COMPARISON OF ALTERNATIVE SILVICULTURAL REGIMES FOR RADIATA PINE

W. R. J. SUTTON
Forest Research Institute, New Zealand Forest Service, Rotorua

ABSTRACT

Unthinned radiata pine plantations on long rotations incur serious risk of insect or disease attack. Economic analysis of a silvicultural regime that incorporated a production thinning revealed that a pulpwood thinning contributed a negligible net return and had the effect of substantially extending the rotation. This led to the development of an alternative regime giving similar volume yields, but economically and silviculturally superior; this regime incorporated wide initial spacing, heavy early thinning (without yield) and severe pruning.

INTRODUCTION

Although New Zealand is not the only country which relies on plantations as the major source of wood, it is probably unique in that most of its wood comes from clearfellings and not thinnings. Since thinning cannot objectively be considered independent of the total management system and since New Zealand is probably nearer to a balanced wood supply from her plantations than any other country her experiences in thinning may be of some relevance to this meeting. This account is essentially similar to an earlier paper (Sutton, 1974).

Historical Background

At the beginning of this century it was recognised that New Zealand's indigenous forests could not provide the country's wood needs beyond the 1960s and large plantations (mainly of radiata pine) were established in the late 1920s and early 1930s. It was always intended that most of these plantations would be thinned, but absence of money, the Second World War and most important, the absence of markets meant that little or no thinning was done. By the late 1940s, stands of radiata pine were approaching 30 m or more in height and 60 m^2/ha or more basal area, and competition within the stands was intense. In the absence of any action by management, nature took the matter into her own hands and, through the agent of the sirex wood wasp (*Sirex noctilio* F), thinned the stands "naturally". The sirex epidemic was certainly not the disaster with which it is generally credited in the world forestry literature. True, the losses do appear dramatic (on a good average site 450 m^3/ha over 35 years — equivalent to an M.A.I. of 13 m^3/ha/yr — the total volume left was 810 m^3/ha, a M.A.I. of 23 m^3/ha/yr) (Spurr, 1962) but losses were usually confined to small lower dominance trees and growth was concentrated on to fewer stems which could be felled and utilised

N.Z. J. For. Sci. 6(2): 350-6 (1976).

earlier than would have been possible without the "thinning". Clearfellings from these sirex-thinned stands now make up more than 90% of radiata wood supplied to New Zealand industry or for export.

The experience of the sirex epidemic demonstrated that stands must be thinned. Early conversion experience also indicated that pruning would be desirable.

The Need for Pruning

Radiata pine's intrinsic wood properties make it a potentially useful species for a wide range of end uses; peeling, sawn timber (both finishing and strength grades) and chipping (mechanical and chemical pulps, chipboard, etc.). These properties, particularly density, are not greatly affected by treatment, especially those, such as thinning, which affect the rate of growth (*see* Sutton and Harris, 1974). By far the most important degrading factor is the branches or, more correctly, the size, condition and distribution of the resultant knots.

Attempts to control branch size and condition by silvicultural means have largely proved unsuccessful or impracticable:

a—Attempts to restrict branch size by close initial spacing and holding stands until the non-response of the branches within the bottom 1½ to 2 log length can be assured has meant that first thinning must be delayed until stands are 20 m or more high. Such treatments suffer wind damage and require long rotations. The potential for restricting branch size by genetic selection appears limited (Shelbourne, 1970).

b—Attempts to control branch condition by maintaining deep live crowns to ensure that resultant knots would remain intergrown have also proved unsuccessful because the knots are large and because radiata pine almost always produces whorls of branches within the green crown which die after only one season's growth.

c—Branch distribution is not influenced by silvicultural treatment.

Sawn knotty radiata pine, no matter how it is grown, is not of a high grade. Rarely would it be better than Scandinavian fifths or the lower common's grades. Yet free of knots its grade (ignoring the restriction on ring width) could be Scandinavian firsts or "B" Select.

The only way to grow quality radiata pine for peeling, finishing and strength uses is to grow it free of knots. This means pruning. (There is one other alternative — viz. grow uninodal trees from which the long clear internodes can be cut and used as such or finger-jointed — but specially selected seed is needed first.)

The First Tending Schedules

Recognising the need for thinning and pruning, and influenced by classical thinning teaching, Ure (1949) developed a schedule which incorporated pruning, early thinnings to waste and two later thinnings with yield. This was later modified to include only one thinning with yield (Penistan, 1960). Virtually the same schedule is in operation today in some forests of New Zealand. Details are given in Table 1.

In 1959-60 the first stands treated on this regime were thinned and the extracted material was sent to a sawmill. After the initial intake the sawmill refused to continue sawing because it claimed the grades were poor, conversion low and the cost of sawing

TABLE 1—Tending Schedule — 'Yield Thinning Regime'

Mean height crop trees m	Operation
—	Plant 2240 stems/ha (spacing approx. 2.4 × 1.8 m)
6.0	Prune 500 stems/ha 0-2.4 m
9.1	Prune 320 stems/ha 2.4-4.3 m
12.2	Prune 320 stems/ha 4.3-6.1 m
12.2	Thin to 500 stems/ha (no yield)
27.0	Thin to 198 stems/ha (with yield)
41-46	Clearfell

high. The cost of extracting the thinnings proved high and the whole operation made a loss. The subject of thinning for yield has been controversial ever since.

Research on Tending and the Development of an Alternative Regime

Initial research took the form of investigations into the quality of thinnings as sawlogs, the effect of thinning on the residual stand, and the economics of the operation. When these investigations confirmed that thinning for yield may not increase overall yields, produce intermediate returns or allow greater selection of the final crop, the research effort was intensified on the development of tending regimes which did not include thinning yields.

The research approach was to study the total system, in particular; the interaction between initial spacing, pruning, thinning and the final crop; the importance of the timing and intensity of silvicultural operations; and the quality of and price differentials for the extracted end products. The work indicated that pruning could greatly enhance the quality and value of the final crop but only if the pruning was severe and associated with thinning. The quality and economics of a regime are determined primarily by the timing and intensity of the silvicultural operations.

The first proposals for an alternative regime were those for a "Short Rotation Sawlog Regime" (Fenton and Sutton, 1968) and further refinements were presented in the "Direct Regime" (Fenton *et al.,* 1972). Details of the regime are given in Table 2.

The object of this regime is to maintain maximum diameter growth on the crop trees; quality being achieved by selective frequent early pruning to restrict the defect core to a minimum. Unselected trees are eliminated as early as possible because their

TABLE 2—Tending Schedule — "Direct Regime"

Mean height crop trees m	Operation
—	Plant 1500 stems/ha (spacing approx. 3.7 × 1.8 m)
4.9	Prune the best 740-620 stems/ha 0-2.4 m Thin all others (no yield)
7.9	Prune the best 370-320 stems/ha 2.4-4.3 m (If incorporating grazing, thin all others)
10.7	Prune the best 198 stems/ha 4.3-6.1 m Thin all others (no yield)
13.7	Prune 198 stems/ha (multinodals) 6.1-8.5 m
16.8	Prune 198 stems/ha (multinodals) 8.5-11.0 m

retention is now known to restrict the growth of the pruned trees (Sutton and Crowe, 1972) and because the earlier their removal the lower the cost.

With genetically superior stock even wider initial spacings are possible; 7.3 × 1.8 m is under investigation.

Comparison of the Two Regimes

The two regimes have been very fully investigated and most of the research is already published (Fenton and Sutton, 1968; Fenton *et al., 1972).* The major findings are summarised below. Comparisons are for the same site (good average North Island forest site).

(a) Growth and Stability

Compared in Table 3 are the expected growth rates of the two regimes and, in Table 4, the expected extracted volumes. The rotation for the regime with a "Yield Thinning" is 36 years (with the thinning at 19 years); the rotation for the "Direct" Regime is 26 years. Also in Table 4 are M.A.I. for the two regimes.

TABLE 3—Comparison of predicted growth rates

		Yield Thinning Regime			Direct Regime		
Height (m)		Stems/ha	Basal Area (m^2/ha)	Mean d.b.h.o.b. (cm)	Stems/ha	Basal Area (m^2/ha)	Mean d.b.h.o.b. (cm)
10.7					198	4.66	17.3
12.2		494	9.18	15.5			
13.7					198	8.56	23.4
15.2		494	17.08	21.1	198	12.23	28.2
18.3		494	24.94	25.4	198	19.70	35.6
21.3		489	32.71	29.2	198	27.13	41.9
24.4	Before	484	40.36	32.5	198	34.55	47.2
27.4	Thinning	474	47.59	35.8			
27.4	Thinning	277	22.36	32.0			
27.4	Main Crop	198	25.23	40.4	198	41.99	52.1
30.5		198	31.45	45.0	198	49.40	56.4
33.5		198	37.70	49.3	198	56.84	60.5
36.6		195	43.55	51.1	195	63.73	64.5
39.6		193	49.33	57.2			
42.7		191	55.05	60.1			

TABLE 4—Extracted volumes (m^3/ha; net of logging waste) at completion of rotation

	Yield Thinning Regime		Direct Regime	
	Volume	Mean d.b.h.o.b. (cm)	Volume	Mean d.b.h.o.b. (cm)
Thinning	147	32.0	—	—
Clearfelling	660	60.0	577	61.7
Total	807		577	
Mean Annual Increment	22.4 m^3/ha/annum		22.2 m^3/ha/annum	

In terms of total volume yield there is a negligible difference between the two regimes, but in terms of wood quality the direct regime is far superior. (See Table 5).

Under New Zealand conditions yield thinning does not increase total volume yields but it does result in poorer quality wood than is possible if the thinning (without yield) is done earlier, so that growth can be concentrated on the final crop trees only.

Stability is difficult to quantify but under New Zealand conditions trees become increasingly susceptible to windthrow after height 15-20 m, particularly if exposure is then increased by thinning. Yield thinning at height 27-m incurs this risk and many stands have suffered serious wind losses. On the other hand, ". . . since stand stability is undoubtedly increased by heavy early thinning . . .", (Chandler, 1970) the direct regime is less likely to suffer loss.

TABLE 5—M.A.I. (m^3/ha/year) by end use categories

	Yield Thinning Regime	Direct Regime
A. Sawn Timber		
Clears and superior grades	2.6	6.1
Other grades	4.5	4.1
Total sawn timber	7.1	10.2
B. Pulpwood		
From sawmill slabs	3.0	4.3
From logs	9.3*	3.2
Total pulpwood	12.3	7.5
C. Losses in sawmilling process	3.0	4.5
Total	22.4	22.2

* Includes all logs extracted in the thinning; these are not suitable for sawlogs.

(b) Damage to Soil and Trees

Removal of thinnings involves considerable soil disturbance and this must involve some root damage to residual trees, especially those along extraction tracks and near loading areas. As yet the effect of this damage has not been properly assessed. Root infection is not usually a problem in New Zealand.

Damage to trees in extraction thinning has been assessed — butt damage (the loss of some bark from the lower portion of the trees) has been observed in every thinned stand — up to 25% of the remaining trees can be damaged in this way (Fenton *et al.*, 1965; Park, 1972).

Another source of loss is the removal of potential final crop trees from major extraction roads and the loading areas. Examination of aerial photographs of thinned stands reveal area losses of 7%. These areas remain non-productive for the remainder of the rotation.

(c) Costs and Revenue

The economics of the two regimes (and many others) have been intensively researched (Fenton, 1972a; 1972b) and summarised (Fenton, 1972c). The relative profitability and break-even growing costs for the two regimes are given in Table 6.

TABLE 6—Relative profitability (including social costs)

Criterion	Thinning Regime	Direct Regime
Land expectation value/ha ($NZ)*		
at 7% compound interest	— 14	+ 240
at 10% compound interest	— 65	+ 14
Internal Rate of Return	6.66	10.5
Break-even growing cost ($/m^3)		
7%	7.33	3.92
10%	19.08	7.55

* Excludes the price of land.

In the calculations the thinnings are assumed to have made a net profit of $1/m^3 — in practice the operation would probably have made a loss.

The direct regime is far more profitable than the yield thinning regime. The real cost of yield thinning is the delay in the growth of the final crop trees.

DISCUSSION

In discussing the results of his economic comparisons, Fenton (1972c) concluded that the regime with a thinning yield was ". . . inferior in every respect to the direct regime; it costs more than twice as much per m^3, produced lower grades, needs as much labour, has great managerial, physical, fire and marketing risks. . . . Results are so different that no such production thinning should be prescribed; it has no advantage to compensate for its disadvantages."

The new direct regime has one additional major attraction. Soon after it was first proposed it became obvious that the very open stand conditions created by the heavy early thinning and pruning favoured the development of understory weeds, grass, etc. It was logical that this growth could be used for grazing (Knowles *et al.,* 1973) and research on this is now well beyond the experimental stage.

The concept of combined forestry and farming is being widely tested in New Zealand. When implemented it eliminates the one objection most theoreticians have to the direct regime; viz, that we are not fully utilising the site. It enables the direct regime to utilise the growth potential of the site and produce intermediate yields of high quality, viz, animal products, which can be walked off the forest. This is in contrast to a thinning yield of poor quality wood that can only be removed at considerable expense and with at least some damage to the remaining stand, and can only be grown on regimes which are economically inferior.

REFERENCES

CHANDLER, K. C. 1970: Site limitations on pruning and thinning. **N.Z. For. Serv., For. Res. Inst., Symposium 12(2):** 85-8.

FENTON, R. T. 1972a: Economics of radiata pine for sawlog production. **N.Z. J. For. Sci. 2(3):** 313-47.

——— 1972b: Economics of sawlog silviculture which includes production thinning. **N.Z. J. For. Sci. 2(3):** 348-68.

——— 1972c: Implications of radiata pine afforestation studies. **N.Z. J. For. Sci. 2(3):** 378-88.

FENTON, R. T., JAMES, R. N., KNOWLES, R. L. and SUTTON, W. R. J. 1972: Growth silviculture and the implications of two tending regimes for radiata pine. Proceedings Seventh Geography Conference, New Zealand. **N.Z. J. For. Serv., Reprint 635.**

FENTON, R. T., MACKINTOSH, J. D. and HOSKING, M. R. 1965: Assessment results from production thinnings of young stands of radiata pine and Douglas fir. **N.Z. For. Serv., For. Res. Inst., Silviculture Report 40** (unpubl.).

FENTON, R. T. and SUTTON, W. R. J. 1968: Silvicultural proposals for radiata pine on high quality sites. **N.Z. J. For. 13(2):** 220-8.

KNOWLES, R. L., KLOMP, B. K. and GILLINGHAM, A. 1973: Trees and grass — an opportunity for the hill country farmer. **Proceedings of the Ruakura Farmers' Conference 1973,** 110-21.

PARK, J. C. 1972: Assessments of production thinned stands — **Pinus radiata. N.Z. For. Serv., For. Res. Inst., Economics of Silviculture Report 52** (unpubl.).

PENISTAN, M. J. 1960: Thinning practice. **Forestry 33(2):** 149-73.

SHELBOURNE, C. J. A. 1970: Genetic improvement in different tree characters of radiata pine and consequences for Silviculture and Utilisation. **N.Z. For. Serv., For. Res. Inst., Symposium 12(2):** 44-58.

SPURR, S. H. 1962: Growth and Mortality of a 1925 Planting of **Pinus radiata** on Pumice. **N.Z. J. For. 8(4):** 560-9.

SUTTON, W. R. J. 1974: New Zealand experience with radiata pine. **Forestry Commission, Great Britain, Bull. 55, Paper 5.**

SUTTON, W. R. J. and CROWE, J. B. 1972: Pruning of radiata pine dominants. Part 4. Effect of pruning on dominance, growth and stem characteristics. **N.Z. For. Serv., For. Res. Inst., Economics of Silviculture Report 53** (unpubl.).

SUTTON, W. R. J. and HARRIS J. MADDERN. 1974: Effect of heavy thinning on wood density in radiata pine. **N.Z. J. For. Sci. 4(1):** 112-5.

URE, J. 1949: The natural regeneration of **Pinus radiata** on Kaingaroa Forest. **N.Z. J. For. 6(1):** 30-8.