Regeneration after seed-tree retention in tall *Nothofagus* rainforest in Tasmania

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Abstract

*A seed-tree silvicultural system was trialled in a three-hectare patch of tall myrtle (*Nothofagus cunninghamii*) rainforest to determine if regeneration would occur after removal of most of the merchantable wood. Sixteen seed trees/ha were retained; seedbed was created by mechanical disturbance.*

A heavy Nothofagus *seedfall occurred one year after harvesting and a second heavy fall occurred four years later. Over half of the seed trees died within eight years of harvesting, either from myrtle wilt (24%) or windthrow (29%). Seed-tree survival after 20 years was negligible.*

Dense myrtle regeneration occurred after one year but seedling growth was slow, at less than 2 cm/yr, 2.6 years after harvesting. By age three, over 40 000 seedlings/ha had established and this resulted in about 16 000 saplings/ha, with a mean height of 7 m, after 20 years. Although myrtle density decreased over the period, stocking of 4 m^2 plots increased slightly, due to recruitment of seedlings from subsequent seedfalls onto areas of unstocked seedbed.

*The 20-year-old regrowth was dominated by myrtle but also contained about 9000 leatherwood (*Eucryphia lucida*) saplings which had regenerated from the incidental retention of small, non-merchantable trees. Sassafras (*Atherosperma moschatum*) and celery-top pine (*Phyllocladus aspleniifolius*) regeneration was sparse but sufficient to maintain the presence of these commercial tree species in the new stand.*

Seed-tree systems may be appropriate in tall myrtle forest if the management objective is to harvest most of the wood, obtain dense myrtle regeneration and maximise growth, and where there is little requirement to maintain a semblance of the original forest structure.

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Introduction

Rainforest logging and regeneration trials established since the late 1970s in north-western Tasmania showed that dense myrtle (*Nothofagus cunninghamii*) and leatherwood (*Eucryphia lucida*) regeneration can be obtained when rainforest is partially harvested and a seed source is available within 40 m of the felled area (Hickey and Wilkinson 1999). Additional mechanical disturbance can be used to increase the area of receptive seedbed and enables regeneration to establish over a greater proportion of the area (Forestry Tasmania 1998).

Selective cutting of rainforest in designated Special Timbers Management coupes is usually for sawlogs rather than pulpwood, and high levels of overwood are retained because the sawlog component of these forests is usually very low: less than 20 m^3/ha (Mesibov 2002). However, an alternative management objective could be to harvest almost all of the pulpwood and sawlog but still regenerate the site to rainforest at low cost. The use of seed-tree systems, where the old stand is removed in one cutting except for a small number of seed trees left singly or in small groups (Smith *et al*. 1997), is potentially compatible with this objective. Seed-tree systems are commonly used in Tasmanian dry eucalypt forests, where 7–12 trees / ha are retained (Forestry Tasmania 2002), but have not previously been formally applied in myrtle rainforest in Tasmania. Seed-tree systems were applied in *Nothofagus* forests in New Zealand (Wardle 1984) but subsequently discontinued as a result of a 1993 amendment to the New Zealand Forests Act which required that indigenous timber could only be produced from forests managed with systems that maintained a continuous canopy cover. Hence, group selection systems or single tree selection systems are now used (Benecke 1996), although even these are now mostly limited to private land.

This paper describes a formal trial of the seed-tree system established in 1981 in tall myrtle forest in north-western Tasmania, and the development of the regrowth over 20 years. The short-term aim was to provide information on the success of regeneration and the mortality of seed trees following logging. Over a longer period, the trial has enabled monitoring of even-aged rainforest stand development on a high quality site.

Methods

Study site

The trial covers 3 ha in coupe PU027B in State forest on the western side of Pruana Road (41°10'S, 145°30'E), approximately 40 km south-west of Burnie. The soil within the trial is a stony brown gradational soil derived from Tertiary basalt. The trial is on a small knoll surrounded by poorer soils derived from Permian mudstone. The elevation is about 480 m.

The site carried 30 m tall myrtle forest with a subcanopy of sassafras (*Atherosperma moschatum*) and leatherwood. Scattered celery-top pines (*Phyllocladus aspleniifolius*) occurred within the trial area but appeared to be outliers from the adjoining forest on poorer soils. Blackwood (*Acacia melanoxylon*) was absent except for a number of saplings that had regenerated along an old track. There were indications that the forest had been lightly logged for sawlogs some decades before.

Selection of seed trees

Prior to harvesting, 49 myrtle seed trees were marked for retention on a 25 m grid (16 myrtle seed trees / ha). Except for one large leatherwood, species other than myrtle were not marked for retention due to the abundance of non-merchantable stems. Seed trees were chosen on the basis of spacing, crown health, size and apparent wind stability.

Harvesting

A Forestry Commission crew carried out the harvesting over six days in late March 1981. Snigging and site preparation was done with a D6 bulldozer. The harvesting prescription was to:

- Remove all merchantable stems other than marked seed trees;
- Fell all remaining myrtle stems over 20 cm DBH;
- Retain non-merchantable stems of other species if they had healthy crowns; and
- Retain any patches of advanced growth.

The reforestation prescription was to:

- Push logging debris into small heaps with the bulldozer and lightly scrape off the fern / litter layer to expose a mineral soil seedbed; and
- Obtain regeneration from natural seedfall.

Measurement

Retained seed trees were scored for damage and crown health at 1.3 years, 2.6 years and eight years after harvesting. A 1 m^2 seed trap was located in the trial in November 1981 and

Table 1. Status of 46 retained myrtle seed trees.

Years since harvesting	Healthy	Crown < 50% dead	Crown > 50% dead	Dead	Windthrown
1.3	28%	28%	20%	2%	22%
2.6	24%	28%	11%	11%	26%
8.0	15%	15%	17%	24%	29%

seed collected at irregular intervals until the end of May 1992. Its purpose was to record heavy myrtle seedfalls that would initiate most of the regeneration. Myrtle has heavy (mast) seed years over large areas, which occur irregularly but with an average frequency of one in three years (Hickey *et al.* 1982).

Eight circular 4 m^2 permanent regeneration plots were established within the trial 1.3 years after harvesting. Two of the plots were located inside small exclosures, fenced with 1 m tall chicken wire, to observe myrtle regeneration in the absence of mammal browsing. The number of myrtle seedlings and the height of the tallest were recorded for 1 m^2 and 4 m^2 plots. These were remeasured 2.6 years and 4.2 years after harvesting.

Regeneration surveys based on temporary 4 m^2 circular plots located at 20 m intervals on lines 50 m apart were conducted 2.6 years, 4.2 years and 20 years after harvesting. The number of myrtle seedlings and the presence of seedlings of other commercial tree species were recorded for each plot. The height of the tallest individual of each species was recorded. The canopy of each plot was classified as open, where no tree crowns were retained within 10 m of the plot; partial, where some of the original tree canopy existed within 10 m; or closed, where a continuous tree cover occurred. The seedbed of each plot was classified according to the presence / absence of soil disturbance due to harvesting.

Results

The harvesting proceeded according to the prescription but three of the marked myrtle seed trees (6%) were felled for safety reasons. An adjacent tree was retained in each case. Two seed trees (4%) sustained severe crown damage during harvesting and another two (4%) suffered moderate crown damage. The site was thoroughly scarified to increase available seedbed. Approximately 460 t of merchantable wood were recovered from the three-hectare area, of which about 12% was classed as sawlog.

Seedbed disturbance due to logging and additional mechanical disturbance was recorded on 93% of the 4 m^2 plots examined during the first regeneration survey. Of the 27 plots, 30% had an open canopy, 66% had a partial canopy and 4% had a closed canopy 1.3 years after harvesting.

A heavy myrtle seedfall was recorded in February 1982, almost one year after harvesting, with 5.6 g / m^2 of myrtle seed (about 3000 seeds) collected during the summer. Over the same period, 0.1 g / m^2 (about 100 seeds) of leatherwood seed were collected. A second heavy myrtle seedfall was recorded in February 1986, five years after harvesting.

Survival of seed trees

Mature myrtle trees are susceptible to death from myrtle wilt caused by the fungus *Chalara australis* (Kile and Walker 1987). Disturbances to rainforest stands, such as logging or thinning treatments, increase mortality due to myrtle wilt (Packham 1991).

Table 1 shows the progressive status of 46 initially healthy myrtle seed trees over eight years. Trees not found at the eight-year measurement were assumed to be dead.

Photo 1. Myrtle seed trees, emergent above regrowth. Few of the 16 myrtle seed trees/ha survived 20 years after logging. Those that did survive had greatly reduced crowns.

Windthrow was severe for the first few years when nearly one-quarter of the trees were blown over. However, little further windthrow occurred from year two to the end of the formal monitoring period at year eight. By year eight, only 15% of the original trees were healthy and 24% had died, apparently due to myrtle wilt. Few retained trees could be identified above the regrowth 20 years after harvesting (Photo 1).

Seedling establishment

The number of myrtle seedlings present on the site was high the year following harvesting, with a mean of 15.5 seedlings / m^2 on the unfenced permanent plots (Figure 1). This declined rapidly to 4.5 seedlings / m^2 after 2.6 years, and then declined gradually to 3.8 seedlings / m^2 after 4.2 years.

Early myrtle height growth was slow, with dominant seedlings taking about four years to reach an average height of 20 cm (Figure 2). There was no apparent difference in seedling density or early height growth in fenced and unfenced plots (Figures 1, 2). This indicates that browsing was not a major problem for myrtle regeneration at this site.

Density and stocking trends over time

The regeneration surveys based on temporary plots indicated seedling densities for all species at 2.6 and 20 years after harvesting (Figure 3). Myrtle seedling density dropped from 47 000 seedlings / ha at 2.6 years to 16 000 seedlings / ha after 20 years. Leatherwood seedling numbers also declined but were still very dense after 20 years. Sassafras seedlings had low survival after 20 years despite being abundant at 2.6 years. There was a low level of celery-top pine present throughout the measurements.

The stocking of 4 m^2 plots for each species at 2.6, 4.2 and 20 years is shown in Figure 4. The percentage of 4 m^2 plots stocked with myrtle remained above 75% throughout the measurements. Percentage stocking was declining at 4.2 years but seedling recruitment continued following another mast seedfall five years after harvesting.

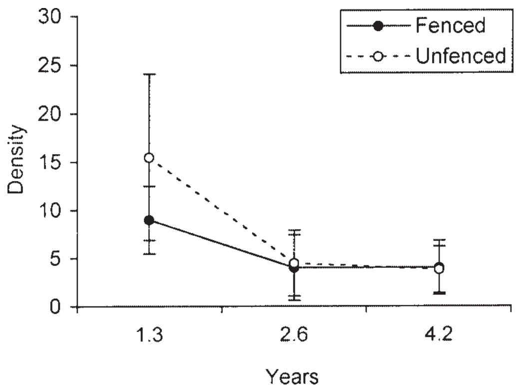

Figure 1. Mean number of myrtle seedlings/m² for fenced and unfenced plots. (Bars show standard errors.)

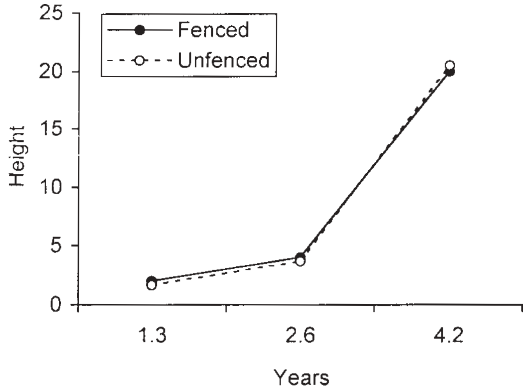

Figure 2. Myrtle seedling height (cm) for fenced and unfenced plots.

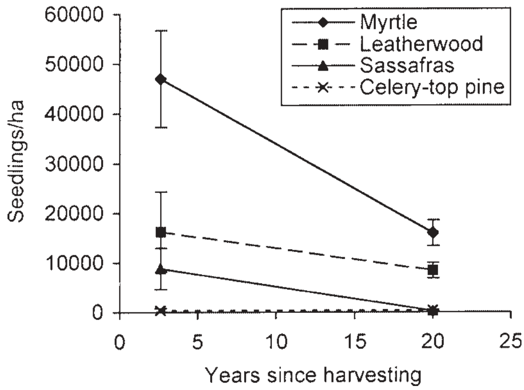

Figure 3. Mean seedling densities for rainforest tree species over time. (Bars show standard errors.)

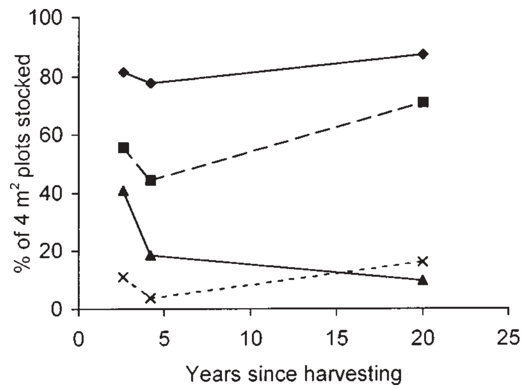

Figure 4. Percentage of 4 m² plots stocked for each rainforest tree species. (Key to species as for Figure 3.)

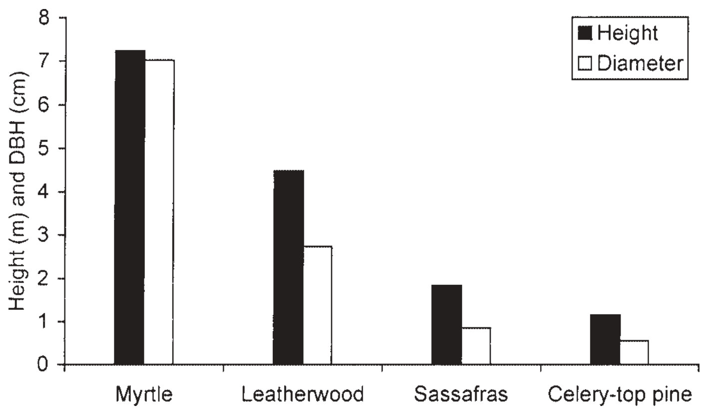

Figure 5. Mean height and diameter at breast height (DBH) of tallest saplings at age 20 years.

Stocking of sassafras declined over time and was only 10% at age 20.

Growth

Mean height and diameter of the four major rainforest tree species 20 years after harvesting are shown in Figure 5, which shows that myrtle had the fastest growth. After the establishment period (Figure 2), myrtle height growth increased significantly and at year 20 the tallest myrtles on the regeneration surveys averaged over 7 m in height (Photo 2).

Mean annual increment (height) for myrtle was 0.36 m / yr while for leatherwood was 0.22 m / yr over 20 years. Both sassafras and celery-top pine grew less than 0.1 m / yr. The difference in diameter growth between myrtle and the other species was even more marked, with myrtle growing at 0.35 cm / yr, leatherwood at 0.14 cm / yr and both sassafras and celery-top pine growing less than 0.05 cm / yr in diameter. Myrtle regeneration clearly dominates this site.

Discussion

The seed-tree retention treatment at Pruana showed that although seed trees suffered windthrow and myrtle wilt, a sufficient number survived for long enough to produce prolific regeneration, which peaked in quantity three years after harvesting (two years after the first mast myrtle seedfall). After 20 years, the seed-tree system resulted in a vigorous stand of even-aged myrtle regeneration with a component of other rainforest species. The structural diversity, and probably the biodiversity and aesthetic appeal, of this silvicultural system is lower than for areas harvested with a much higher retention level. Mesibov (2002) notes that current rainforest logging in Special Timbers Management coupes is a relatively low-impact operation aimed at recovering sawlogs. Some pulpwood is recovered in the form of headlogs in sawlog trees and ‘duds’ (i.e. myrtle trees that appear to contain sawlog when standing but when felled are found to have excessive levels of internal decay). On average, this equates to a sawlog / pulpwood production ratio of about 1:2 which is far greater than the 1:8 ratio that resulted from the seed-tree system at Pruana.

The seed-tree system allowed a higher level of harvesting and therefore a greater economic return. Dense regeneration of myrtle was obtained and all four major rainforest tree species maintained a presence on the site although the sassafras stocking declined to a low level. Read and Hill (1988) found that sassafras rarely regenerates successfully from seed in canopy gaps in undisturbed forests. This has been attributed to susceptibility to summer desiccation (Read and Hill 1988) and to browsing (Hickey 1982). Even so, the 10% 4 m^2 stocking obtained at Pruana is above the minimum level for ecological stocking (Lutze 2001). Although absolute numbers of myrtle and leatherwood seedlings declined with time, stocking increased, showing clearly that recruitment of these species continues as long as a seed source and receptive seedbed are available (Figures 3, 4).

The Pruana trial was unreplicated and further work would be needed to confirm that dense myrtle regeneration could be reliably obtained with low numbers of seed trees. The trial was only three hectares and had a width of less than 200 m; hence, some of the seed at the perimeter would have come from trees from outside the harvested area. However, Hickey (1982) found that most myrtle seed falls within 20 m of the seed source and it is mostly light, non-viable seed which is dispersed over 40 m or more. The regeneration appeared to be uniformly dense across the trial so the effect of edge seed is unlikely to have been important in regenerating the stand.

The regeneration at Pruana was also favoured by a mast seed year within 12 months of harvesting. If the system was

Photo 2. Dense myrtle saplings averaged 7 m in height after 20 years.

applied routinely, some coupes may not receive a mast seed year for up to four years after harvesting (Hickey and Wilkinson 1999). In this event, myrtle regeneration might be less successful due to colonisation of the seedbed by other species and by inadequate seedfall due to attrition of seed trees from windthrow and myrtle wilt.

Seed-tree systems, with low numbers of retained trees, should achieve near maximum growth rates for myrtle regeneration. Hickey and Wilkinson (1999) found that height growth of myrtle was highly variable across different harvesting treatments, with the lowest growth rates associated with treatments that had a dense canopy cover. They reported a maximum height growth of 0.46 m / yr for myrtle seedlings in a clearfell treatment over 18 years after harvesting. This is slightly faster than myrtle height growth of 0.36 m / yr following seed-tree retention at Pruana (Figure 5), but the clearfelled site had a lower elevation and milder growing conditions.

The density of myrtle regeneration will eventually lead to severe growth restriction. Wardle (1984) notes that successful regeneration of beech (*Nothofagus* spp.) in New Zealand usually leads to the development of dense thickets of saplings and poles. Diameter growth rates are extremely slow and are balanced by occasional losses of stems from intra-specific competition so that these stands become virtually stagnant. Dominant trees are slow to emerge, leading to long rotations in natural beech forests. Gleason (1982) advocated heavy early thinning and pruning to produce clean butt logs of 45–75 cm large-end diameter in New Zealand red beech (*Nothofagus fusca*) stands on rotations as short as 60 years. It is uncertain if these growth rates could be achieved in Tasmanian myrtle forests. Even if achievable, the cost of non-commercial thinning and pruning treatments is most unlikely to be recouped by stumpage prices, particularly if financial analyses based on discount rates are applied. A further impediment to thinning myrtle forest is that it induces myrtle wilt unless stands are treated at a very young age (Packham 1991).

The seed-tree system may be appropriate where the management objective is to harvest most of the wood, obtain dense myrtle regeneration and maximise initial growth, and where there is little requirement to maintain a semblance of the original forest structure. However, in most cases, selective sawlogging or overstorey retention is prescribed (Forestry Tasmania 1998) so that some of the original stand structure is retained. While intensive seed-tree systems may have little application in Tasmanian rainforests, the results reported here give confidence that systems that employ higher levels of retention should have a high likelihood of regeneration success.

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