SAWING METHODS FOR PINUS RADIATA PRUNED LOGS – AN INDICATIVE STUDY

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ABSTRACT

Three hundred pruned logs from two compartments in Kaingaroa Forest in the central North Island were sawn in Rotorua in a preliminary study to examine the effects of different sawing strategies on conversion and grade recovery in an actual sawmill trial. The results showed that grade sawing has the potential to substantially increase the proportion of high-value timber grades over fixed-sawpattern breakdown methods. Log positioning (no taper, split taper, and full taper) had little influence on grade recovery but split taper showed a clear advantage in conversion.

Keywords: pruned logs; sawing methods; timber grade recovery; defect core; **Pinus radiata.**

INTRODUCTION

The evolution of silvicultural practices in New Zealand has been towards increasingly intensive management. Most plantations established from the 1960s onwards have received some degree of thinning and pruning, with the result that such stands will be harvested at an earlier age and will generally contain a pruned log component. The main features of the pruned logs are a tendency to more taper than upper logs because of butt flare and the presence of a clearwood zone surrounding the central knotty core. The average sizes of both the defect core and the clearwood zone are dependent on stand treatment, in particular the timing of pruning and the rotation age.

High-grade hardwoods and softwoods (e.g., North American oaks, *Pinus strobus* L. (white pine), and *P. ponderosa* P. et C. Lawson) are normally processed in specialist mills according to traditional procedures, e.g., live sawing or grade sawing with or without full taper set to recover long-length, wide, high-value clear timber from the outside of the log. Taper sawing requires the use of taper knees on a carriage in order to saw one or two pairs of opposite faces parallel to their bark surfaces. True grade sawing (also called around-and-around sawing) gives most flexibility at the headrig, but is more time-consuming (Bousquet & Flann 1975; Cassens & Maeglin 1987). Live sawing (through and through) is more efficient of headrig time as log turning is minimised, but places heavy emphasis on good resawing practices for grade recovery (Flann 1978). Cant sawing is a common breakdown method in high-production mills with good resawing facilities (Williston 1976) and, although best suited to producing "dimension" items such as framing, it is nevertheless an option for pruned logs, with the defect core making up the bulk of the cant.

The sawing of pruned logs in New Zealand is still in its infancy, and only a handful of mills specialise in recovery of clears. The breakdown methods used are often more a function of the existing mill design than a conscious decision of optimum processing, and range from cant sawing to maintain mill production to taper sawing for grade.

Many aspects of the sawing of *P. radiata* D. Don pruned logs can be addressed using computer models such as SEESAW (Park 1987) or SAWMOD (Whiteside & McGregor 1987) but to date there is no simulation procedure to cater for the full taper sawing option.

The study reported here was undertaken as a joint research/industry project with the objective of comparing a range of possible breakdown methods using a specified cutting list. Two different sources of pruned logs were used to give some insight into the variability of the current resource.

LOG SUPPLY

One hundred and seventy-five logs were obtained from Cpt 1068 in Kaingaroa Forest for the main part of the study. In addition, 100 logs were made available from another area of the same forest (Cpt 1205). The two stands had different silvicultural histories (Table 1) and were harvested at different rotation ages.

Neither of these stands can be regarded as typical of future crops in respect to silviculture. Compartment 1068 received a single pruning to 6 m at age 10 years, combined with a waste thinning operation. A second waste thinning to 320 stems/ha was performed at 19 years and the stand then left until harvest at 40 years. Compartment 1205, on the other hand, was planted in 1959 and waste thinned in 1972, at which time the remaining stems were pruned to 4 m. Two years later, at age 15, the stand

TABLE 1–Crop histories

Cpt	Age (yr)	No. of logs	Treatment	
			Date	Operation
1068	40	175	1947	Planted
			1957	Pruned 0–6.0 m
			1957	Waste thinned to 646 stems/ha
			1966	Waste thinned to 321 stems/ha
			1987	Study logs felled
1205	28	100	1959	Planted
			1972	Pruned 0–4.0 m
			1972	Waste thinned to 500 stems/ha
			1974	Pruned 4.0–5.8 m
			1987	Study logs felled

was pruned to 5.8 m. Both stands may be described as "transition crop" in that they were established between 1940 and 1960 and received some silvicultural treatment, although not to the degree generally prescribed for stands planted in the 1960s.

METHOD

The Timber Industry Training Centre at Rotorua was selected for the trial because of the facility for independent knee positioning on the headrig carriage. Without this ability, full taper sawing is not possible. Batch sawing was selected as the method of generating results as the objective was to compare the outturn from different sawing methods. Individual log sawing (Park & Leman 1983; Cown *et al.* 1987), while yielding detailed information on the relationships between log characteristics and sawn timber grades, is much more time-consuming both at the mill and in the office and becomes impractical with large numbers of logs such as in this study.

One disadvantage of batch sawing compared to individual log sawing is that no estimate of accuracy is obtained. However, from extensive individual log studies carried out previously (Cown *et al.* 1987) estimates of accuracy can be derived. These show that for batch sizes of 25 logs, the 95% Least Significant Difference (LSD) is around 3.5% for timber conversion and 9% for percentage of clear grades. The LSD is the minimum difference between two batch averages which is statistically significant.

All study logs were delivered to the sawmill where they were debarked and then measured for small-end diameter (s.e.d.), taper (based on s.e.d. and diameter at 1.3 m from the butt – Park & Lemon 1983), and sweep (calculated from the maximum deviation from the central axis in the plane of worst sweep). A sample of 10 logs was selected randomly across the diameter range from each compartment. These were individually sawn, reconstructed, and measured according to the method of Park & Leman (1983) to yield detailed information on the internal log characteristics.

The main study was performed on 175 logs from Cpt 1068. In order to compare sawing strategies, three breakdown methods (cant, live, and grade sawing) and three log positioning options (no taper set, split taper, and full taper on opposite sides of logs and cants) were considered (Fig. 1). Final selection of methods for the study was limited to those considered by sawmill staff to be most applicable to current and future sawmill designs (Table 2). Other combinations are possible, e.g., no taper for the log and split taper for the cant.

Fixed Cant/No Taper (CNT): This is a common method of sawing in many mills where the objective is to produce a high proportion of flat-sawn material in specified sizes. The headrig carriage knees are kept aligned with the saw blade during sawing and the cant is sawn with the aid of a fence. The cant size is selected on the basis of log size and final dimensions required. Emphasis is on production rather than grade recovery. When used on pruned logs, the clearwood will be flat sawn. Cant size in this study was 105 mm or 210 mm, depending on log size, and decided before the opening cut was made.

Fixed Cant/Split Taper (CST): This method is most commonly used in multiple-saw headrigs such as chipper canters and reducer twin or quad bandsaws. The log centre is aligned with the saws, allowing the taper to be apportioned to each side of the log

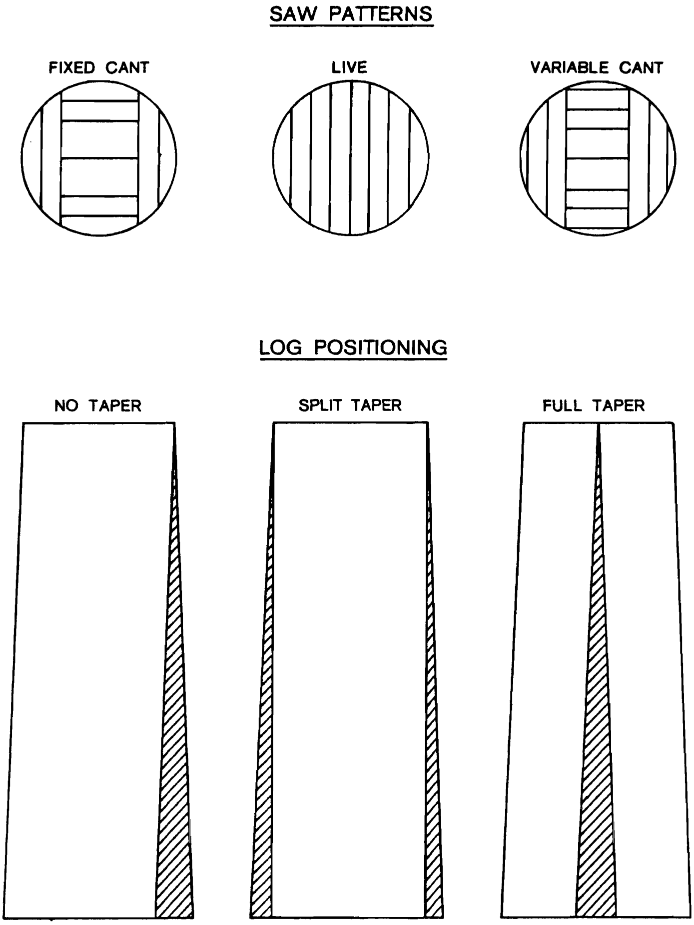

FIG. 1—Sawing procedures.

TABLE 2–Sawing strategies and sample numbers

Log position	Sawing method			Totals
	Cant (C) (fixed cant)	Live (L)	Grade (G) (variable cant)	
No taper (NT)	25	25	25	75
Split taper (ST)	25	25	25	75
Full taper (FT)			25	25
Totals	50	50	75	175

and cant. Most modern sawmill designs would probably use this approach for unpruned logs, although some chipping headrigs sawing small logs use a fence and the CNT method above (Anderson & Ailport 1973).

Live Sawn/No Taper (LNT): The "through and through" method breaks the log down into wide flitches at the headrig and relies on good edging for grade recovery. When used for high-grade hardwoods in Europe or with the "Saw-Dry-Rip" procedure in the United States (Harpole 1983), edging is left until after drying. Clearwood is a mixture of flat-sawn and quarter-sawn boards.

Live Sawn/Split Taper (LST): As above, but with the taper equally distributed on either side of the log and cant. This is a common pattern for framesaws.

Grade Sawn/No Taper (GNT): True grade sawing (around and around) is reputed to give the maximum value recovery, but can be justified only with very high-value material because of the extra log handling required at the headrig (Bousquet & Flann 1975). In this study, grade sawing was restricted to variable cant sawing because of commercial requirements to recover specified sizes from the defect core. Clearwood boards (27 mm) were cut until the defect core was exposed for about 50% of the length of the log, at which time a decision was made on the cant size and the number of 41-mm boards needed to achieve it. Cants of 105, 160, and 210 mm were permitted. Two-sided cants from the headrig were further grade sawn either at the headrig or at the vertical band resaw.

Grade Sawn/Split Taper (GST): A variation of GNT above in which both the log and cant axes were aligned with the saw blade prior to breakdown.

Grade Sawn/Full Taper (GFT): Each side of the log and cant is aligned with the saw blade and treated on its merits. This produces a tapered cant which has to be squared before it can be broken down.

The 25 logs were allocated to each batch on the basis of their external dimensions in an effort to make the samples as uniform as possible. It is particularly important that log size and sweep are equally apportioned as both these parameters have a significant influence on conversion and grade recovery (Cown *et al.* 1984).

The logs from Cpt 1205 were fewer in number than those from Cpt 1068 and were used mainly to give more information on full taper grade sawing and provide a comparison of grade recovery from a stand with different silvicultural history. From the 100 logs, two matched batches of 45 were prepared for sawing according to the Fixed Cant/No Taper (the common bandsaw/carriage method) and Grade Sawn/Full Taper methods, and 10 were sawn separately to provide defect core data for the compartment. The latter were chosen randomly across the diameter range before the matched batches were made up.

Sawing was carried out to an "order book" of sizes to simulate commercial reality by avoiding production of unwanted items. Grading priorities are listed in Table 3.

TABLE 3–Grade priorities

Clearwood	Defect priority	Intermediate zone (Cuttings grades)
210 × 27 mm	105 × 105 mm	210 × 41 mm
155 × 27 mm		155 × 41 mm
105 × 27 mm		105 × 41 mm
80 × 27 mm		80 × 41 mm

All timber was graded on the green table by professional graders according to the New Zealand Standard (NZS 3631, 1978), except for No. 1 and No. 2 Clears which were defined as follows:

No. 1 Clears – perfectly clear on all four sides

No. 2 Clears – minimum clear length of 1.8 m.

The timber from each batch was tallied by grade and piece (length measured down to the nearest 0.3-m increment) and the total volume calculated on the nominal sizes.

RESULTS

Log External Characteristics

Distributions of s.e.d., sweep, and taper for the sample logs from the two stands are shown in Fig. 2 and 3. The 40-year-old logs from Cpt 1068 were significantly larger than the 28-year-old material (s.e.d. 462 mm *v.* 400 mm) and had slightly higher taper and sweep averages. The batch data are given in Table 4.

Main Study (Cpt 1068)

Conversion

Conversions for the individual batches are given in Table 5 and for the sawing methods in Table 6. In previous studies it was found that batches of 25 logs yield 95% confidence limits of about 2%. The overall conversions 60.5% and 56.8% respectively for the two sources of logs are in line with previous studies (Park & Parker 1983; Cown *et al.* 1987), and reflect the relatively large average log size. Similar conversions have been documented in commercial trials of pruned logs (Cown 1985).

Batch averages for the larger study ranged from 52.5% to 65.7% – highly significant differences – but the general patterns are more clearly distinguished when batches are combined as in Table 6. Although the sample numbers are not always equally balanced, it can be concluded that:

(1) Log positioning has affected conversion. The best results over-all were obtained from split taper positioning (about 3% better than the conventional no-taper method). The poorest results were from full taper positioning.

(2) Grade sawing gave significantly lower conversions than both cant sawing and live sawing, by an average of about 5%.

Grade recovery

Grade recovery by batches and sawing methods are given in Tables 7 and 8. The Least Significant Differences (LSD) for the tables are approximately 9% and 6% respectively (M.O. Kimberley pers. comm.). As with conversion, the batch data were variable and the trends are best determined from the combined results in Table 8. Here the patterns were:

(1) Log positioning did not have a significant influence on the recovery of Clears grades.

(2) Grade sawing produced significantly more Clears grades than cant sawing – live sawing was intermediate.

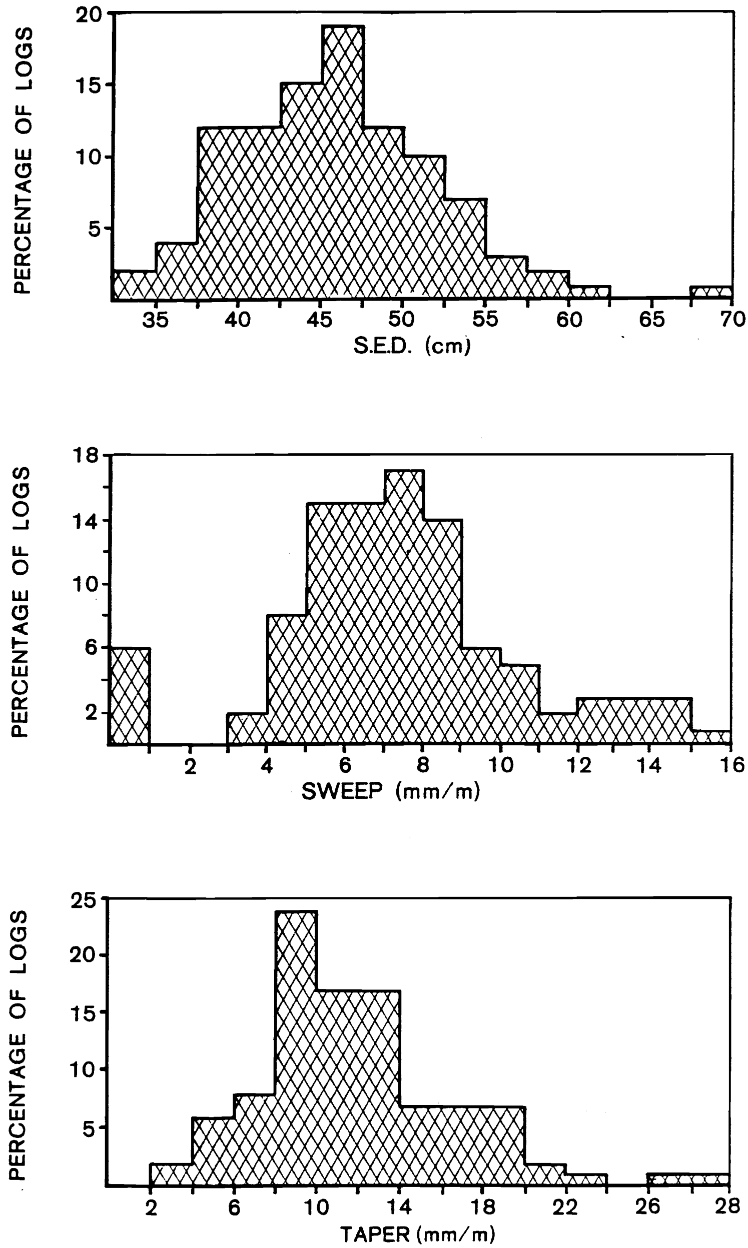

FIG. 2—Distribution of log characteristics, Cpt 1068.

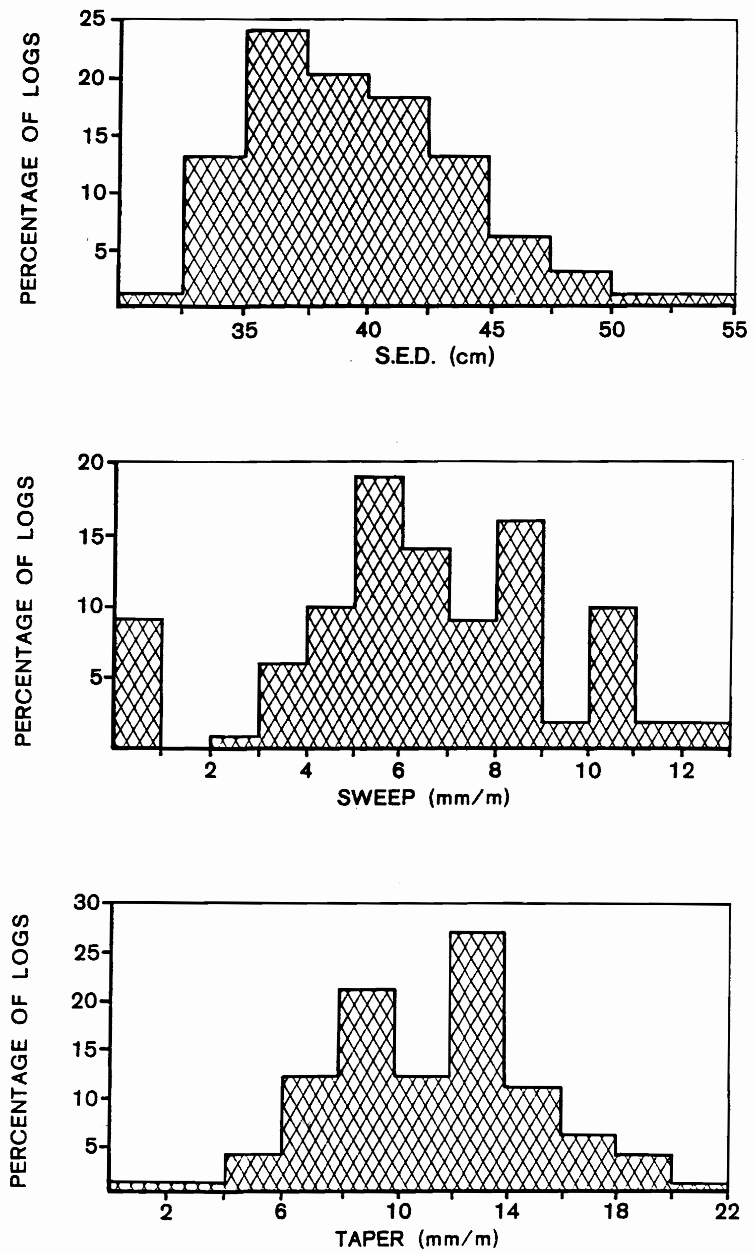

FIG. 3—Distribution of log characteristics, Cpt 1205.

TABLE 4–Log characteristics

Code*	No. of logs	dbh (mm)	s.e.d (mm)	Length (m)	Taper (mm/m)	Sweep (mm/m)	Log volume (m^3)	Total volume (m^3)
Compartment 1068								
CNT	25	500	456	4.94	12.0	6.8	0.929	23.22
CST	25	493	452	4.98	11.4	6.8	0.911	22.77
LNT	25	506	464	4.92	11.5	6.9	0.966	24.15
LST	25	503	460	4.94	11.7	7.0	0.946	23.65
GNT	25	514	469	4.94	12.6	7.1	0.982	24.55
GST	25	507	458	4.95	13.6	8.0	0.951	23.78
GFT	25	514	472	4.96	11.5	7.2	0.998	24.95
Overall	175	505	462	4.95	12.0	7.1	0.954	167.07
Compartment 1205								
CNT	45	442	402	4.91	11.1	6.1	0.727	32.74
GFT	45	438	397	4.90	11.7	6.3	0.716	32.24
Overall	90	440	400	4.90	11.4	6.2	0.722	64.98

* C Fixed cant
L Live sawn
G Grade sawn
NT No taper
ST Split taper
FT Full taper

TABLE 5–Batch conversions

Batch*	No. of logs	Log volume (m^3)	Timber volume (m^3)	Conversion (%)
Compartment 1068†				
CNT	25	23.22	14.53	62.6
CST	25	22.77	14.95	65.7
LNT	25	24.15	15.47	64.1
LST	25	23.65	14.82	62.7
GNT	25	24.55	13.52	55.1
GST	25	23.78	14.77	62.1
GFT	25	24.95	13.11	52.5
Over-all	175	167.07	101.17	60.5
Compartment 1205†				
CNT	45	32.74	18.90	57.7
GFT	45	32.24	18.04	55.9
Over-all	90	69.48	36.94	56.8

* C Fixed cant
L Live sawn
G Grade sawn
NT No taper
ST Split taper
FT Full taper

† Cpt 1068 estimated 95% LSD = 3.6%, based on previous studies.
Cpt 1205 estimated 95% LSD = 2.6%

TABLE 6–Sawing method conversions, Compartment 1068

Method	No. of logs	Log volume (m^3)	Timber volume (m^3)	Conversion (%)
No taper	75	71.92	43.52	60.5
Split taper	75	70.20	44.53	63.4
Full taper	25	24.95	13.11	52.5
Fixed cant	50	45.99	29.48	64.1
Live sawn	50	47.80	30.29	63.4
Grade sawn	50	48.33	28.29	58.5*
Grade sawn	75	73.28	41.40	56.5†

Estimated 95% LSD = 2.5%
* Excluding full taper
† Including full taper

Compartment 1205

The smaller logs from the 28-year-old stand gave a lower average conversion (Table 5), as would be expected (Cown *et al.* 1987) and the difference between the two sawing methods was less pronounced (not statistically significant). In terms of grade recovery, the younger, smaller logs gave a significantly higher yield of No. 1 Clears (Table 7).

TABLE 7–Batch grade recovery

Batch*	No. logs	Timber grade (%)						
		Clears No. 1	Clears No. 2	Fact.	Dress.	Merch.	Box.	Ungraded (100 × 100 mm)
Compartment 1068†								
CNT	25	42	6	2	7	9	0	34
CST	25	40	12	1	7	7	1	32
LNT	25	42	9	4	9	16	0	20
LST	25	52	6	10	8	6	0	18
GNT	25	62	3	8	2	4	0	21
GST	25	45	7	18	11	2	0	17
GFT	25	47	8	12	7	10	0	16
	175	47	7	8	7	8	0	23
Compartment 1205†								
CNT	45	53	4	4	8	5	0	26
GFT	45	64	7	4	10	4	1	10
	90	58	5	4	9	5	1	18

* C Fixed cant
  L Live sawn
  G Grade sawn
  NT No taper
  ST Split taper
  FT Full taper

† Cpt 1068 estimated 95% LSD = 8.8%.
  Cpt 1205 estimated 95% LSD = 6.5%.

TABLE 8–Sawing method grade recovery, Compartment 1068

Batch*	No. logs	Timber grade (%)						
		Clears		Fact.	Dress.	Merch.	Box.	Ungraded
		No. 1	No. 2					(100 × 100 mm)
NT	75	49	6	4	6	10	0	25
ST	75	46	8	10	9	5	0	22
FT	25	47	8	12	7	10	0	16
C	50	41	9	2	7	8	0	33
L	50	47	8	7	8	11	0	19
G	75	51	6	13	7	5	0	18

Estimated 95% LSD = 6.2%

* NT No taper
ST Split taper
FT Full taper
C Fixed cant
L Live sawn
G Grade sawn

Log Internal Characteristics

The 10 logs from each compartment selected for defect core measurements yielded the data in Table 9.

The silvicultural histories suggested that Cpt 1068 with the early one-lift pruning and two thinnings to waste should, all things being equal, have yielded large logs with small defect cores and hence good grade recoveries. The sawing study data showed clearly that the smaller logs from Cpt 1205 gave more Clears grades, and the reason is apparent from Table 9. Despite the earlier pruning, the defect cores in the Cpt 1068 logs were both larger and more variable (average 317 mm, s.d. 27 mm, compared to 229 mm and s.d. 21 mm respectively). The defect core standard deviations are significantly lower than the average for other pruned log samples sawn in the past (Cown *et al.* 1987).

The large difference in timber grade recoveries from the two log supply areas is due primarily to the effect of stand treatments on the average defect core : s.e.d. ratios. The larger the ratio, the lower the recovery of Clears grades (Cown *et al.* 1987), and here the averages were 0.64 for Cpt 1068 and 0.54 for Cpt 1205. The lower ratio for the younger stand more than compensated for the smaller logs.

It was concluded that either the records for Cpt 1068 are wrong, or the pruning was done to such a low standard that many years were required for complete occlusion.

DISCUSSION AND CONCLUSIONS

The study set out to give a preliminary indication of the extent to which value recovery from pruned logs can be affected by the sawing procedure. A batch sawing approach was adopted because of the sawmill company's interest in local stands and their preference for physical evidence rather than results from computer simulations.

The results dramatically confirmed that external log characteristics and even silvicultural records can be a poor guide to pruned log quality. The older, larger logs from

TABLE 9–Log characteristics (defect core logs)

Log No.	dbh (mm)	s.e.d. (mm)	Length (m)	Taper (mm/m)	Sweep (mm/m)	Volume (m^3)	Max branch (cm)	Sum of internode >0.6 m (m)	Defect core (mm)			
									Max.	Mean	Lift 1	Lift 2
Compartment 1068												
141	420	390	4.987	8.3	10.2	0.648	4.5	2.6	290	290	290	–
149	450	405	4.95	12.5	6.1	0.745	6.5	2.7	366	366	366	–
158	420	380	4.91	11.1	6.1	0.643	5.0	2.1	300	300	300	–
170	500	450	4.97	13.9	9.2	0.917	6.0	1.5	326	326	326	–
179	630	580	4.96	13.9	8.2	1.476	5.5	2.1	281	281	281	–
185	480	455	4.96	6.9	10.2	0.863	8.0	2.9	351	351	351	–
190	505	460	4.95	12.5	8.2	0.948	5.0	2.9	343	343	343	–
193	625	580	4.93	12.5	5.1	1.435	5.0	2.9	302	302	302	–
198	570	520	5.18	13.2	9.0	1.230	7.0	2.5	317	317	317	–
203	500	440	5.21	15.4	8.6	0.945	5.5	2.3	296	296	296	–
Means	510	466	5.00	12.0	8.1	0.985	5.8	2.4	317	317	317	–
Compartment 1205												
303	525	440	4.88	24.3	6.3	0.972	4.5	3.5	215	205	215	178
312	470	440	4.93	8.3	7.1	0.841	6.0	2.1	220	216	220	185
351	485	440	4.86	12.9	3.1	0.848	3.5	2.2	204	202	204	182
355	470	415	4.89	15.7	11.9	0.781	4.5	1.9	231	228	231	196
373	470	435	4.90	9.7	4.1	0.827	5.0	3.0	215	214	215	170
376	435	395	4.94	11.1	7.1	0.701	3.5	1.9	227	218	227	190
381	415	365	4.98	13.9	12.2	0.630	3.0	2.4	227	227	227	–
384	500	470	4.92	8.3	12.9	0.963	3.5	2.3	222	216	222	175
386	460	410	4.91	13.9	9.2	0.768	6.5	0.9	244	241	244	212
388	445	405	4.90	11.1	7.1	0.751	5.0	2.4	283	283	283	–
Means	468	422	4.91	12.9	8.1	0.808	4.5	2.3	229	225	229	186

a compartment reputedly pruned to 6 m in one lift at age 10 years proved to yield significantly less Clears grade timber than a stand 12 years younger and pruned later. This emphasises the danger of relying on silvicultural records and the need for some form of quality assessment prior to log sales as a basis for price negotiation.

Logs were separated into batches on the basis of their external features only, and so it is likely that variations in defect core sizes may have contributed to the individual batch results. However, despite limitations in the design of the trials (an unbalanced factorial) the over-all trends were clear:

- High conversions can be achieved with pruned logs when sawing to commercial sizes. (There has in the past been some criticism of conversions publicised by FRI on the basis that cutting is unrestrained by market requirements.)
- Log positioning (no taper, split taper, and full taper, had little effect on grade recovery but appeared to influence conversion slightly. The highest volumes of timber over-all were obtained from split taper sawing (3% more than conventional no taper) whereas full taper tended to give the poorest results.
- Sawing methods have a strong effect on grade recovery. The highest value products were obtained from grade sawing (up to 10% more No. 1 Clears), closely followed by live sawing. The fixed cant procedure achieves its objective in maximising dimensioned timber from the core but allows little flexibility to break down the log to best advantage.

There is no one ideal method for sawing pruned logs – the procedure adopted will depend on the quality of the logs (and the price paid for them), the sawmill design, and the existing timber price gradients. On standard carriages the poorest faces should be opened first to ensure that the best faces are sawn parallel to the bark. The results of this study show that mills would benefit from having the facility to set the carriage knees independently to permit more flexible log positioning. For instance, poor quality logs could be split-taper sawn to maximise conversion and production (thus minimising sawing cost) while good logs could be full-taper sawn to maximise grade recovery if timber price gradients were sufficient to cover the losses in conversion.

Some of the limitations of batch sawing studies can be overcome by the use of computer simulation models such as SEESAW (Park 1987) and SAWMOD (Whiteside & McGregor 1987). These allow the same logs to be processed an infinite number of times according to different sawing methods and timber price lists. However, they cannot yet cater for all the possible processing methods that can be applied in the sawmill, e.g., full taper sawing, or give estimates of relative processing times for alternative equipment options, e.g., single-cutting compared to double-cutting bandsaws.

REFERENCES

ANDERSON, G. W.; AILPORT, J. L. 1973: Double taper chipping canters. Pp. 130–44 **in** "Modern Sawmill Techniques" Vol. 1. Miller Freeman Publications Inc., San Francisco.

BOUSQUET, D. W.; FLANN, I. B. 1975: Hardwood sawmill productivity for live and around sawing. **Forest Products Journal 25(7):** 32–7.

CASSENS, D.; MAEGLIN, R. R. 1987: Live-sawing low-grade red oak logs. **Forest Products Journal 37(10):** 49–53.

COWN, D. J. 1985: FRI study concludes that computer simulation is useful in log conversion and grade recovery predictions. **New Zealand Forest Industries 16(9):** 29–35.

COWN, D. J.; McCONCHIE, D. L.; TRELOAR, C. 1984: Timber recovery from pruned **Pinus radiata** butt logs at Mangatu: effect of log sweep. **New Zealand Journal of Forestry Science 14:** 109–23.

COWN, D. J.; WHITESIDE, I. D.; KIMBERLEY, M. O. 1987: Conversion and timber grade recoveries from radiata pine logs. Pp. 147–61 **in** Kininmonth, J. A. (Comp.) "Proceedings of the Conversion Planning Conference, Rotorua, 8–11 April 1986", **Ministry of Forestry, FRI Bulletin No. 128.**

FLANN, I. B. 1978: Live sawing hardwoods! Can it mean dollars to you? **Fisheries and Environment Canada, Eastern Forest Products Laboratory Report OPX198E.** 15 p.

HARPOLE, G. B. 1983: Economics of manufacturing structural lumber from low- to medium-density hardwoods. **U.S. Forest Service Forest Products Laboratory, Research Paper FPL 432.** 4 p.

PARK, J. C. 1987: A visual simulator (Part 1). Pp. 97–106 **in** Kininmonth, J. A. (Comp.) "Proceedings of the Conversion Planning Conference, Rotorua, 8–11 April 1986". **Ministry of Forestry, FRI Bulletin No. 128.**

PARK, J. C. LEMAN, C. S. E. 1983: A sawing study method for evaluating timber from pruned logs. **New Zealand Forest Service, FRI Bulletin No. 47.**

PARK, J. C.; PARKER, C. E. 1983: Regional validation studies of pruned radiata pine butt logs sawn to boards. **New Zealand Forest Service, FRI Bulletin No. 51.**

WHITESIDE, I. D.; McGREGOR, M. J. 1987: Radiata pine sawlog evaluation using the sawing log-yield model. Pp. 124–46 **in** Kininmonth, J. A. (Comp.) "Proceedings of the Conversion Planning Conference, Rotorua, 8–11 April 1986", **Ministry of Forestry, FRI Bulletin 128.**

WILLISTON, E. M. 1976: "Lumber Manufacturing: The Design and Operation of Sawmills and Planer Mills." Miller Freeman Publications Inc., San Francisco. 512 p.