Growing *Acacia melanoxylon* using *Eucalyptus nitens* and *Pinus radiata* nurse crops on farmland in northern Tasmania.

Arthur Lyons[1,2], Henry Chan[1], Greg Unwin[2,3] and Sally-Anne Smith[3]

1. **Private Forests Tasmania (PFT)**
2. **Australian Forest Growers (Tasmania)**
3. **School of Land and Food, University of Tasmania**

Abstract

In 1997, a replicated trial was established on 3 hectares of wind-exposed marginal farmland near Sheffield, northern Tasmania. The trial was used to test techniques to grow and manage *Acacia melanoxylon* (Blackwood) for timber production using sacrificial *Eucalyptus nitens* or *Pinus radiata* nurse crops. In addition, each nurse species was grown in a pure stand with an aggressive pruning and thinning regime to produce clearwood timber. *A. melanoxylon* trees were form and variable lift pruned annually and the *E. nitens* nurse trees were later selectively culled using glyphosate injections. This proved extremely promising for production of *A. melanoxylon* timber.

15 year old *A. melanoxylon* under a managed *E. nitens* nurse crop. The nurse trees were killed by stem injection.

On this site, trees required protection from wind throw and wind damage. Silvicultural issues included timing and frequency of both pruning and stem injection. Selection of final crop *A. melanoxylon* trees at an early age proved unreliable. In single-species stands, *E. nitens* responded very well to non-commercial thinning and high pruning. Farm Forestry Toolbox growth modelling indicated *A. melanoxylon*, grown with an *E. nitens* nurse crop, has potential to produce *A. melanoxylon* timber on this site although *E. nitens* and *P. radiata* can be grown successfully in pure stands for high quality wood.

Introduction

Lyons & Swanson (2006) estimated that if 50 hectares of *A. melanoxylon* plantation was planted on suitable Tasmanian farm sites annually and managed and harvested at age 40 years, approximately 10,000 m^3 (or 200 m^3ha^{-1}) of sawlogs could be produced annually. A total area of 1,500 - 2,000 ha has the potential to double the supply of *A. melanoxylon* currently produced in Tasmania. In comparison, New Zealand has an estimated 3,000ha of *A. melanoxylon* plantations established. In addition, NZ research shows plantation grown *A. melanoxylon* has a sawn recovery of 50% with component breakdown of 64% dressing grade, 31% select grade and 5% standard grade (compared to native forest recovery of 25-35% in Australia).

Swanson (2006) concluded that a fast growing, well managed, sacrificial *E. nitens* nurse crop facilitates increased height growth of *A. melanoxylon*, along with improved tree form, reduced stem taper, reduced branch development (thus reduced pruning requirements), and a reduced knotty core diameter - all essential benefits in producing high value blackwood. Wood quality may also be improved. Swanson (2006) also reports that nurse crops are adaptable to a range of sites.

The trial was part of a series of six sites established by Private Forests Tasmania and landholders under the Australian Government's Wood and Paper Industry Strategy program (1996 – 2000) to evaluate species selection and site establishment for commercial tree species on marginal sites on cleared farmland. Thereafter the trial was largely managed by Private Forests Tasmania to evaluate *A. melanoxylon* clearwood production with selected nurse crops and also clearwood production of *E. nitens* and *P. radiata* in pure stands.

The trial is at Claude Road, 20 km south of Devonport in northern Tasmania. It is on a lower gully slope surrounded by open grazing land, with a westerly aspect, moderate to poor loamy gravelly soils, 1200 mm long-term average annual rainfall, moderate to heavy frosts and high exposure to strong westerly winds, particularly in late Winter and early Spring. The adjacent Mount Roland is snow covered during late winter. In 1998 – 2000 the site experienced severe frosts. Rainfall from 1997 to about 2007 was significantly less than average, including 2006 which was the driest year on record in Tasmania. Late Winter and Spring are very windy and gusts up to 100km/hr have been recorded in the locality. The site is considered to be of low to moderate quality for growing *A. melanoxylon*.

Two *A. melanoxylon* provenances (Smithton in the NW of Tas. and Ringarooma in the NE, both renowned for *A. melanoxylon* production), were inter-planted with alternate nurse rows of either *E. nitens* or *P. radiata* in a 'traditional nurse configuration'. This trial (1997 – 2000) was not initially designed to examine the silviculture of *A. melanoxylon*. In 2000, Lyons and Swanson, (unpublished, PFT) considered the potential returns from a sacrificial *E. nitens* nurse crop regime, in expectation of either an increase in *A. melanoxylon* stumpages and / or the increased application of on-farm sawmilling and drying. It was decided to test the response of *A. melanoxylon* to both intensive pruning and nurse crop management. At that time, *A. melanoxylon* had not been grown in Australia using sacrificial eucalypt nurse crops. Growing pure *E. nitens* and *P. radiata* under an aggressive clearwood regime was also considered to be potentially viable on this site. Hence the trial has since been managed for clearwood production of *A. melanoxylon*, *E. nitens*, and *P. radiata* in a number of comparative nurse and pure stand configurations. A harvesting plan was recently prepared for a two stage thinning operation to thin both *A. melanoxylon* and all *P. radiata* in 2014 and 2016/17 to final crop stocking.

As a plantation tree, *A. melanoxylon* requires intensive early form control and light environment management to eliminate side light exposure and produce high quality clearwood for milling (Unwin, Jennings, & Hunt, 2006). The use of nurse trees is an established silvicultural technique used to shade out problematic sidelight from young trees. Nurse trees reduce the need for other management techniques, such as later form pruning and on-going clearwood pruning required to achieve a high quality blackwood sawlog (Medhurst J. L., Pinkard, Beadle, & Worledge, 2003).

Nurse trees provide more services than sidelight suppression alone, as they also provide shelter as a buffer to wind and extreme temperatures, however they are unlikely to provide protection from frost (Pinkard & Beadle, 2001). If managed poorly however, nurse trees may also compete excessively for resources other than sunlight, especially if nurse trees are allowed to continue growing past their intended purpose, in this case potentially resulting in suppression of the desired blackwood stems. Given this and other such findings, nurse crops were employed on this site from the time of planting. The option of establishing a pure stand of *A. melanoxylon* without nurse species, as commonly pursued in New Zealand, was not deemed to be appropriate because of the local site conditions and increased pruning requirements.

Design & Establishment

The trial included a grid of 44 small plots with three replicate plots of each species and nurse treatments randomly assigned within the grid (Fig. 1). Each plot of 7 rows by 7 trees contained 49 trees. Rows are 3.5m apart and trees within rows are 3.0m apart. The original tree stocking was therefore at the rate of 952 trees per hectare. *A. melanoxylon* was planted in rows 2, 4 and 6 and a traditional nurse crop in rows 1, 3, 5 and 7, which on a plot basis equates to planting densities of 408 *A. melanoxylon* trees/ha and 544 nurse trees/ha. Each of the two nurse species was also planted separately in replicated single species plots at a density of 952 trees/ha.

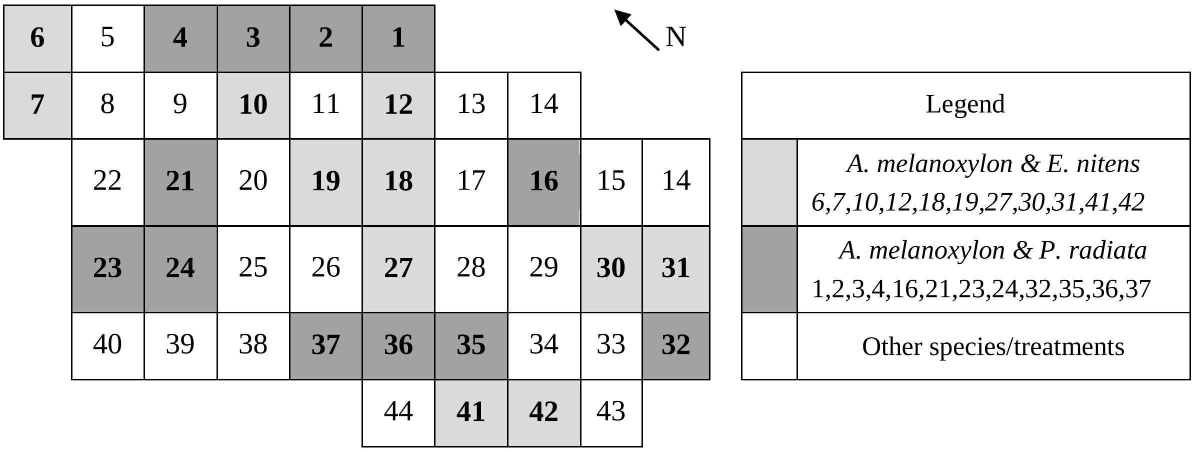

Fig. 1. Trial plan showing the layout of plots, treatments and species treatments at the Claude Rd. site in northern Tasmania. The pure stands of *E. nitens* are located in plots numbered; 13, 14, 22, 26, 34, and 40 were first thinned at age 6 years. *P. radiata* plots are numbered; 11, 15, 28 and 38 and were first thinned at age 7 years.

Table 1. Establishment and early silvicultural operations (1997 – 2000)

Operation	Description
Establishment	
Weed control	Sprayed out in Autumn 1997. Residual herbicides applied after cultivation and 4 weeks before planting. All rows were sprayed with a knockdown in late Spring 1997. From about 3 years the site was grazed with sheep, then cattle and later horses.
Cultivation	In late Autumn 1997 the western half of the site was spot rotary cultivated and the eastern half ripped and mounded with a Savannah mound plough.
Planting	Over 3 consecutive days in mid-winter 1997.
Fertilising	Spot application of 100 gram DAP to all trees 6 weeks post planting.
Browsing Animals	1.2m Tubex re-usable tree guards installed at planting.
Toppling	In the second and third year about 15% of trees, predominately *P. radiata* across the site were staked upright after toppling events.
Early Silviculture	
From Pruning	Commenced in April 2000.
Clearwood Pruning	None done in the first 3 years as the Tubex guards overcame the need to prune below 1m.

Nurse Crop Management (2000 – 2006)

A. melanoxylon has poor apical dominance and its irregular seasonal periods of tip growth result in double or multiple leaders, hence annual form pruning is essential in early years to ensure a single dominant leader. From 2000 to 2006, form pruning was undertaken nearly every year in Autumn, Winter or Spring, followed by clearwood pruning as appropriate. At every pruning visit, form pruning was undertaken as required in the upper part of each tree crown until clearwood pruning ceased. The best leader was selected and competing leaders removed at their base regardless of diameter. Both 25 mm and 17 mm gauges were used to guide clearwood pruning. Branches exceeding 25 mm were removed at the base and branches between 17 and 25 mm diameter were clipped and shortened, removing half of the foliage, with the remaining half removed at the next visit. Most trees were clearwood pruned higher than 6.5 m on the stem and heights up to 9.0m were reached. The initial intention was to prune 2 of 7 trees per row resulting in 116 evenly spaced trees of the final crop species per hectare. In practice, because of the dramatic response to form pruning in the early years, nearly all the *A. melanoxylon* trees were clearwood pruned. This unexpectedly revealed that early selections of trees with good form and diameter growth were not reliable as these trees did not necessarily perform best during the first 9 years.

At assessment at 6 years it was concluded that the *E. nitens* nurse trees were competing or could soon compete adversely with the growth of *A. melanoxylon* and it was decided to remove the nurse species by culling sequentially so as to maintain continuing benefits of partial shelter and form control. Nurse crop treatments are shown in Table 2.

Table 2. *E. nitens* and *P. radiata* nurse treatments for final stands of *A. melanoxylon*

Nurse Species	Treatment	Age		Plots
		5 years	7 years	
P. radiata	A	No thinning	No thinning	1, 2, 3, 4, 16, 21, 23, 24, 32, 35, 36, 37
E. nitens	B1	Stem Inject 50% of nurse trees (full dose*)	Stem Inject remaining nurse trees (full dose*)	6, 10, 39, 41, 42
E. nitens	B2	Stem Inject 50% of nurse trees (half dose**)	Stem Inject remaining nurse trees (full dose*)	7, 18, 19, 30, 31
E. nitens	B3	Fell 50% of nurse trees	Fell remaining nurse trees	12, 27

* Full dose - 50% of nurse trees (every second tree) was injected with 100% Glyphosate (~2ml injected every 15 cm of stem circumference) to kill the tree.

**Half dose - Remaining live nurse trees were injected with 50% Glyphosate (50/50 mix of water and Roundup, ~2ml injected every 15cm of circumference) to retard growth.

Nearly all trees (95%) of those injected with a full dose died slowly over the 12 months following treatment. Most trees injected with a half dose died slowly over 18 – 24 months.

Stem injection proved a very efficient and effective way to slowly kill and or slow the growth of the *E. nitens* nurse trees and still provide some continuing nurse benefits. The successive culling treatments ensured the nurse effect slowly declined over time and reasonable levels of ongoing shelter and sidelight suppression were provided. *P. radiata* nurse tree culling was abandoned as stem injection was ineffective and felling would cause unacceptable damage to the *A. melanoxylon*.

Results

A. melanoxylon form and growth at 6 and 9 years

Table 3 lists the criteria used in the visual appraisal of tree form which was assessed prior to form pruning of blackwood at ages 6 and 9 years (Tables 4 and 5).

Table 3. Scoring criteria for stem form of *A. melanoxylon*.

Form	Criteria	Management
1	Excellent form or expected to have suitable form with further form pruning.	Trees in this class require relatively little corrective pruning to ensure a dominant leader and good form.
2	Trees with average form (sweep, stem kinks, slight lean) that would be selected as a final crop tree only if a tree with a form score of 1 was not adjacent.	Trees in this class generally require considerable form pruning to ensure a dominant leader and acceptable form.
3	Inadequate form for a final crop tree.	Little or no pruning had been conducted upon such trees.

Table 4. Mean height and stem diameter (DBHOB) of *A. melanoxylon* at age 6 years, by nurse species and blackwood form class.

	Nurse Species					
Attribute	*Eucalyptus nitens*			*Pinus radiata*		
Blackwood Form Class	1	2	3	1	2	3
Mean Height, Blackwood (m)	6.7	6.0	5.5	6.1	5.6	5.2
Mean Diameter, Blackwood (cm)	7.8	7.2	7.9	8.4	7.9	8.4
Trees in each form class (%)	52	33	15	16	37	47
A. melanoxylon survival (%)	96			94		

Table 5. Mean height and stem diameter (DBHOB) of *A. melanoxylon* at age 9 years, by nurse species and blackwood form class.

	Nurse Species					
Attribute	*Eucalyptus nitens*			*Pinus radiata*		
Blackwood Form Class	1	2	3	1	2	3
Mean Height, Blackwood (m)	10.3	10.0	9.6	9.5	9.3	8.4
Mean Diameter, Blackwood (cm)	11.0	11.0	11.7	10.5	10.5	11.2
Trees in each form class (%)	34	32	34	11	27	62

Blackwood stem diameter and height growth

Figs. 2 and 3 show the relationships of average stem diameter and tree height with tree form of *A. melanoxylon*, at ages 6 and 9 years. At age 9 years, significant proportions of *A. melanoxylon* grown with *E. nitens* nurse trees had some degree of lean from the vertical, as shown in Table 6.

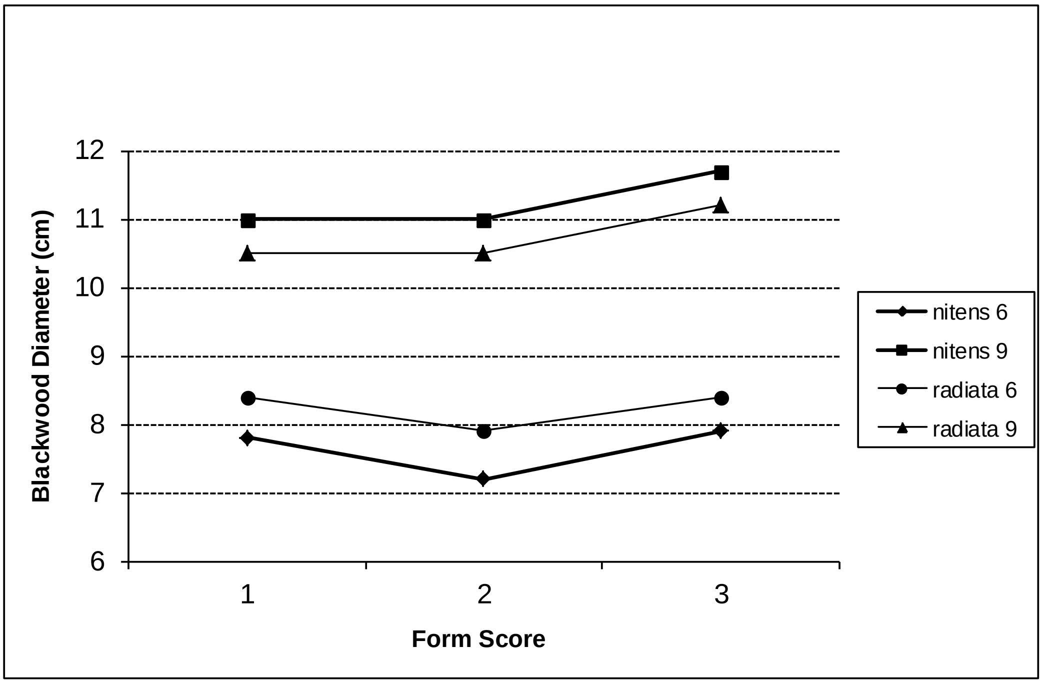

Fig. 2. Average stem diameter (DBHOB) by tree form class for *A. melanoxylon* at ages 6 and 9 years, with *E. nitens* and *P. radiata* nurse species respectively.

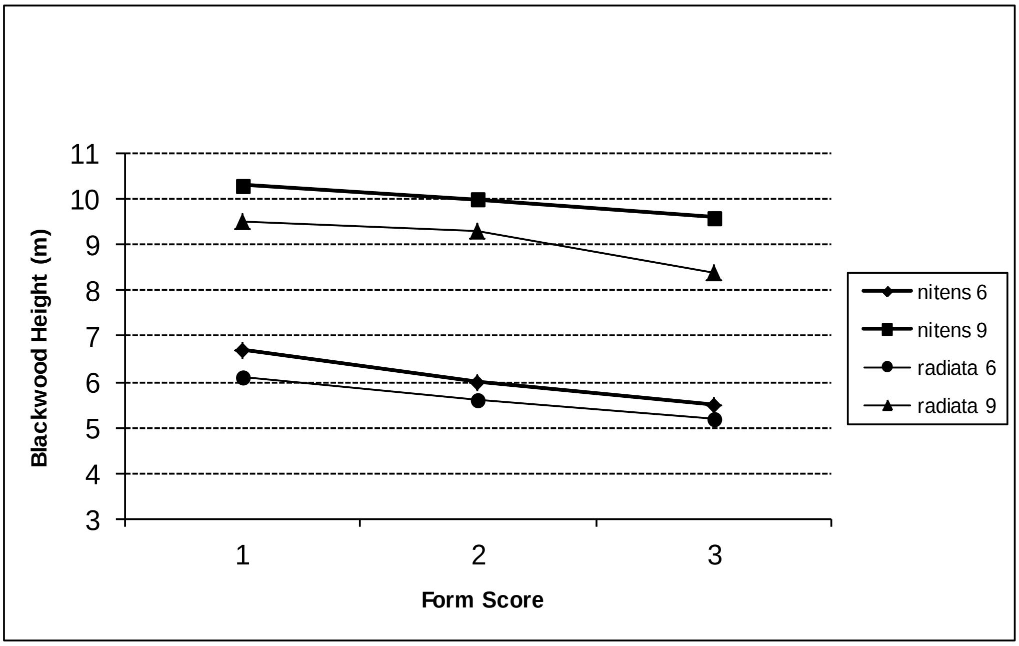

Fig. 3. Average tree height by tree form class for *A. melanoxylon* at ages 6 and 9 years, with *E. nitens* and *P. radiata* nurse species respectively.

Table 6. Percent lean of *A. melanoxylon* at age 9 years, by tree form class and nurse species, respectively.

	Form Class of *A. melanoxylon*		
Nurse Species	1	2	3
E. nitens	20%	48%	39%
P. radiata	10%	19%	28%

Nurse Species Treatments

Smith (2013) used 2-way ANOVA analysis to compare growth of the *A. melanoxylon* at age 15 years, accounting for nurse species (and plot exposure to the prevailing south-westerly winds). In this analysis, Smith combined Treatments B1 and B2 of Table 2 (above) and compared this treatment with Treatment A, *viz.*

- Treatment A - *A. melanoxylon* with *P. radiata* nurse species
- Treatment B (B1 plus B2) - *A. melanoxylon* with *E. nitens* nurse species.

Smith (2013) found statistical difference between Treatments A and B, that is with regard to choice of nurse species. Mean growth results for *A. melanoxylon* at age 15 years are shown for each of the two nurse selections respectively, in Table 7.

Table 7. Mean growth results for *A. melanoxylon* at age 15 years, with *P. radiata* and *E. nitens* nurse species respectively.

	Treatment A (*P. radiata* nurse)	Treatment B (*E. nitens* nurse)	Level of Significance
Mean Stem Diameter, DBHOB (cm)	13.3	19.3	**
Mean Tree Height (m)	13.1	15.0	*
Stand Basal Area (m^2ha^{-1})	6.4	15.1	***
Mean abundance of Form Class 1 trees (%)	32	40	**
Mean abundance of Form Class 2 trees (%)	39	40	NS

Note; in the comparison above, the silvicultural treatments A and B are different because the *P radiata* nurse crop was not thinned as intended and thus had a detrimental impact on the *A. melanoxlyon.*

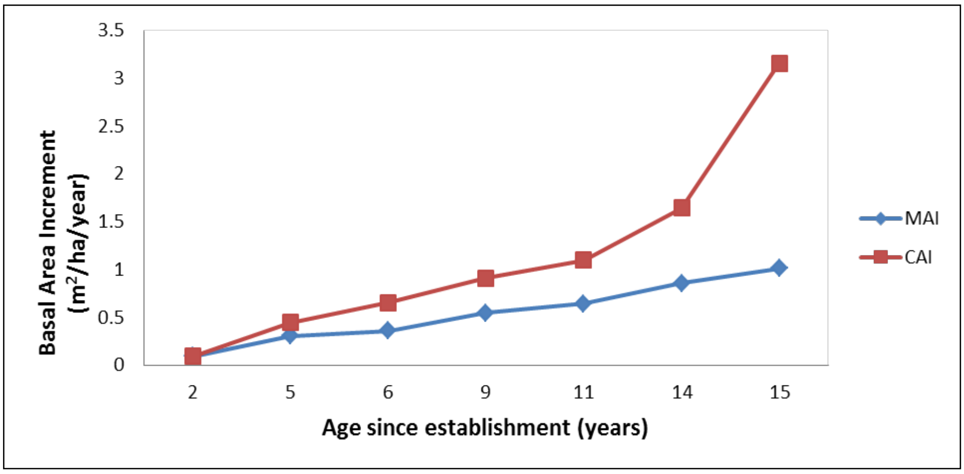

Fig. 4. Basal area increment (CAI and MAI) for *A. melanoxylon* with *E. nitens* nurse species.

Smith (2013) also examined growth in plot basal area of blackwood. Fig. 4 shows the average current annual increment (CAI) and average mean annual increment (MAI) for basal area of *A. melanoxlyon* during ages 2 to 15 years, combining the tree data for blackwood across all plot replicates with *E. nitens* nurse species. There was a steady increase in basal area (CAI) during ages 2 to 15 years and no response was observed following thinning / culling of the nurse trees during age 5 – 7 years. There was no evidence therefore that the *E. nitens* nurse species had begun to suppress the stem growth of *A. melanoxylon* prior to culling of the nurse species during age 5 to 7 years.

Smith (2013) compared treatments B1, B2 and B3, as listed in Table 2, according to the dosage, timing and method of removal of the *E. nitens* nurse species by stem injection or felling. Allometric results indicated that injection Treatment B1 with full dosage to 50% of nurse trees phased over each of two years resulted in the least growth outcomes at age 15 years, for diameter, height and basal area of *A. melanoxylon*, among the three culling methods tested (Table 8). Results of Treatments B2 and B3 were not significantly different at age 15 years (Table 8).

Table 8. Growth of *A. melanoxylon* at age 15 years, in relation to culling treatment of the *E. nitens* nurse species.

Method of nurse species removal	Treatment B1 (First injection 50% of trees, full dose)	Treatment B2 (First injection 50% of trees, half dose)	Treatment B3 (First felling 50% of trees at age 5 years)
Mean Diameter (cm)	18.0	20.2	19.1
Mean Height (m)	14.6	15.2	15.4
Stand basal area (m^2ha^{-1})	13.0	16.7	15.1
Mean abundance of form 1 & 2 trees (%)	13	14	15

E. nitens and *P. radiata* for clearwood

E. nitens and *P. radiata* were also planted in single species plots which were waste thinned and form and lift pruned to produce a final stand for clearwood production. The aim for *E. nitens* was to produce minimum 6.4 m clearwood logs with maximum 10 cm knotty core diameter in 3 or 4 pruning lifts, and to maximise the financial return. Pruning exceeded 6.4 m height above ground and most branches were removed before they exceeded 3 cm in diameter. The initial target was to retain the best two of every 7 trees per row (~272 trees/ha). In practice, thinning to 272 trees/ha at the second lift followed by a second thinning in December 2006 reduced the average final stocking to 211 trees/ha.

For *P. radiata*, a standard form and variable lift pruning regime was applied with a core diameter of 10 - 15 cm over stubs. *P. radiata* form was variable and tree characteristics were largely determined by site conditions, the initial effect of the tree guards, and subsequent toppling due to windthrow of some stems. Trees were high pruned and waste thinned to remove toppled trees and to reduce stocking to 287 trees/ha. A commercial thinning was to occur when small diameter logs were of merchantable size for processing by an available Hewsaw which is about 100km distant from the site. Markets changed and thinning is now scheduled for late 2014 and 2016/17 with the logs to be processed for knotty pine product at a local sawmill.

Discussion

Establishment and early growth, to age 3 years (1997 – 2000)

The initial focus was on the assessment of survival and early growth of *A. melanoxylon* (Lyons & Swanson, 2006) and relevant findings include:

- Tree survival of blackwood exceeded 98%.
- *A. melanoxylon* with nurse protection had better form than without nurse competition.
- *A. melanoxylon* under a *P. radiata nurse* crop had poor form as *P. radiata* grew slowly in the first two years and failed to provide essential early screening from sidelight.
- *A. melanoxylon* established with a *E. nitens* nurse crop showed superior form compared with the *P. radiata* nurse treatment, and compared with comparable open grown blackwood (Plot 44).
- Within three years, nurse crops increased shelter from wind and generally improved tree health, growth rate, height and form of the blackwood. The extra cost to establish and manage the nurse plantation, particularly the cost of using tree guards on the blackwood, was considerably offset by shelter benefits, shielding of herbicide spray and no requirement to prune the blackwood below 1.0 m stem height.

Early stand management, ages 3 to 9 years (2000 – 2006)

Pruning and thinning of the *E. nitens* nurse crop was completed in 2006 and form and lift pruning of *A. melanoxylon* was done to specification and continued thereafter as required (Lyons & Swanson, 2006).

Positive benefits of the managed nurse regime include:

- Faster growing (taller) *A. melanoxylon* had better tree form which was dramatically improved under *E. nitens* when compared to the *P. radiata* nurse crop.
- At 6 years, form pruning had suppressed diameter growth and trees assigned a form score of 2 required more form pruning than trees with a form score of 1.
- Branch shortening to reduce subsequent branch development proved successful for *A. melanoxylon.*

- At 6 years, *A. melanoxylon* height growth was slightly increased with the *E. nitens*, compared with the *P. radiata* nurse species. However average stem diameter of the blackwood was significantly less with the *E. nitens* nurse, most probably reflecting added competition from the faster growing young eucalypt compared to the pine. At 9 years (two years following culling of the nurse species) this pattern had reversed and both *A. melanoxylon* height and stem diameter were greater under the *E. nitens* nurse treatment than under the unculled *P. radiata*. This was because the *E. nitens* was managed (i.e. suppression was controlled or avoided by the phased removal of the eucalypt nurse) whereas the *P. radiata* nurse crop was not managed by thinning or culling and it continued to compete strongly with the blackwood.
- *A. melanoxylon* form scores declined significantly between ages 6 and 9 years, particularly under the *E. nitens* nurse crop. Possible reasons for this include:
  (a). The phased removal of the *E. nitens* nurse cover during ages 5 – 7 years progressively removed the nurse control on blackwood crown development and new growth.

  (b). Assessment methodology. Lean was only assessed at 9 years. Wind exposure was increased by earlier thinning of the *E. nitens* nurse crop by stem injection or felling. This potentially increased tree lean and subsequently reduced form scores at 9 years. This highlights the caution that is required when thinning nurse crops, particularly on sites subject to strong winds.

  (c). Form pruning does not always achieve the desired results. At age 6, form assessment (to 6 m) included trees that were anticipated to respond to form pruning and but not all such trees responded as expected.

  (d). All *A. melanoxylon* trees were retained and pruned experimentally to investigate what continued form pruning could achieve. Normally the more poorly formed *A. melanoxlyon* trees (say 50%) would have been culled from the final stand, thus increasing the remaining percentage of superior form 1 trees.
- Crown development of *A. melanoxylon* was considerably different with each respective nurse species. *A. melanoxylon* with *E. nitens* generally produced fewer competing leaders and a relatively narrow crown, whereas *A. melanoxylon* with *P. radiata* tended to produce more leaders and a rounded crown which required more form pruning.
- Branch development of *A. melanoxlyon* was greater under the *P. radiata* nurse crop and with more and larger branches having to be removed during clearwood pruning.

- The potential pruned height in open grown *A. melanoxylon*(e.g. Plot 44) was only 3 - 4 metres compared with the 6 - 7 metres achieved with the *E. nitens* nurse crop. This demonstrates the negative impact of exposure on both *A. melanoxlyon* form and growth in the absence of effective nurse protection and indicates that suitably managed nurse crops are required on this site**.**
- Manual felling of the *E. nitens* nurse trees at age 6 years (e.g. Plot 12) resulted in abrupt wind exposure and damage whereas the gradual removal of the *E. nitens* nurse by phased stem injection served to slowly acclimate the *A. melanoxylon* to withstand added exposure, thereby reducing the potential risk of wind damage.
- By age 9 years the *P. radiata* was considered too aggressive and too costly to be culled or managed effectively as nurse cover. Although selected *P. radiata* trees were both form and also first and second lift pruned from about 4 years, removal of the coniferous species was more labour intensive and time consuming than the progressive removal of *E. nitens*. Accordingly, at age 9 years, the *P. radiata* which was originally intended as a sacrificial nurse species now became commercial and the *A. melanoxylon* was left to fend for itself in the face of increasing suppression by the pines.

Stand management, to age 15 years (2000 – 2014)

Smith (2013) analysed the tree data collected up to 2012/13 and reported the main outcomes as follows:

- The average annual diameter increment of *A. melanoxylon* was 1.3cm/yr under an *E. nitens* nurse crop. This compares favourably to *A. melanoxylon* grown in other environments, viz. this varies between 0.55 to 0.75cm/yr in Tasmanian swampland, 1.00cm/yr in sheltered forests and in plantations up to a maximum of 2.5cm/yr in the most ideal conditions (Unwin, Jennings, & Hunt, 2006; Forestry Commission, 1991; Pinkard, 2003).
- *A. melanoxylon* trees under an unmanaged *P. radiata* nurse crop had significantly lower growth rates and poorer form than under *E. nitens* because the *P. radiata* suppressed *A. melanoxylon* from an early age.
- In response to thinning treatments, including no thinning, the stand basal area (m^2ha^{-1}) indicates competition between the *P. radiata* nurse and *A. melanoxylon* was present from as young as age 3 to 4 years.

- The highest diameter increment and maximum proportions of form 1 and form 2 trees occurred in *A. melanoxylon* planted with *E. nitens* nurse trees, which were culled during ages 5 to 7 years.
- Removal of the *E. nitens* nurse trees at 5 to 7 years resulted in significantly poorer form where *A. melanoxylon* was exposed to prevailing winds. This potentially indicates the need for continued tree shelter extending beyond nurse removal at age 6 years. Smith (2013) also compared different nurse removal methods (Treatments B1, B2 and B3 in Table 2) and found only small or non-significant differences in *A. melanoxylon* form and growth rates in favour of 50% first herbicide dosage to half of the nurse trees compared to 100% dosage. Manual felling produced intermediate, non-significant differences.

The principal challenges of growing *A. melanoxylon* with manageable nurse species are (a) to 'match' the early growth rate and growth habit of the nurse species with that of *A. melanoxylon* and (b) to silviculturally manage the nurse species to prevent suppression of the slower growing *A. melanoxylon* by excessive competition for canopy light, nutrients and water, whilst at the same time providing the essential shelter from sidelight and wind exposure which is required for improved tree form and a high value product. However, the evidence here of wind throw and poor form on exposed sites following the removal of nurse trees indicates the ongoing need for some remaining shelter on such sites as the *A. melanoxylon* matures. Swanson (2006) reported that *A. melanoxylon* with *E. nitens* nurse crops at Claude Road displays both better form and a higher proportion of better formed trees than in many plantations elsewhere in Australia and NZ.

Financial Assessment

Farm Forestry Toolbox V5.3.3 growth modelling excluded some less representative plots to analyse comparative *A. melanoxylon* stand data (Chan & Lockwood, 2006). In absence of a *A. melanoxylon* growth model, *E. saligna* was used as a verified growth analogue. Stocking and competition parameters defined by Reid (2006) were applied. Modelling indicated that *A. melanoxylon* grown with an *E. nitens* nurse crop (Treatment B2) on a marginal site, has potential to yield 220 m^3ha^{-1} of clearwood and other sawlogs at age 40 years. At current stumpages of \$110 /m^3 for clearwood and \$50 /m^3 for non-clearwood sawlogs, such a venture is unprofitable and stumpages would need to increase threefold to \$330 /m^3 and \$150 /m^3 respectively to break-even. Accordingly revenue generated would increase from $13,480 /ha (with NPV (-)$3,475 and IRR 2.07%) to $40,450 /ha (NPV (+) $365 and IRR 5.18%). Lyons & Swanson (2006) estimated on-site sawmilling, with NZ sawn recoveries, for green timber sales or air-dried sales significantly increased profitably with respective revenues of $67,000 and $137,000 /ha.

By way of comparison, *E. nitens* and *P. radiata* themselves grown for clearwood, and pruned and waste thinned to final crop stocking by age 9 years, show a maximum NPV at about 25 years and at current log prices the IRR is are 1.6% and 8.9% respectively. The poor return on *E. nitens* reflects the currently very low clearwood prices for this species.

Conclusions

Principally, this trial investigated one non-industrial scale option for growing *A. melanoxylon* on farms, that is in combination with a suitable non-commercial nurse species. Silviculturally, the study reinforces the need to:

1. Focus on the objective, i.e. the production of a final crop of high quality *A. melanoxylon* clearwood timber.
2. Pay close attention to the silvicultural requirements of *A. melanoxylon* and ‘match’ the nurse crop to essential growth and form requirements of *A. melanoxylon* throughout stand development. The essential objective of the nurse strategy is that the nurse species must compete for early sidelight, especially for optimal form of desired species such as *A. melanoxylon* which has minimal shoot apical dominance.
3. Be prepared to sacrifice the nurse crop when its benefits as a nurse become redundant, that is before it competes excessively to suppress further growth of *A. melanoxylon.*
4. Use an ongoing adaptive management strategy based on appropriate research to suit individual sites.
5. Commit to the strict adoption of timely and appropriate nurse treatments (e.g. culling schedules), and pruning techniques.

This work shows *A. melanoxylon* can be grown with *E. nitens* nurse crops with considerable initial success and with potential for high value *A. melanoxlyon* sawlog production in the long term. Unfortunately there has been a recent decline in *A. melanoxylon* plantation research effort in Australia when considerable gains had been made both in Tasmania and in New Zealand (particularly without nurse crops) during previous decades. There is potential to evaluate alternative plantation designs (both with and without nurse crops) and more timely pruning regimes which may be likely to be adopted by farmers in Tasmania and on suitable sites elsewhere in southeast Australia.

A. melanoxylon is a small scale, long-term but potentially high value-adding timber species that can be integrated into farms on selected sites but even with good nurse management, significant stumpage increases are required before such investment is potentially profitable to the grower.

Acknowledgements

The authors acknowledge Brett Miller and Stuart Swanson for their valuable assistance in establishing, managing and monitoring the trial at various stages from 1997 to 2014. We also thank landholders Ray and Kerrie Cross for providing the land and assisting to plant, prune and maintain the trees to 2010, and from 2011, landowner Greg Turner.

References

Chan, H., & Lockwood. P. (2006). Silvicultural management of Australian *A. melanoxylon* (*Acacia melanoxlyon*) in plantations and multi-purpose forests. Proceedings of *A. melanoxylon* Industry Group: fourth *A. melanoxylon* workshop, Victoria, 26-29 April 2006. Rural Industries Research and Development Corporation Publication No. 07/095, pp 122-125.

Forestry Commission. (1991). Blackwood. Native Silviculture Technical Bulletin No 10, Forestry Commission Tasmania.

Lyons, A., & Swanson, S. (2006). Claude Road and Site Suitability Demonstration. *Australian Forest Growers International Biennial Conference.* Launceston.

Lyons, A., & Swanson, S. (2006). *Claude Road Species and site Suitability Demonstration.* Launceston: Private Forests Tasmania.Medhurst, J. L., Pinkard, A. L., Beadle, C. L., & Worledge, D. (2003). Growth and stem form responses of plantation-grown Acacia melanoxylon (R. Br) to form pruning and nurse crop thinning. *Forest ecology and management*, *179* (1 - 3), pp 183 - 193.

Pinkard, E. A., & Beadle, C. L. (2001). *A. melanoxylon(Acacia melanoxylon R. Br) plantation silviculture: a review.* CISIRO, CISIRO Forestry and Forest Products. Hobart: CISIRO Forestry and Forest Products.

Reid, R. (2006). Silvicultural management of Australian Blackwood (*Acacia melanoxlyon*) in plantations and multi-purpose forests. Proceedings of *A. melanoxylon* Industry Group: fourth *A. melanoxylon* workshop, Victoria, 26-29 April 2006. Rural Industries Research and Development Corporation Publication No. 07/095, pp 70-74

Swanson, S. (2006). *A. melanoxylon* (*Acacia melanoxlyon*): Refining successful plantation silviculture. Australian Forest Growers Conference 2006, pp 217-226.

Swanson, S. *(2006).* Producing Acceptable Form in *A. melanoxylon* Plantations. *Australian Forest Grower*, Autumn 2006, Volume 29, No 1.

Smith, S. (2013). Silvicultural nurse treatments used in plantation grown A. *melanoxylon* in North West Tasmania. University of Tasmania (Internal Student Report).

Unwin, G. L., Jennings, S. M., & Hunt, M. A. (2006). Light environment and tree development of young Acacia melanoxylon in mixed-species regrowth forest, Tasmania, Australia. *Forest Ecology and Management*, *233* (2 - 3), pp 240 - 249.

Contacts

Arthur Lyons
Manager Services,
Private Forests Tasmania,
171 Westbury Road, Prospect, Tasmania 7249
arthur.lyons@pft.tas.gov.au
03 6777 2716
0419 000 630

Henry Chan
Private Forest Advisor,
Private Forests Tasmania,
2-4 East Cam Road, Camdale, Tasmania 7320
henry.chan@pft.tas.gov.au
036477 7050
0400 548 434

Dr Greg Unwin
Adj. S/Lecturer (Forest Ecosystems / Agroforestry),
University of Tasmania,
Locked bag 1376, LAUNCESTON, Tasmania. 7252
G.Unwin@utas.edu.au
03 6324 3822
0417 540 745