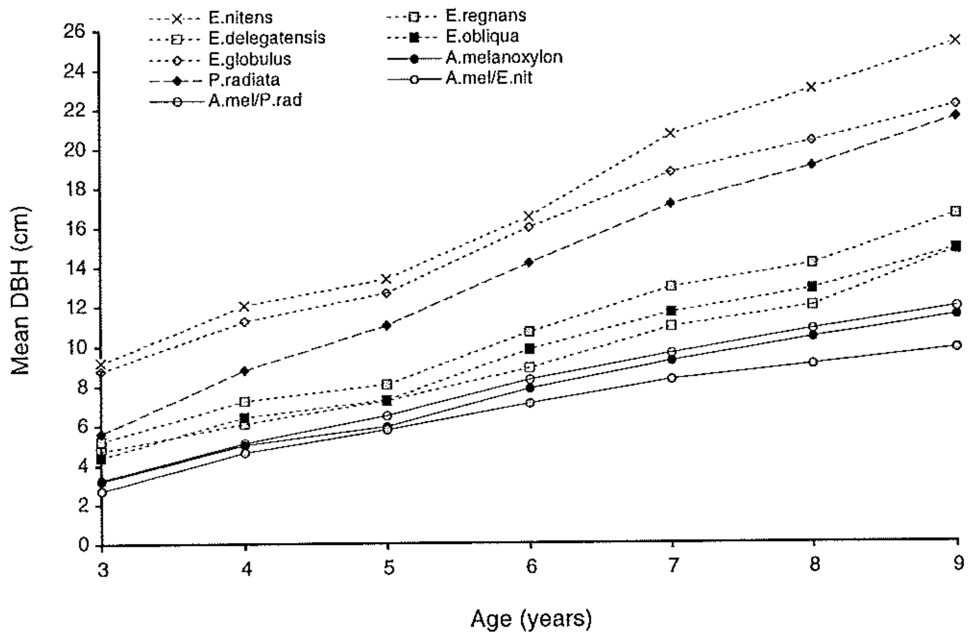

Figure 2. Mean DBH for ages three to nine years for species established in north-eastern Tasmania. (Legend: A.mel = Acacia melanoxylon, E.nit = Eucalyptus nitens, P.rad = Pinus radiata.)

The trial consisted of block plantings of 25 treatments. There were four replicates. Plots were all 0.2 ha, with dimensions of 12 rows (39.6 m) by 50 m. The 25 treatments included six blackwood-only treatments, seven blackwood-under-*P. radiata* treatments, six blackwood-under-*E. nitens* treatments, five blackwood-under-*E. globulus* treatments and one *P. radiata*-only treatment.

Despite fencing and repeated poisoning with 1080, browsing by rabbits had a major influence on the growth rates of many of the blackwood seedlings. Slow growth led to suppression of many seedlings by competition from weeds re-establishing after control in the first year.

Severe frosting throughout the trial area at age one year affected both the blackwood and the *E. globulus* nurse crop. Almost all blackwoods survived, with the majority sprouting from the base. Heights at age two years reached the original heights recorded at age one year. Heavy frosts during winter at age two years caused further damage but not on the scale of the first winter. Growth of the three nurse-crop species was good, despite some frost damage to *E. globulus*. Frosting continued to affect the blackwood to age six years. On this frosty site at Meunna, the nurse crop significantly improved both survival and growth. By age six years, measured survival was 81%. There were no significant differences for survival between blackwoods under the three nurse crops, but survival without a nurse crop was significantly less (Figure 3). Height growth to age six years was poor due to repeated frosting but improved significantly with increasing shelter. *Eucalyptus nitens*, *P. radiata* and *E. globulus* provided increasing shelter in that order (Figure 4).

Growth

Good establishment and early growth were obtained on the sites with a mild environment and with effective browsing and weed control. In north-eastern Tasmania, growth to age nine years was 1 cm/yr DBH and 1 m/yr height (Figure 5). A mean height of only 3 m

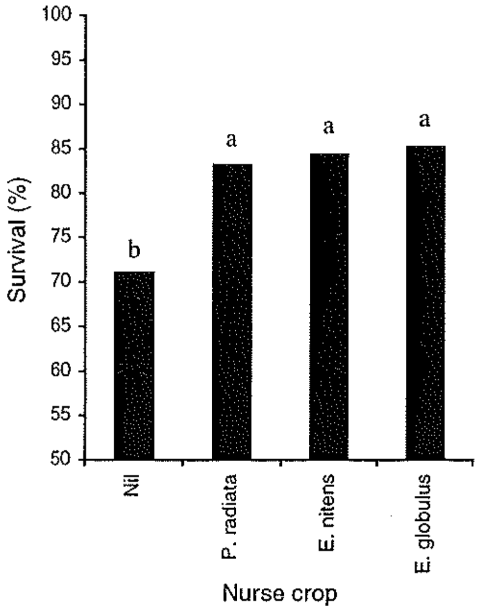

Figure 3. Survival of A. melanoxylon *at age six years for silvicultural treatments under various nurse crops. (Different letters are statistically significantly different* ($P \leq 0.05$) *from each other.)*

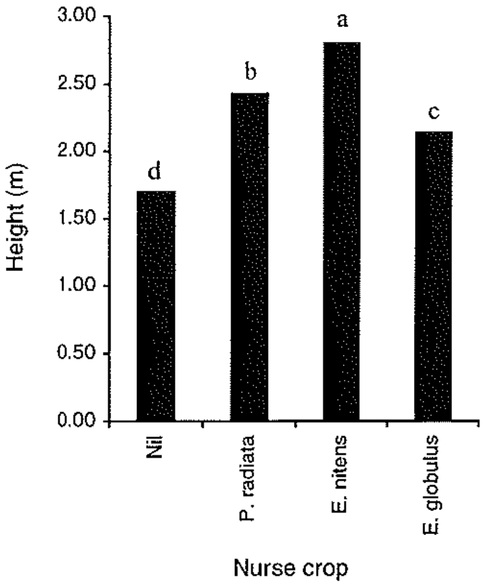

Figure 4. Height for A. melanoxylon *at age six years for silvicultural treatments under various nurse crops. (Different letters are statistically significantly different* ($P \leq 0.05$) *from each other.)*

on the best plots at age six years at Meunna was due mainly to establishment difficulties. Diameter growth rates of 1.45 cm/yr have been obtained in New Zealand (New Zealand Forest Research Institute 1982) while up to 3.5 cm/yr has been recorded in South Africa (de Zwaan 1984). Good establishment should allow rotation objectives of about 45 years for blackwood sawlogs to be achieved.

B. Plant protection research

Successful blackwood establishment in Tasmania requires protection of young seedlings from browsing by native and domestic animals. Blackwoods are browsed in preference to other species by ground-based animals such as rabbits and wallabies. Although individual bagging of seedlings can provide adequate protection (Mesibov 1984), this has been uneconomic on a commercial scale with protectors previously tested (Forestry Commission 1989; Allen 1992). The use of 1080 poison alone provides inadequate protection (Statham 1983) and plastic mesh, although offering some protection, has failed to adequately protect blackwood seedlings in the long term (Neilsen 1990; Allen 1992; Plumpton and Neilsen 1996).

The option of fencing alone or in combination with 1080 poison has been used routinely for plantation establishment. Great care and attention to installation and maintenance is required if fencing is to be effective. Possums have not proved to be a severe pest in browsing blackwoods in Tasmania, and electrified fences, specifically to stop possum entry, have not been required. Mesh fencing topped with barbed wire is a successful deterrent against macropods. However, integrity of fencing is difficult to maintain (Neilsen and Wilkinson 1995), and this has proved to be the case with fencing of some blackwood research and plantation blocks.

For small areas of plantation, grow-tubes or some similar product may be the only method currently available of achieving successful establishment.

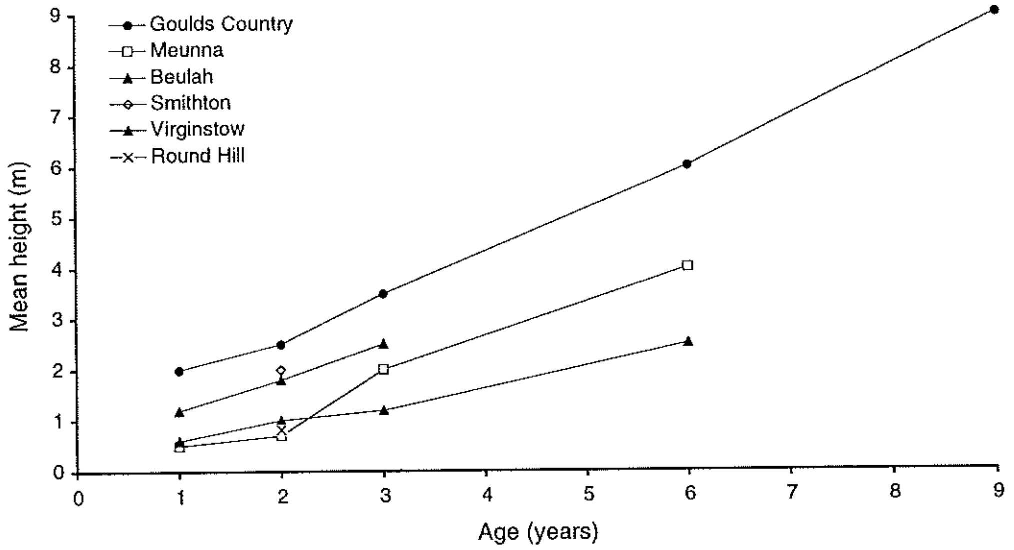

Figure 5. Height of A. melanoxylon, *at various sites, to age nine years in Tasmania.*

The following protectors were evaluated in a series of trials:

- 200 mm diameter grow-tubes which require a number of stakes. These are the normal UV (ultra-violet) stabilised polythene (ICI) grow-tubes. They were tested at 800 mm and 1200 mm lengths.
- Narrow grow-tubes (65 mm diameter) which can be established with one stake. This tube was not UV stabilised. It was tested only at 1200 mm length.
- Tubex and KBC protectors, made of coreflute, a twin-walled polypropylene material, which also require only one stake.

Trials were conducted in both fenced and unfenced areas. For fenced areas, a standard wire netting fence, buried 10 cm in the ground and topped with barbed wire, was used. Within the area, all windrows and game cover were removed and 1080 poisoning was carried out. Open-root and container stock were used in the trials, which were randomised complete blocks with three replicates. Plots were single rows of 20 seedlings of open-root stock and 10 seedlings of container-grown plants.

Seedling protection

Frost and wind

Protectors provide a microclimate which increases early growth by protecting seedlings from wind and frost. Although the use of protectors, either grow-tubes or tubex, significantly increased growth in the first year, the actual increase in growth and survival was not cost effective for protection from frosting alone. However, in other trials, protection has proved essential on harsh sites as survival has been unacceptable without it (Neilsen and Brown 1996). Protection was also essential where frosting aggravated a browsing problem.

In the absence of browsing in fenced plots, height growth of blackwood in protectors on a mild site (Figure 6) was significantly greater than without protection over the first 12 months. Growth slowed once the trees grew above the height of the protectors. By age three years, the height of the trees without protection was the same as that with the narrow grow-tube. Other treatments maintained their advantage over the unprotected seedlings.

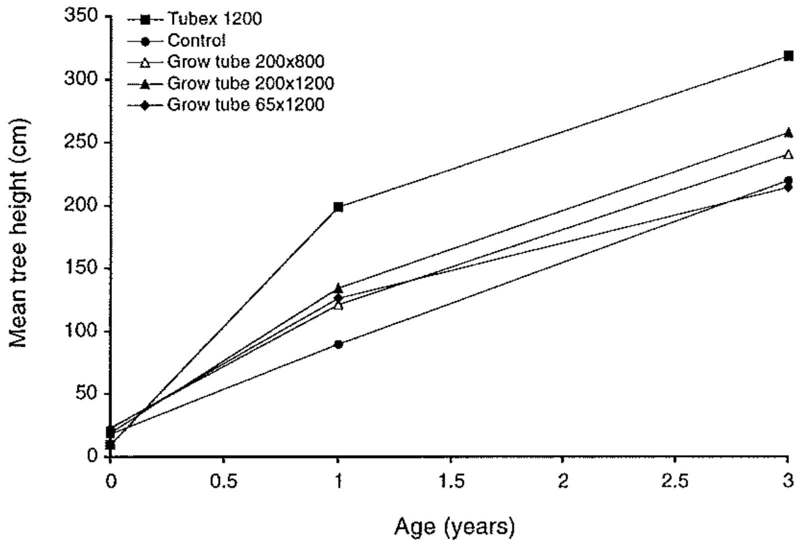

Figure 6. Height growth to age three years of A. melanoxylon *with or without various grow-tubes on a mild site protected from browsing.*

There were no differences between treatments for survival, trees unsuitable for final crop trees or well-formed stems suitable for pruning.

Browsing

In unfenced trials, browsing was a major problem. At age six months, over 50% of unprotected seedlings were browsed, and browsing continued throughout the trial period of three years (Figure 7), keeping seedling height below that recorded at planting (Figure 8). Browsing of the protected seedlings occurred when they grew above the protectors at about age one year, reducing height growth (Figure 8). However, browsing lessened with additional height growth and eventually seedlings grew in height to a point where they were clear of browsing. The survival of unprotected seedlings declined over the three years, due to browsing, to unacceptable levels of 50%, while protected seedlings continued at high survival rates of over 90% (Table 2). At age three years, there were significant differences in height for treatment (Figure 8). The taller tubex protector generally resulted in significantly better height growth to age three years than other protectors. The 65 mm diameter grow-tube and the shorter tubex also provided good protection from animal browsing and allowed good growth. The 200 mm diameter grow-tube was not as effective in providing protection from browsing, as animals could pull the protector down.

Cost of protection and recommendations

Cost of protection from browsing by fencing is about $0.60 per seedling but, in plantation developments, the additional cost of total clearing to remove animal cover has resulted in costs of $1.65 per seedling. Cost of protectors varied, with the Tubex, at $3.52, being expensive. Normal grow-tubes were competitive with fencing plus related costs, at $1.76. Narrow grow-tubes at $0.85/seedling were cost effective in comparison to fencing.

The narrow grow-tube may well prove a cost-effective means of providing protection for seedlings in small plantation areas or for areas where stockings of around 200–400 stems/ha only are required. The narrow grow-tube required the planted seedling to be tall at the time of planting, thus

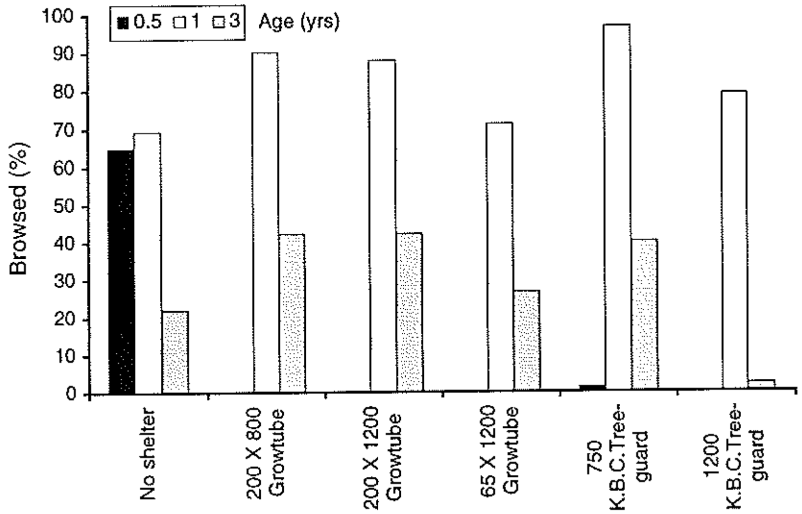

Figure 7. Browsing percentage at ages six months, one year and three years of A. melanoxylon *protected or unprotected with various grow-tubes.*

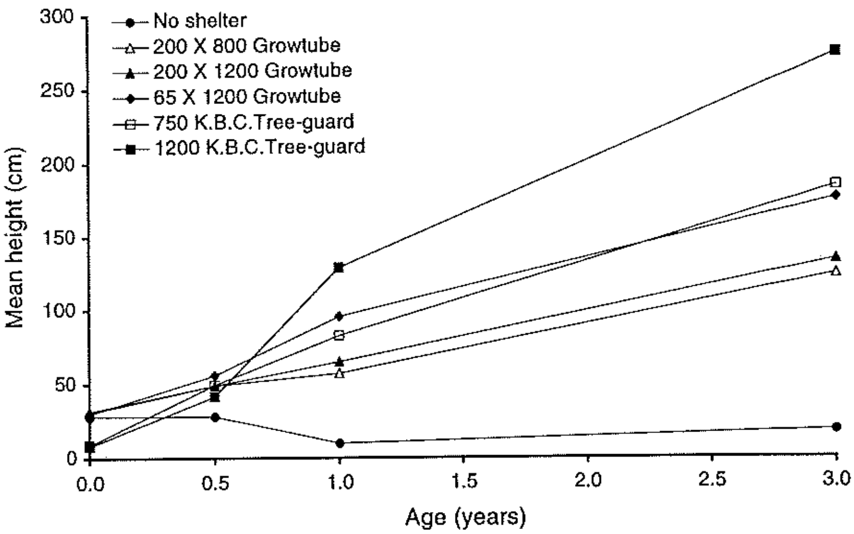

Figure 8. Height growth to age three years of A. melanoxylon *protected or unprotected from browsing with grow-tubes or tubex.*

necessitating open-root or large container seedlings. The narrow grow-tube, not being UV stabilised, deteriorates within 18 months. It is recommended that tape be placed around the top of the tube and a single staple be used to attach this to the top of the stake. This will hold the tube open, improve ventilation and support the seedling once the tube has disintegrated, as the low diameter growth within the tube may leave the seedling liable to being pulled over by browsing animals.

Table 2. Survival at age three years of A. melanoxylon *protected or unprotected with grow-tubes.*

	Treatment	Survival (%)	Significance*
1	Nil	45.5	b
2	Grow-tube 200 x 800	93.0	a
3	Grow-tube 200 x 1200	93.0	a
4	Grow-tube 65 x 1200	93.8	a
5	Tubex, 1200	100.0	a
6	Tubex, 750	98.8	a

* Different letters are statistically significantly different ($P \leq 0.05$) from each other.

C. Provenance research

Blackwood occurs over a wide range of latitudes and altitudes, covering a broad range of climates. The aim of the blackwood provenance studies was to compare, over a range of sites, the survival, form, branching habit, growth and wood characteristics of planted blackwood originating from different localities within its natural geographic range.

Seed collections

Blackwood seeds were collected from 127 Tasmanian trees. Six mainland provenances were supplied by the Australian Tree Seed Centre of the CSIRO Division of Forestry. Tasmanian seeds were collected during the summers of 1988 and 1989 and in 1991, 1992 and 1993. In 1988 and 1989, Tasmanian seeds were collected from single trees of superior phenotype, with attention being paid to high- and low-altitude seedlots. From 1991, seeds were collected to supplement high-altitude provenances, and to provide additional trees so that within and between provenance comparisons could be carried out.

Seedlots of similar genetic composition can be grouped together on the basis of: (a) similar climate and soils, (b) similar altitude, and (c) contained within the one major catchment and/or preferably within 30 km of one another. Using this set of criteria, the Tasmanian seedlots have been divided into 18 groupings for future trial work (Table 3).

Performance at different sites

High quality, frosty site

In 1988 and 1989, two research trials were established on a frosty site at Meunna, north-western Tasmania, at 250 m altitude and 1600 mm rainfall. The trials aimed to test the performance of Tasmanian and mainland blackwood provenances under a nurse crop of *Pinus radiata*. Severe frosting and browsing by rabbits has had a major influence on the growth of many of the blackwoods.

The trials consisted of two replicates of block plantings of blackwood provenances under *P. radiata* (Table 4). Plots were all 0.2 ha, with dimensions of 12 rows (39.6 m) by 50 m. Four hundred stems per hectare of blackwood and 800 stems/ha of *P. radiata* were planted in alternate rows, with the blackwood at 3.8 m spacing and the *P. radiata* at 1.9 m spacing.

The northern mainland provenances showed below average height growth and survival. This was pronounced in those from Queensland, which ranked lowest for height and survival at age two years and by age six years only a few specimens remained. The provenances from New South Wales and Victoria behaved similarly to Tasmanian provenances (Figure 9). There were significant and substantial differences in height growth and per cent survival between provenances at age six years (Figure 9).

Dry site

A range of blackwood provenances was tested on a site of medium soil quality and 950 mm rainfall (Table 5). Plots were single rows of 20 trees. Stocking was 800 stems/ha planted at 4.2 m spacing, and a nurse crop was not used. There were five replicates as randomised blocks. At age six years, there were significant differences between provenances, with mean height and survival varying from 1.9 m to

Table 3. Acacia melanoxylon *seedlots grouped on the basis of similar environments and altitudes, and within approximately 30 km of each other.*

Number	Grouping	Coding	Altitude range (m)	Severe frosting	No. of seedlots
1	Far north-west	NW-L	30–160	N	7
2	Meunna (north-west)	NW-ME	100–280	Y	4
3	High altitude (north-west)	NW-H	450–620	Y	7
4	Low altitude west coast and Henty River	WC-L	2–180	N	7
5	High altitude west coast	WC-H	440–520	Y	3
6	Kentish area	NW-M	200–440	N	7
7	Frankford area	N-M	210–280	N	5
8	Meander (high altitude)	N-H	440–560	Y	5
9	Low altitude north-east	NE-L	110–400	N	8
10	High altitude north-east	NE-H	500–620	Y	4
11	Upper Esk	NE-UE	350–400	Y	3
12	East coast	NE-EC	140–220	N	5
13	Strickland area	C-ST	180–540	Y	8
14	South-West and Styx Valley	C-SW	280–400	Y	7
15	Oatlands area	C-OT	400–440	Y	3
16	Lower east coast	E	200	N	1
17	Huon and Esperance	S	60–220	N	17
18	King Island	KI	40–100	N	7

3.7 m and from 58% to 100% (Figure 10). There was some browsing, and its effect on growth and survival affected the trial. There were no clear differences between this trial and others on the performance of provenances.

High-altitude, frosty site

This research trial aimed to evaluate the growth and survival of a range of selected blackwood provenances at 710 m altitude and 1400 mm rainfall (Table 6). Each plot was a single row, 20 m long, with seedlings spaced 1.5 m apart. There were three replicates as randomised blocks.

There were significant differences between provenances for height growth, survival and frosting damage. Provenances from higher altitudes in the north-east and provenances from the far north-west performed poorly compared to others (Figure 11). There was a significant negative correlation of provenance altitude with height at age two years. Altitude was not correlated overall with frosting effects.

Table 4. Acacia melanoxylon *seedlots used in the 1988 and 1989 trials.*

Seedlot number	Grouping	Number of seedlots
1	Far north-west	8
2	Meunna (north-west)	2
3	High altitude north-west	3
4	Low altitude west coast and Henty River	1
5	High-altitude west coast	2
7	Frankford area	2
8	Meander (high altitude)	2
9	Low altitude north-east	3
10	High altitude north-east	1
11	Upper Esk	3
12	East coast	6
13	Strickland area	2
14	South-West and Styx Valley	6
16	Lower east coast	4
17	Huon and Esperance	5
18	King Island	1
19	Atherton	2
20	South Queensland	2
21	South New South Wales	1
22	South Victoria	2

Table 5. Acacia melanoxylon *seedlots used in the dry-site trial.*

Number	Grouping	Number of seedlots
1	Far north-west	1
2	Meunna (north-west)	2
4	Low altitude west coast and Henty River	1
5	High altitude west coast	1
7	Frankford area	2
10	High altitude north-east	1
11	Upper Esk	2
12	East coast	2
14	South-West and Styx Valley	1
16	Lower east coast	1
17	Huon and Esperance	2

Table 6. Acacia melanoxylon *seedlots used in the high-altitude trial.*

Number	Grouping	Number of seedlots
1	Far north-west	5
3	High altitude north-west	5
4	Low altitude west coast and Henty River	3
5	High altitude west coast	1
8	Meander (high altitude)	4
10	High altitude north-east	4
11	Upper Esk	3
14	South-West and Styx Valley	3
17	Huon and Esperance	6
18	King Island	4

Table 7. Acacia melanoxylon *seedlots used in the protection trial.*

Number	Grouping	Number of seedlots
1	Far north-west	5
3	High altitude north-west	2
10	High altitude north-east	2
17	Huon and Esperance	5

Frosty site with tree protectors

This research trial was established to evaluate whether stock type and polythene tree shelters influenced field frost resistance across a range of *A. melanoxylon* provenances. The trial was a randomised block, with two replications, on a frosty site at 280 m with a rainfall of 1600 mm (Table 7).

There were differences between provenances for frosting damage and height growth (Figure 12). High-altitude provenances from the north-west suffered less frost damage than other provenances. High-altitude north-eastern provenances were no better than low-altitude provenances. Low-altitude north-western provenance seedlots and high-altitude north-eastern seedlots were the most frost susceptible. The grow-tubes protected the seedlings from browsing and provided some protection from frost.

Blackwood is considered by some to be frost tolerant (Bean 1970; Pollock *et al.* 1986) while others consider it to be frost sensitive (Powell 1971; Nicholas 1988). Laboratory tests have shown reasonable tolerance (Pollock *et al.* 1986; Brodribb 1992). Blackwood research trials in Tasmania have suffered frost damage, even at heights of 4–5 m. There appears to be some difference between laboratory determinations of frost resistance and field performance. Variation in frost resistance between provenances and families has been noted by Franklin (1987) and is evident in trials here.

General provenance differences

Although significant differences between provenances for height and survival have been found on most trials, there were no consistent trends for Tasmanian provenances, except for frosting effects which were found to be consistently worse for high-altitude north-eastern provenances and far north-western provenances on evidence mainly from the unbrowsed plots. High-altitude north-western provenances were generally

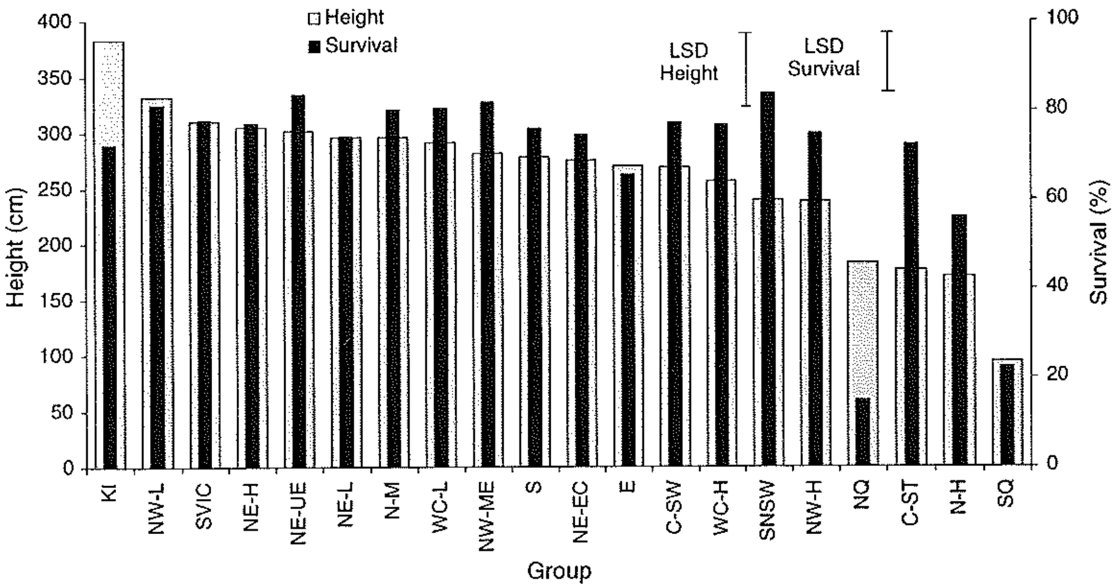

Figure 9. Mean height and survival for A. melanoxylon *provenances, established in 1988 and 1989 in north-western Tasmania, at age six years. (Group codes are given in Table 3.)*

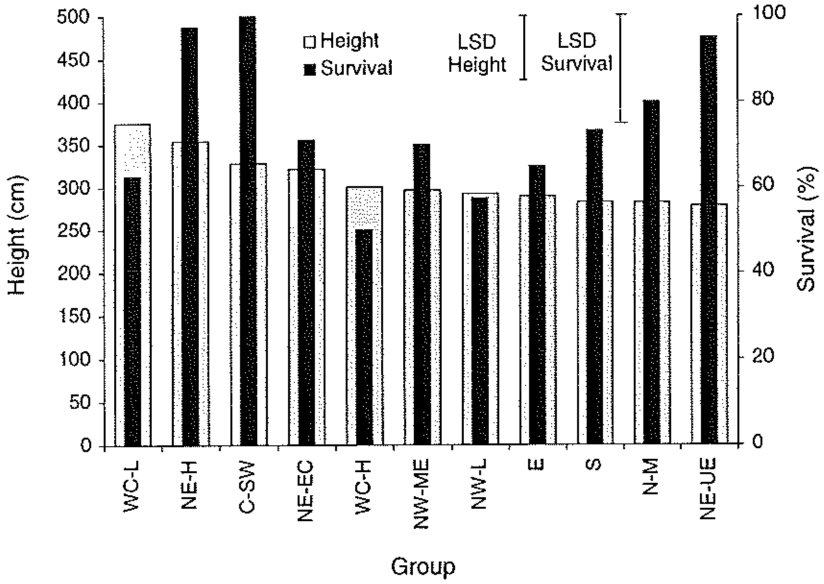

Figure 10. Mean height and survival for A. melanoxylon *provenances, at age six years, established on a dry site in Tasmania. (Group codes are given in Table 3.)*

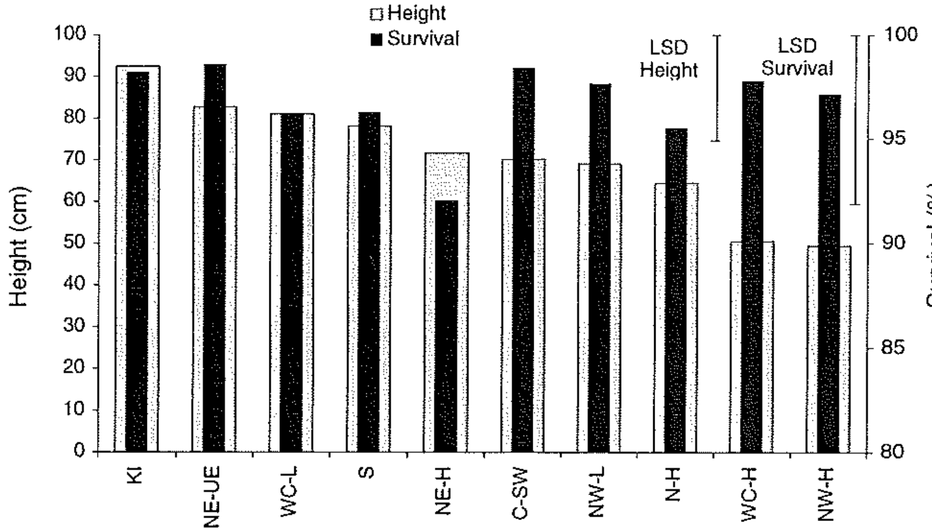

Figure 11. Mean height and survival for A. melanoxylon *provenances, established on a high-altitude frosty site in Tasmania, at age six years. (Group codes are given in Table 3.)*

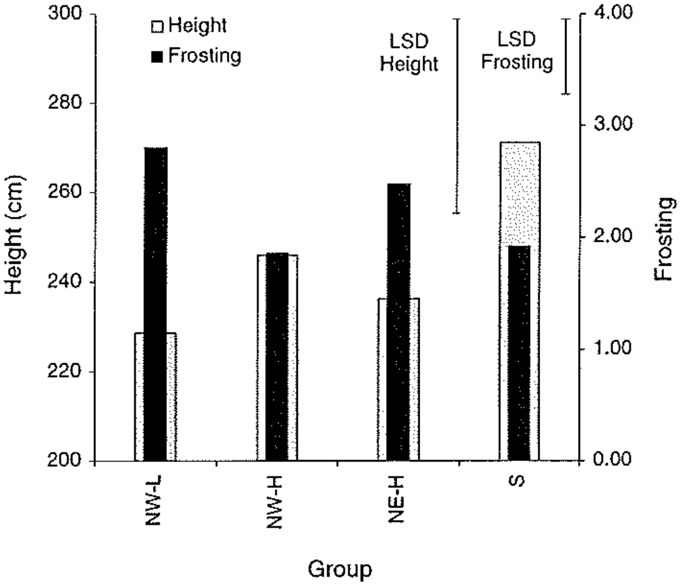

Figure 12. Survival and mean severity of frosting of A. melanoxylon *protected with grow-tubes. (Frosting scale: 1, nil; 2, tips burnt; 3, red phyllodes; 4, frosted and splits in stem; 5, dead.) (Group codes are given in Table 3.)*

less affected by frosting but were also slower growing in the established trials.

Provenances from northern Australia failed due to poor frost resistance, but there was no substantial difference between provenances from Tasmania, Victoria and southern New South Wales. Further information on growth, frosting and wood characteristics may indicate superior provenances but, at this stage, local provenances are still recommended for planting in various areas.

D. Seed treatment

For seedling production in the nursery, seed-lots need to have high germinative capacity and high germinative energy to produce a well-stocked, uniform crop of seedlings.

It had been considered that seed collection and propagation were straightforward (de Zwaan 1978, 1985). Hot-water stratification and inclusion of an inoculum of *Rhizobium* in the propagation media have given satisfactory results although variation in germination per cent and time to germinate with the hot-water treatment posed problems (Doran and Gunn 1986). In Tasmania, the effectiveness of the hot-water treatment varied with the seed source. Germination testing of seed collected for a major blackwood plantation in north-western Tasmania resulted in only 48% germination using the boiling water method.

Different techniques for breaking seed dormancy of *Acacia melanoxylon* were tested, with the aim of increasing germinative capacity. The most common method in the past has been to pour boiling water onto the seeds and let them soak until the water cools (approximately half an hour). A range of hot-water pre-treatments were tested but there were no statistical differences between any of the treatments at 90°C and above. Initial germination trials showed that alternative hot-water pre-treatments could lift germination up to a maximum of 74% at 28 days.

Various methods of mechanical scarification were tested. All had different germination patterns. The best was manual clipping, closely followed by scarification using the CSIRO bulk scarifier. In addition to increasing the germinative capacity, mechanical scarification enhanced germinative energy, resulting in most of the germination taking place approximately two weeks earlier than with hot-water treatments. This effect was reproducible across provenances. The CSIRO bulk scarifier achieved a germination pattern that closely resembled the clipped treatment. Consequently, a method now exists for achieving rapid and high germination rates for container-grown blackwood in the nursery. However, the better performance of manually clipped seed indicates there is scope for further improvement.

Treatments

Hot-water treatment

Trials indicated that treatments at 90°C or above were significantly better than treatments at lower temperatures. In all cases, the pattern of germination was the same. Germination commenced from six to 13 days after treatment and the majority of germination occurred from about day 10, up to 28 days. Germination commenced some four to 10 days after the clipped treatments, and this time difference was maintained or lengthened as germination proceeded (Figure 13).

Differences were observed between seedlots, not so much in the final germinative capacity but rather in the time taken to reach maximum germination. Beulah seed treated at 90°C for one minute took 72 days to approach the germinative capacity attained by clipping, while the same result was achieved by the Smithton seedlot after 28 days.

Due to the slow and variable response of hot-water treatments, this method should only be used for germinating blackwood seed where it is known that the seedlot responds satisfactorily. From the results reported here and those from elsewhere, there is no reason to alter the standard treatment that Doran and Gunn (1986) recommended (90°C in a hot-water bath for one minute).

Clipped seed

Clipped seed has the best germinative energy and the highest germinative capacity. Maximum germination was reached within 14 days of treatment. These outcomes support the proposition made by Doran and Gunn (1986) that nicked seed closely approximates the maximum viability of the seedlot. Clipping seed is ideal for very small and valuable research lots, and is the preferred method of treating seed prior to conducting germination tests.

CSIRO bulk scarifier

The bulk scarifier was by far the best practical method of pre-treating blackwood seedlots in excess of 20 g in weight. Although clipped seed out-performed that from the best bulk-scarifier treatment, their germination patterns were similar, with the initial germination rate up to eight days being almost identical, and the majority of the germination being achieved by day 14. Results from this method most closely approximated those from the clipped treatment (Figure 13). This applied to both the Beulah and Smithton seedlots. A cross-section of provenance seed treated with this machine and sown in the nursery have shown excellent, even germination.

Initially, a 10-minute (500 g) treatment was superior to a three-minute (500 g) treatment. Subsequently, five-minute treatments were used in place of three minutes, and it was found to be satisfactory for blackwood seedlots weighing between 20 g and 200 g. In practice, variable results were obtained with the five-minute treatment.

Recommended treatment

In the absence of any further testing, blackwood seed should be scarified for 10 minutes in 100 g lots, using 40 grit sandpaper. The sandpaper should be changed regularly. The scarified seed should then be immersed in a hot-water bath at 90°C for one minute immediately prior to sowing.

E. Financial analysis

An economic analysis of blackwood plantations is complicated because growth rates for the blackwood and nurse crops can only be estimated at this early stage, although growth is promising.

The current international price for blackwood (fob) is about US$1600/m^3 for 15 cm boards

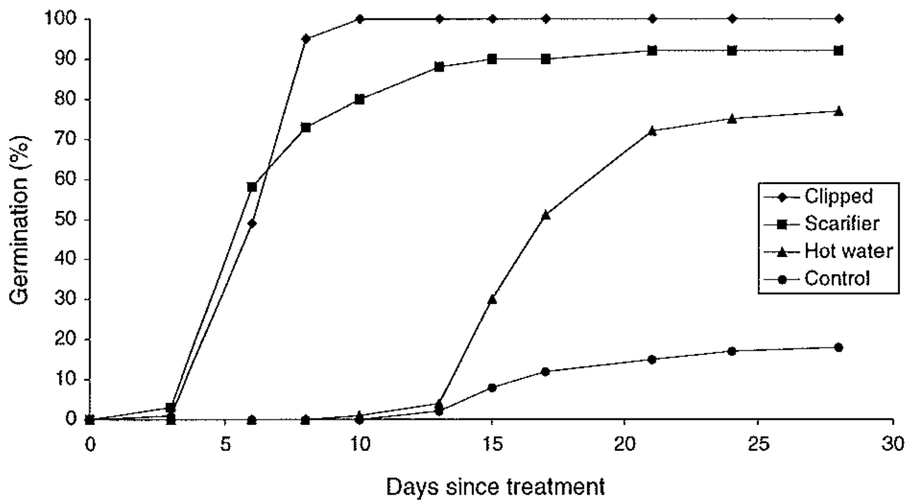

Figure 13. Germination of A. melanoxylon *seed following various methods of seed-coat treatment.*

and about US$1350/m^3 for 8–13 cm boards. In the local market, most material is used for cupboard doors, furniture and joinery (wall lining and architraves). Average sales in Smithton over the four years 1993–96 have been 3096 m^3 of category 1 logs and 1280 m^3 of lower quality material. Average stumpages for category 1 logs and lower quality logs have been US$38.23/m^3 and US$18.70/m^3 respectively. Logging and cartage cost about US$20.00/m^3. Recovery from sawlogs is low: 40% from good logs but only 20% from most logs. Recovery from lower quality material would be about half that of normal logs. It would be anticipated that a higher recovery of sawn timber would be possible from plantation-grown logs and consequently a substantial increase in stumpage would be possible, given the sale price of the timber. Even so, returns anticipated for pruned blackwood sawlogs may not be much higher than those anticipated for *Pinus radiata*.

A previous analysis (Allen 1992) used estimated costs and returns to estimate nett present value (NPV) based on an interest rate of 5% and indicated a positive NPV for various regimes with nurse crops. To re-evaluate the economics for 1995, it was assumed that blackwood would be planted with a *P. radiata* nurse crop. The pine would be treated as a clearwood crop to be high pruned and harvested at age 25 years, yielding around 400 m^3 /ha of sawlog and pulp. The blackwood would be harvested at age 40 years, yielding about 450 m^3 /ha; 95% merchantability of gross bole volume was assumed, with 40% of that as a pruned sawlog, 30% as a lower quality sawlog and the remaining 30% as pulpwood. Establishment costs of $2500/ha were used. Total pruning costs were assumed to be $2200/ha. Using actual product prices from 1995 for *P. radiata*, a return on investment of around 7% was indicated. If Australian parity prices are used, a return of 9.6% was indicated.

The economics were also estimated for blackwood planted with an *E. globulus* nurse crop. The eucalypts would attain about 30 cm DBH and be harvested at age 10 years, yielding 150 tonnes of pulpwood. The blackwood would be harvested at age 40, yielding 600 m^3 /ha. A 95% merchantability of gross bole volume was assumed, with 40% of that as a pruned sawlog, 30% as a lower quality sawlog and the remaining 30% as pulpwood. Using actual prices for *E. globulus* in 1995 for the various products, a return on investment of about 5.5% was indicated. If Australian parity prices were used, a return of 8.0% was indicated.

Despite uncertainties of growth, costs and prices, the economics of blackwood plantations appear to be satisfactory. However, the economics indicate that blackwood must obtain at least the same stumpage as *P. radiata*. Even with this, the economics are not as good as for growing *P. radiata* alone and a premium price for blackwood needs to be sought.

Acknowledgements

Research establishment, measurement and treatment has been undertaken by a number of staff members, including Lindsay Wilson, Tom Lynch, Martin Piesse and Simon Brooks. Simon Brooks also assisted in processing data. Peter Kube, Mike Peterson, Sue Jennings, John Kelly and Dave Allen assisted with the design, layout, establishment and remeasurement of several of the trials.

References

Allen, D. (1992). *Blackwood Plantations in Tasmania.* Tasmanian NRCP Report No. 8. Forestry Commission, Tasmania, and Department of the Arts, Sport, the Environment, Tourism and Territories, Canberra.

Barr, N. (1981). Growing Tasmanian blackwood for furniture timber. *New Zealand Farmer* 102: 62–63.

Bean, W.J. (1970). *Trees and Shrubs hardy in the British Isles.* Vol. 1, 8th ed. John Murray, London.

Bishop, D., Buckman, I. and Eastman, D. (1985). *Trees for Timber and Shelter on the West Coast.* New Zealand Forest Service.
Brodribb, T.J. (1992). The evolution and advantages of non-leaf photosynthesis in *Acacia*, Casuarinaceae and *Phyllocladus*. Hons. thesis, University of Tasmania.
de Zwaan, J.G. (1978). The effects of hot-water treatment and stratification on the germination of blackwood (*Acacia melanoxylon*) seed. *South African Forestry Journal* 105: 40–42.
de Zwaan, J.G. (1984). Blackwood (*Acacia melanoxylon*) group system in the indigenous forests of the Tsitsikamma. IUFRO excursion on the site and productivity of fast growing plantations South Africa, May 1984.
de Zwaan, J.G. (1985). Practical recommendations in connection with the growing of blackwood (*Acacia melanoxylon*). Unpublished report. Forest Research Station, Saasveld, South Africa.
DEST (1988). *Report of the Commission of Inquiry into the Lemonthyme and Southern Forests.* Australian Government Publishing Service, Canberra.
Doran, J.C. and Gunn, B.V. (1986). Treatments to promote seed germination in Australian acacias. In: *Australian Acacias in Developing Countries* (ed. J.W. Turnbull), pp. 57–63. Proceedings of an ACIAR international Workshop, Gympie, Queensland, 4–7 August, 1986.
Forestry Commission (1989). Working Plan for the Blackwood Working Circle in the Smithton District 1988–1998. Forestry Commission, Tasmania.
Forestry and Timber Bureau (1957). *Forest Trees of Australia.* Government Printing Office, Canberra.
Franklin, D. (1987). Resistance of Tasmanian Blackwood to Frost Damage. *New Zealand Tree Grower*, August, 1987, pp. 74–75.
Hickey, J. (1988). Management and silviculture of blackwood in forests in Tasmania. Forestry Commission, Tasmania. Paper presented AFDI Conference, Albury 1988.
Mesibov, R. (1984). Riverflat blackwood regeneration: SU15. Unpublished report, Forestry Commission, Tasmania.
Neilsen, W.A. (ed.) (1990). *Plantation Handbook.* Forestry Commission, Tasmania.
Neilsen, W.A. and Brown, D.R. (1996). Acacia melanoxylon *Plantations in Tasmania: Research and Development.* Forestry Tasmania.
Neilsen, W.A. and Wilkinson, G.R. (1995). Browsing damage, site quality and species selection - a case study of their effects on the economic viability of eucalypt plantations in north eastern Tasmania. In: *Proceedings 10th Australian Vertebrate Pest Control Conference*, pp. 161–170. Hobart, 29th May – 2nd June, 1995. Tasmanian Department of Primary Industries and Fisheries.
New Zealand Forest Research Institute (1982). Australian Blackwood (*Acacia melanoxylon*). *What's New in Forest Research* No. 121.
Nicholas, I.D. (1981). *Acacia melanoxylon* (Australian Blackwood) establishment. In: *New Zealand Forest Researh Institute Symposium No. 22: Forest Nursery and Establishment Practice in New Zealand*, pp. 216–221.
Nicholas, I.D. (1988). The silviculture of blackwood in New Zealand. In: *Proceedings from the The international Forestry conference for the Australian Bicentenary.* Albury-Wodonga, 25th April – 1st May 1988. Australian Forest Development Institute.
Plumpton, B. and Neilsen, W. (1996). Effectiveness of mesh protectors for protecting various species of seedlings from browsing. Unpublished report, Forestry Tasmania, Hobart.
Pollock, K.M., Greer, D.H. and Bulloch, B.T. (1986). Frost tolerance of *Acacia* seedlings. *Australian Forest Research* 16: 337–346.
Powell, R.H. (1971). Winter losses of ornamental trees and shrubs in Canberra 1971. *Australian Forest Research* 6: 43–47.
Statham, H.L. (1983). Browsing damage in Tasmanian forest areas and effects of 1080 poisoning. Bulletin No. 7. Forestry Commission, Tasmania.
Wilkinson, G.R. and Neilsen, W.A. (1990). Effect of herbicides on woody weed control and growth of plantation eucalypt seedlings. *Australian Forestry* 53: 69–78.