Radiata Pine

Info Sheet No. 3 – Management Regimes

Private Forests Tasmania

This series on Radiata Pine has four parts. Each part can be read individually or as part of the series.

1. Overview
2. Establishment
3. **Management Regimes**
4. Labour Estimates

MANAGEMENT REGIMES

Radiata pine plantations can be managed to produce a range of high value products. These products are maximised when grown on a clearwood management regime with pruning and thinning. An alternative management regime, knot control (high initial stocking to keep branches small, followed by commercial thinning/s), is often favoured by industrial growers due to lower input costs and is more suitable to low productivity sites.

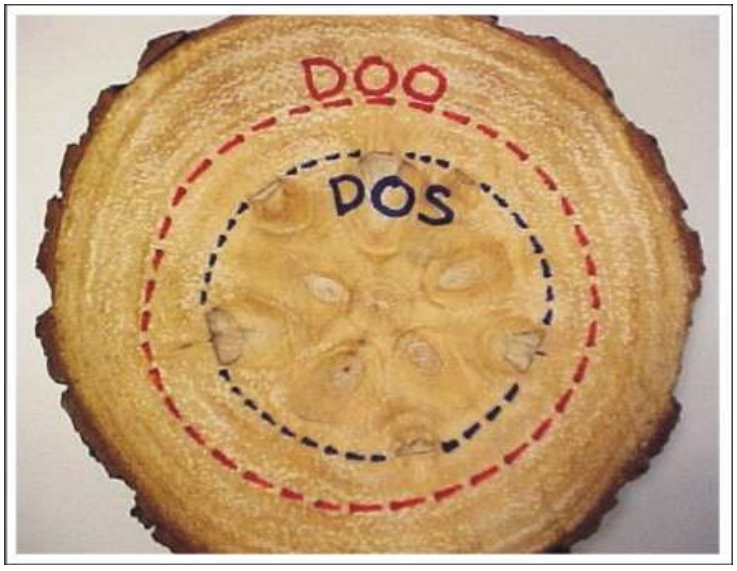
PRUNING FOR CLEARWOOD

Clearwood pruning involves the removal of the lower branches to a height that enables the production of clearwood logs for appearance-grade products. The pruned height is typically 6.4m. Either fixed or variable lift pruning may be undertaken (Figures 3 & 4).

DOS (Diameter Over Stub) refers to the diameter of the stem at the point of pruning, including branch stubs.

DOO (Diameter Over Occlusion) may be up to 6cm larger than the DOS[1] and includes abnormal wood that occludes the branch stubs and a small amount of occluded bark. Normal wood forms beyond this point to produce clearwood.

Figure 1



The largest DOS within the pruned stem, plus additional growth (the resultant DOO), determines the ultimate size of the **defect core**. Ideally, the defect core should be a straight cylinder with a diameter of approximately 25cm or less.

The disk in **figure 1** contains a pruned branch whorl that was cut from a 9-year-old tree pruned to about 2 metres. Assuming the largest DOS within a pruned tree with no sweep is 19cm, the resultant defective core would be about 25cm in diameter. Excessive pruning and competition from surrounding unpruned trees will restrict diameter growth, reducing the volume of the juvenile core.

Figure 2

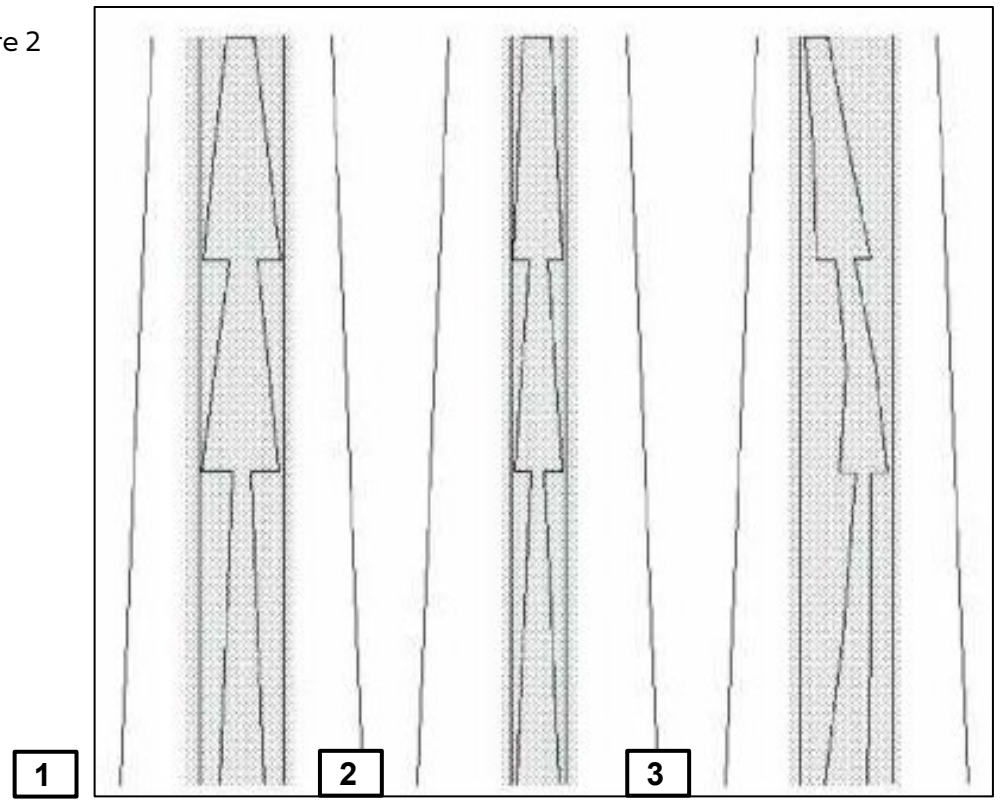


Figure 2 – Representative defect cores

1. Late pruning, resulting in a large DOS and defect core (shaded region). All lifts must be conducted on-time to ensure a consistent DOS. In this example, the value of achieving a small DOS on the first lift has been compromised by late pruning on subsequent lifts.
2. A small consistent defect core maximises clearwood recovery.
3. Significant bends or sweep due to poor form can reduce clearwood recovery, even when pruned on time.

THE IMPORTANCE OF PRUNING ON TIME

Studies of the DOS and defect core show that sawn recovery of clearwood from pruned logs can be significantly reduced if pruning is not done on time to restrict the defect core.

Table 1 - *Impact of the defect core size upon recovery of sawn timber*[2]

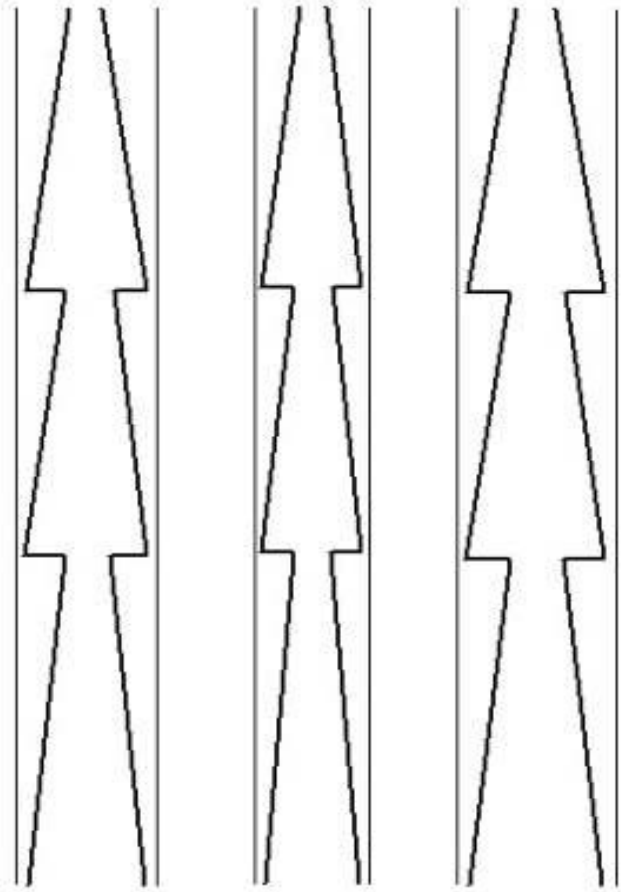
DOS (cm)	Defect Core (cm)	SED (cm)	% Recovery
18	24	47	50
22	28	47	40
26	32	47	30

% Recovery - Sawn timber volume as a % of the log volume: based upon 5.4m logs with minimal sweep. **SED (**Small End Diameter) of the log, excluding bark.

The above results and associated study indicate a 2.5% loss in sawn timber for each 1cm increase in the size of the defect core. If processors pay on the basis of recovery, late pruning could significantly reduce the stumpage received by the grower.

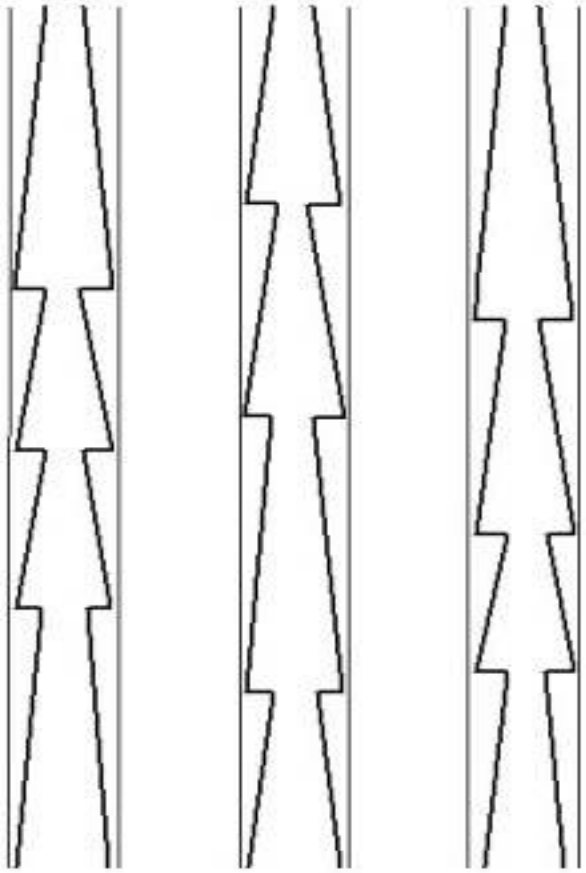
Sweep (**Figure 2**) effectively increases the size of the defect core. As a general rule, trees with sweep should not be pruned if the stem passes outside a straight line between the centre of the tree at stump height (0.3m) and the leader[1].

Figure 3 - FIXED LIFT PRUNING



- Cheap and easy pruning option.
- Pruning is undertaken in 3 lifts of set heights, typically 2.4m, 4.4m and 6.4m.
- Each pruning lift commences when the average expected DOS throughout the stand reaches the upper desired limit (e.g. 18cm).
- Inconsistent growth rates (height and diameter) between trees can result in considerable variation in the amount of green crown retained on individual trees following each pruning lift. Dominant trees that have been 'underpruned' will grow at an even faster rate compared to trees that have been 'overpruned'. This results in considerable variation in the DOS achieved throughout the stand.
- Less vigorous trees may have a DOS of 15cm or less, while larger dominant trees may have a DOS of 25cm or more.

Figure 4 - VARIABLE LIFT PRUNING



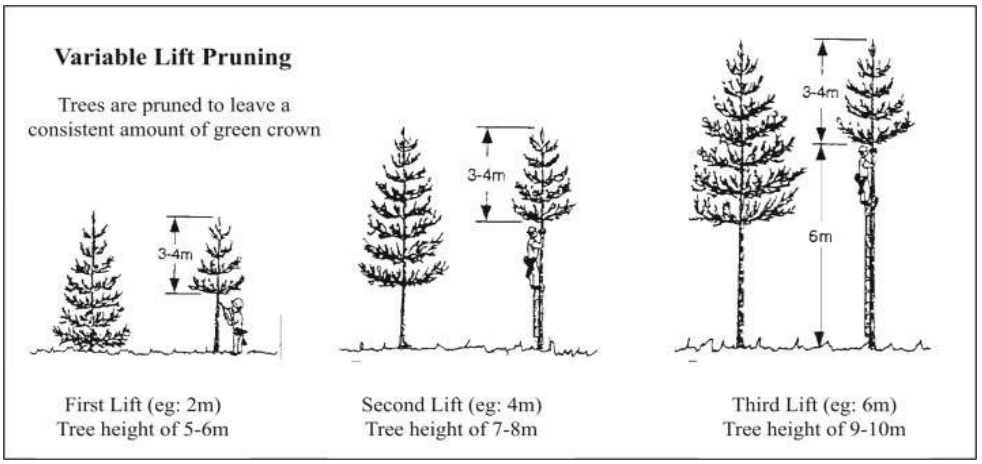
- This is a more expensive option than fixed lift pruning. It is estimated that total pruning costs are ~20% greater than fixed lift pruning.
- Pruned height following all but the last pruning lift varies from tree to tree.
- Each tree is pruned such that a consistent amount of green crown is retained on all trees, typically 3-4m.
- More consistent tree growth is achieved throughout the stand, with a relatively consistent DOS.
- Pruning is undertaken in 3 to 5 lifts, depending upon the desired DOS. As a guide, a consistent DOS of 17cm to 20cm may be achieved with 3 to 4 lifts while a DOS of 14cm to 17cm may be achieved with 4 to 5 lifts.
- 'Extension' type ladders are beneficial because of the variable pruning height

NB *The diagrams of fixed and variable lift pruning represent the defect core following the completion of pruning. The largest DOS within any single lift is usually towards the bottom of each lift. The largest DOS for all lifts determines the size of the defect core within the tree.*

Caliper Pruning

The easiest method to ensure that all trees receive a similar level of pruning is to use a stem caliper. Caliper size can be established by measuring a sample of trees to determine the average stem diameter at 3-4 metres below top height. For most situations, a 10cm caliper is considered adequate. A caliper with a 10cm gap is placed on the stem at the point where the stem diameter is 10cm. All branches below this point are removed.

Figure 5



TREE SELECTION

The aim is to produce a crop of trees pruned to 6.4m, at the desired stocking and with relatively even spacing throughout the stand. The following guidelines assume an initial stocking of 1,000 stems/ha, with 4.0m between rows and 2.5m between trees within the rows.

Trees should be selected for pruning based upon:

- ***Dominance*** - Prune vigorous trees while ignoring trees with suppressed growth rates.
- ***Form*** - Trees with double leaders, leaning trees or those with poor form due to excessive sweep and/or particularly heavy branching, should not be pruned. Form pruning can improve the selection ratio by removing form problems associated with double leaders.
- ***Spacing*** - The final crop should not have pruned stems closer than 4 metres.

First Lift - *Prune no more than two adjacent trees within a row.*
At this stage, 10-20% more trees than the desired final stocking should be pruned, as not all trees selected during first lift pruning are guaranteed to retain sufficient form, vigour and spacing to warrant further pruning. If the rows are closer than four metres, then the spacing of pruned trees between rows will need to be taken into account. Pruned heights when variable lift pruning may vary from 1.5m to 2.5m throughout the stand. At the completion of the first lift, an assessment of stocking should be undertaken.

Second Lift - *No two adjacent trees (those closer than four metres) should be second lift pruned.*
Where two adjacent trees were pruned in the first lift pruning operation, the best tree should be selected for further pruning, based upon dominance and form. If both trees are of similar form and dominance, then spacing in relation to the surrounding pruned trees should be considered. With variable lift pruning, pruned heights may vary from 3.0-4.5m throughout the stand. An assessment of stocking should be conducted during the pruning operation to ensure the number of pruned stems/ha is within the top half, or just above, the desired range (refer to recommended final stockings).

Third and Subsequent Lifts
Final pruning lifts are to attain a pruned height of 6.4m on all trees. Form above 6.4m should also be considered, particularly forking. If the stocking is above the desired range, trees that have developed forks (multiple leaders) above the final pruned height can be ignored and no further pruning conducted. Trees with poor form above 6.4m should be pruned to 6.4m and retained if they are required to ensure sufficient stocking.

Clearwood Pruning & Tree Growth

The removal of branches during clearwood pruning has the potential to reduce growth rates. When thinning is delayed, it is common to observe pruned trees that are suppressed compared to unpruned trees. A shift in dominance can occur, even though the trees initially selected for pruning were dominant and co-dominant at the time of the first lift pruning.

High to Very High Productivity Sites

Suppressing growth rates by pruning and allowing competition from surrounding unpruned trees can be beneficial, as it can reduce diameter growth and the size of the juvenile core. Non-commercial thinning can be used to ensure that pruned trees are released from competition and not permanently suppressed.

Medium to Low Productivity Sites

On lower productivity sites where rapid growth does not occur, the juvenile core is not a major concern. On such sites, pruning should aim to restrict the defect core to less than 25cm while minimising any impact upon growth. Again, non-commercial thinning can reduce competition from unpruned trees when required.

Minimum Distance between Pruned Trees

It is recommended that the minimum distance between pruned trees, regardless of final stocking, should be about 4 metres. Clumping of pruned stems, with large gaps between clumps, should also be avoided.

Pruned trees closer than about 4 metres can develop unbalanced crowns, resulting in the development of compression wood. Competition between trees closer than 4m often results in adjacent trees with reduced diameter at final harvest. Alternatively, one tree becomes dominant while the adjacent tree is suppressed and may not attain sufficient diameter to meet market specifications for clearwood.

NB *When rows are spaced 4 metres apart at establishment, there is little or no need to take into account tree spacing between rows during selection for pruning.*

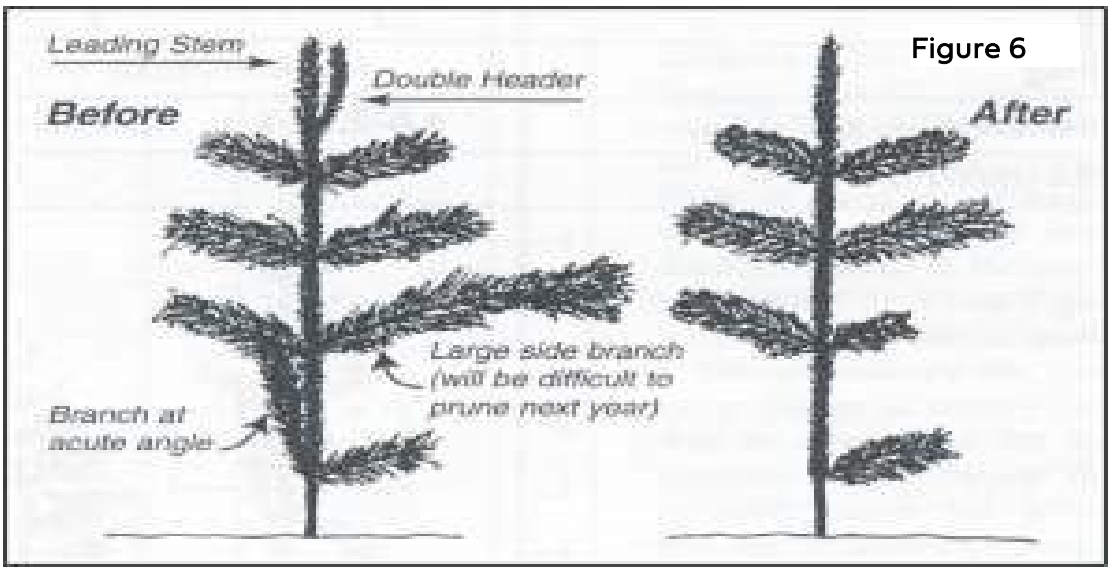


Figure 6

Figure 6 - Form Pruning Objectives

- Double leaders are removed.
- Large branches are shortened or removed prior to clearwood pruning.
- Branches on steep (acute) angles are removed.
- Basket whorls (more than 5-6 branches within a single whorl of branches) thinned to 4-5 to improve access for loppers at the time of clearwood pruning.

Successful establishment at or above the recommended stocking levels usually ensures an adequate number of trees with suitable form and spacing for clearwood pruning. Form pruning may be beneficial where low initial stockings and/or poor form limits the number of suitable trees from which to select. Poor form is less likely with improved seedling stock, although excessive fertilisers or browsing damage can induce poor tree form. Form pruning is generally light work and can be performed from the ground at age 2-3 onwards.

RECOMMENDED FINAL STOCKING & ROTATION AGE

Note: *The following figures in Table 2 are a guide only. Indicative Site Index (measured as the Mean Dominant Height at age 20) is based upon an unthinned stand planted at 1000 stems/ha. If required, seek professional advice to determine potential site productivity and appropriate final stocking rates. Clearwood production is not recommended on very low productivity sites.*

Table 2 - A guide to recommended final stocking levels and anticipated rotation ages for clearwood production.

Potential Site Productivity	Very High	High	Medium	Low
Potential MAI (m3/ha/yr)	>30	20 - 30	15 - 20	10 - 15
Indicative Site Index (m)	>32	26 - 32	22 - 26	<22
Recommended Final Stocking (stems/ha)	350	275	200	150 max
Average Distance Between Trees (m)	5.3	6.0	7.0	8.0
Acceptable Stocking Range (stems/ha)	300 - 400	225 - 325	150 - 250	100 - 150
Anticipated Rotation Age (yrs)	25 - 30	30 - 35	35 - 40	40+

Keep final stockings within an acceptable range

Table 3 considers final pruned stockings of 250, 350 and 450 stems/ha growing on a very high productivity site with non-commercial thinning. Recommended stocking range for sites with very high productivity is 300-400 stems/ha. Table 3 provides an example of the potential impact of stockings that are outside the recommended range. Economic returns are maximised when a balance is achieved between individual tree growth, total stand productivity, tree and wood quality and rotation age.

Table 3 - Indicative impact of final stocking on rotation age, diameter, height, wood quality and log quality for sites of very high productivity.

Final Stockings (stems/ha)	250	350	450
Rotation Age (yrs) [A]	~20	25 - 30	~35
Tree Diameter (dbh) [B]	>65	55 - 60	<50
Tree Height (m) [C]	32	35	38
Wood Quality / Density	Low	Mod to Good	Good
Branch Size / Log Quality	Large / Low	Small / Good	Small / Good

[A]Indicative years required to grow a 55-60 cm diameter tree.
[B] Indicative tree diameter at age 25-30.
[C] Heights are an example only and vary with factors including tree genetics, thinning history and wind exposure.

Rotation Age - Trees will attain a given diameter in a shorter time period at lower stockings.

Tree Diameter - If a 25-year rotation is the objective, then lower stockings will produce trees with greater diameter. Likewise, higher stockings will produce smaller diameter trees, with the potential for insufficient small-end diameter to meet market specifications. With high stockings, longer rotations may be required to produce trees of adequate diameter.

Tree Height - Stocking is one factor that can influence final tree height, with higher stockings resulting in greater height growth.

Wood Quality/Density - For a given tree diameter at harvest, lower stockings reduce the rotation age. However, overall wood quality is often low for trees aged less than 25 years. Sawmillers may refuse to purchase trees as young as 20 years of age[1], due to a relatively low percentage of wood with acceptable wood properties for high quality end uses.

Log Quality/Branch Size - At low stockings, the log quality above the pruned butt log may be compromised, with the potential for poor form and large branches. Large branches may downgrade.

Tree Stocking & Profitability - New Zealand studies have shown that final tree stocking is not a major factor in terms of profitability, provided that the stocking is within a reasonable range[1]. Higher stockings produce more wood per hectare, with less value per tree due to reduced tree size. While the overall value per hectare is usually greater at higher stockings, increased pruning costs per hectare are carried through the rotation and harvesting costs are often higher with decreasing tree size.

CLEARWOOD REGIMES WITH COMMERCIAL THINNING

Medium and Low Productivity Sites

The commercial thinning of unpruned trees from a stand that has been pruned to produce clearwood should be restricted to low to medium productivity sites for the following reasons:

- Markets generally require trees aged >15 years to meet wood quality characteristics. As previously outlined, high to very high productivity sites require early thinning to avoid potential windthrow.
- For high to very high productivity sites, maximum economic returns and maximum value at harvest are enhanced by concentrating on clearwood production with non-commercial thinning.

Non-commercial thinning of all unpruned stems to low stockings of 150-200 pruned trees/ha can be undertaken early in the rotation. This will maximise clearwood production. Low wood quality may not be a significant issue on lower quality sites as growth is slower

and longer rotations are required. Subsequently, the juvenile core is not likely to account for a significant portion of the total log volume.

Excessive branch size above the pruned butt log may develop when all unpruned trees are non-commercially thinned relatively early in the rotation, particularly where long rotations with low final stockings are required to grow clearwood logs of sufficient diameter. Branch size can be reduced in such circumstances by utilising commercial thinning in combination with clearwood production.

Commercial Thinning Options

- Undertake commercial thinning prior to a Mean Dominant Height (MDH) of 20 metres, usually at around age 15-18. Thinned trees of this age may be suitable for pulpwood, preservation material or small diameter sawlogs. Diameter growth of the pruned stems will be restricted by competition from unpruned trees.
- Undertake light non-commercial thinning at or prior to the completion of clearwood pruning. Unpruned trees that are dominant or co-dominant and immediately adjacent to pruned trees are thinned, as are those of poor form. Stocking is reduced to 150-200 pruned trees / ha and 300-450 well-formed unpruned trees/ha. Commercial thinning of the remaining unpruned trees can be undertaken at age 18-22 for pulpwood, preservation material or small to medium diameter sawlogs (MDH may exceed 20m by a few metres as earlier thinning improves wind stability).

Advantages of Commercial Thinning

- Income is generated mid-rotation.
- Branch development above the pruned butt log may be reduced, increasing tree quality.

Disadvantage of Commercial Thinning

- Competition from unpruned trees will reduce diameter growth of the pruned trees and reduce clearwood volume at harvest. This can be overcome by increasing the rotation length (or time until harvest).

NON-COMMERCIAL THINNING & CLEARWOOD REGIMES

Pruning for clearwood usually involves non-commercial thinning or thinning to waste. It may be considered a waste of resource, but is often essential for the following reasons:

- Thinning must be undertaken to concentrate growth on the pruned trees.
- Stands require thinning before a Mean Dominant Height of 20m is reached to avoid the potential for severe windthrow. (MDH is the average height of the 100 largest diameter trees per hectare, measured as height in metres at age 20).
- There may be a shift in dominance following pruning, as pruning can reduce growth rates.
- Commercial thinning may result in unacceptable damage to pruned stems.
- It may not be economic for harvesting contractors and growers to extract low volumes of low value wood from young stands, particularly from smaller stands that may be difficult to harvest such as steep slopes and areas with poor access.

On high to very high quality sites, an MDH of 20m may be obtained as early as age 11-12. On such sites thinning must be undertaken by age 10 at the latest. Thinning too late is expensive and often results in excessive damage to pruned stems and subsequent windthrow. This is a common outcome where growers have delayed thinning with the expectation of a commercial thinning. Commercial thinning is not feasible for the following reasons:

- Pulpwood markets are very limited for young fast growing trees.
- Fast grown trees are not suitable for posts and poles due to a lack of strength.
- Trees are often too small for sawlog markets and consist primarily of juvenile wood.
- On high fertility ex-farm sites, branch development is often too excessive even for very small diameter sawlogs.

TIMING OF NON-COMMERCIAL THINNING

Clearwood regimes on high to very high productivity sites require non-commercial thinning of all unpruned stems relatively early in the rotation. Thinning should be undertaken either immediately after first lift pruning or at the completion of all pruning operations (photo 1).

Non-Commercial Thinning after 1st Lift Pruning

Advantages

- Cheapest and easiest thinning option.
- No damage to pruned stems during thinning, as trees are small.
- Volume of slash from thinned trees is relatively small. Access for further pruning is adequate, because the slash decays relatively quickly.

Disadvantages

- Wind exposure can reduce height growth and result in reduced form and tree quality, particularly within the unpruned stems above the pruned butt log.
- Branch development on fertile sites can be rapid, with little between tree competition, increasing the pruning costs and the DOS. Increased pruning costs are not as expensive as the cost of delayed non-commercial thinning.
- Diameter growth on fertile sites can be rapid unless the trees are 'over-pruned' to reduce growth rates. The size of the juvenile core can be a significant component (1/3 or more) of the tree volume at harvest, reducing overall wood quality.

Non-Commercial Thinning after the Completion of all Pruning Lifts

Advantages

- Competition from adjacent unpruned trees reduces the growth rate of the pruned trees, particularly diameter growth. This is advantageous as the size of the juvenile core can be further restricted.
- Branch development above the pruned height is restricted by competition from adjacent trees. Pruning costs of subsequent lifts are reduced. The size of the defect core can be further restricted by achieving a smaller DOS.
- A greater window of opportunity exists for appropriate timing of subsequent pruning lifts, as diameter growth and branch development is not as rapid as when non-commercial thinning is conducted after the first lift.

- Reduced wind exposure can improve tree form above the pruned height, particularly on exposed sites.

Disadvantages

- Cost of non-commercial thinning is estimated to be twice that of non-commercial thinning after the first lift.
- Some damage to pruned stems may occur. Damage is generally minor bark damage that can heal relatively quickly and be maintained within the defect core.
- The volume of slash from thinned trees can be relatively large, reducing access. As pruning is complete, access is not a significant issue. However, the slash can present an increased fire risk for several years.

Photo 1 - Non-commercial Thinning following final pruning to 6.4 metres. This stand is growing on a very high productivity site in NW Tasmania. Tree form and branch habit above 6.4 metres is excellent. A considerable volume of slash remains (foreground).

Photo 2 - Competition from the surrounding unpruned trees has restricted branch development above the pruned log prior to the completion of pruning and non-commercial thinning.

On high to very high productivity sites, it is recommended that non-commercial thinning be delayed until the completion of all pruning operations. Although more expensive, the size of the juvenile core can be greatly reduced while the timing of pruning lifts to achieve a consistently small DOS is more flexible. The additional cost is partially offset by reduced pruning costs.

Photo 1

Photo 2

CLEARWOOD REGIME (Plan of Operations)

The table on the following page is an example regime for clearwood production with a final stocking of 300 stems/ha, established on a high-quality ex-pasture site with non-commercial thinning and anticipated harvest at age 28. Ages indicated for silvicultural

activities (particularly pruning and thinning) will vary with site productivity and growth rates. Final harvest age will vary with growth rate and landowner intentions.

High quality pruning equipment is recommended including bypass loppers, holster (for carrying loppers when climbing ladder), pruning ladder (lightweight aluminum in 2.4m and 4.2m lengths) and safety harness for use with ladder. Safety must be a priority when working at any height above ground level.

Year	Time	Silvicultural Operation
-1	~12 months prior to establishment	**Obtain planning permission** from local council (if required) **Undertake site planning** (mapping of area, weed species, etc.) **Pre-planting weed control** - Spray difficult to control woody weeds such as blackberry or gorse (if present). **Order seedlings**
	~6 months prior to establishment	**Forest Practices Plan** (if required) Determine method of browsing control and obtain **permits** if required.
0	Summer	Graze the site heavily to reduce pasture species Arrange site inspections and quotes from contractors for establishment. Mark planting lines for initial spraying operations.
	Autumn	**Pre-planting weed control** (pre-cultivation) - Strip spray the planting lines with knockdown herbicides. **Cultivation** - Ripping and mounding prior to the autumn break. **Fencing** to exclude stock/browsing animals. **Browsing control**
	Autumn to Spring	**Pre-planting weed control** - Apply residual herbicides to planting mounds. **Planting** at desired stocking (eg: 1000 stems/ha) **Fertilising** (eg: DAP @ 100g/tree) 6-8 weeks post planting and ensure that weeds are adequately controlled prior to fertilising.
1	Early Summer	**Stocking survey** - Determine seedling numbers if re-planting is required. (determine reason for failures and address the issue if possible)
	Autumn - Spring	**Re-planting** (if required) **Post-planting weed control** - Spot or strip application.
1+	Ongoing	**Monitoring** - Annual inspections for pruning requirements and stand health.
3	Spring	**Form pruning** - Remove double leaders and excessive branches.
4.5	Spring	**First Lift** - Variable Lift Pruning & PSC (~360 stems/ha)
6.0	Spring	**Second Lift** - Variable Lift Pruning & PSC (~33 0 stems/ha)
7.5	Spring	**Third Lift** - Variable Lift Pruning & PSC (~300 stems/ha)
8.5	Spring	**Final lift** - Variable Lift Pruning & PSC. Conducted on those trees not yet pruned to 6.4m during the third lift. **Non-commercial thinning** - Release of pruned stems.
26	Winter	**Inventory** to estimate growth rate and standing volumes, appropriate clearfell age and potential volumes at clearfell harvest.
27	12-24 months pre-clearfell	**Marketing** - Arrange sale contract and harvesting contractor. **Forest Practices Plan** (required for clearfell harvest)
28	Dry conditions	**Final harvest**

FURTHER READING

TAS Land & Forest, (2003). Management Regimes for Low Rainfall Radiata Pine Plantations. Report prepared for Private Forests Tasmania. This report outlines potential regimes, growth rates and markets for Radiata Pine grown on low rainfall sites (<1,100mm annual rainfall) in Tasmania. Copies available from Private Forests Tasmania.

REFERENCE

[1]Maclaren, J.P., (1993). Radiata Pine Growers' Manual, FRI Bulletin No. 184, New Zealand Forest Research Limited. (Copies can be purchased through Private Forests Tasmania)
[2]Todoroki, C.L., Importance of Maintaining Defect Cores, New Zealand Journal of Forestry Science 33(1):25-34

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