TENDING PINUS RADIATA FOR OPTIMUM TIMBER-GRADE RECOVERY

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SYNOPSIS

Logs of 41-year-old Pinus radiata (D. Don) trees were sawn to one-inch timber in a frame-saw mill, and subsequent recovery of the higher board grades was poor. The original stand had been low and high pruned, and thinned three times, but this tending had been too light in intensity, and had been timed too late to be effective in improving grade recoveries.

The major defects of the timber were bark encasement of the knots, cone-stem holes, and pith associated with low-density corewood and spike knots.

Final-crop trees should ideally be straight-stemmed, with branches of small diameter set at wide angles to the trunk; should be relatively free of stem cones, and without marked nodal swellings, and should have a reasonable degree of vigour.

In stands of 59-year-old trees studied, natural pruning was negligible, and stem cones were particularly persistent.

Contemporary tending schedules in New Zealand now prescribe very heavy thinning combined with pruning to 32 ft or higher. A conservative projected grade yield from final-crop trees produced according to the 1960 tending schedule for Southland Conservancy indicates that at least 35 percent of the timber will be clear wood at a rotation age of 50 years.

Foresters should have a good knowledge of timber grading and of the defects likely to cause degrade, in order to prescribe proper tending for the next rotation of this species.

INTRODUCTION

The object of commercial forest management is to produce the forest products required for any given region or market. The object of tending operations is primarily to enhance the value of the forests

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by increasing the ratio of high-quality to low-quality produce. With sawn timber this means the production of clear or finishing grades.

Wartime labour shortages and general economic conditions prevented extensive tending of radiata pine (Pinus radiata) during the first rotation of this species in New Zealand. The course of establishment and tending of these forests has been given by Pollock (1952). The outstanding exceptions to this general absence of tending were the forests of the Tapanui district in Southland Conservancy, and in particular Dusky Forest (McKinnon, 1957), which had the reputation of being one of the few tended forests in the country. Logs from thinning operations in Dusky Forest have been sawn for about 25 years, but thinning logs do not necessarily indicate which timber grades will be obtained from the final crop. It can be assumed that final-crop trees from well tended stands will yield a higher percentage of better timber grades than will trees from thinning operations. The forest manager expects to recover more than his costs of tending throughout the rotation in increased stumpage for improved timber quality in his final-crop trees.

Increasing attention is being given to the effect of tending upon the ultimate grade recovery of sawn timber from stands of radiata pine. The total acreage of this species in New Zealand exceeds 400,000 acres, the annual cut from which is approximately 300,000,000 bd. ft. In view of these figures there is a rather surprising lack of literature both on the effects of silvicultural treatment on timber quality, and on the general grade out-turn.

In June 1958 widespread windthrow occurred in stands in the Tapanui district. Salvaging operations provided an opportunity of carrying out a grade study on timber from final-crop trees from a stand which had been placed under reservation by the Pomahaka Working Plan 1953, and which was to have received ideal silvicultural treatment.

The authors considered that in order to define more clearly the aims of tending, more information should be acquired on the average grade returns a typical sawmill currently obtains from radiata pine, on which log-height classes yield the most profitable returns, and on the percentage of the final timber yield that comes from each log-height class. (Log-height class refers to the sawlogs obtained at various heights up the tree from butt, or first, log up to nth or topmost log.)

The first part of the paper describes the grade study and its results, and defines the qualities required in final-crop trees to ensure profitable grade returns. The second part shows how these qualities can best be promoted by tending schedules.
PART 1: THE GRADE STUDY

Stand Description

Details of the stand-history are:

1918  Planted at 6 × 6 ft spacing.
1920-21  Blanked; percentage not recorded.
1931  Low pruned to 8 ft, at estimated top height of 43 ft.
       First thinning to 400 per acre, at estimated top height of 43 ft
       24 percent relative spacing (Hummel, 1953).
1938-41  Second thinning to 280 per acre, at estimated top height of 75 ft
       16-17 percent relative spacing (Hummel, 1953).
1950-51  Third thinning to 150 per acre, at estimated top height of 102 ft
       16-17 percent relative spacing (Hummel, 1953).
1956  Selective high pruning to 16 ft.
1957  Standing total volume per acre: 11,328 cu.ft.
       Standing volume, to 6 in. top, per acre: 10,761 cu.ft.
       Mean top height: 116 ft.
       Site index (Lewis, 1954): 72-73 ft.
       Average height to base of green crown: 70 ft.

By the standards of development of radiata pine further north, the site index is relatively low, and it is probably only average for the latitude (about 46°S) of Southland Conservancy. The altitude is about 750 ft. The heavy mortality associated with drought and Sirex epidemic in similar stands of North Island is insignificant hitherto in the exotic forests of Southland.

Study Methods

The windthrow had resulted in considerable confusion in the stand, but in some places groups of trees extending over an acre had been overthrown together. It was not possible to take random samples from the chaos of fallen trunks, but it was decided that all full-length logs of normal form extracted from the largest separate area of windthrow would be a fair sample of the final-crop trees. Only butt ends of logs were visible, and it was not considered that any bias was shown in tree selection. The area from which logs were taken was slightly over an acre in extent. Owing to shortage of staff, it was necessary to arrange the study to fit in with salvage logging and saw-milling operations. Such an arrangement inevitably complicated the study.

The logs were sawn at Conical Hill sawmill. They were distributed to the mill skids, and were sawn in the normal course of production in the frame-saw mill. This is of an orthodox type with a log frame feeding a cant frame and a double edger. The cutting pattern is such that the maximum quantity of wide one inch thick timber is sawn; this affects the results, and is considered further in this paper.

The cross cutting of long-length logs from the forest was not under the control of the authors, and depended upon the particular requirements of the mill's timber orders. For example a 32 ft-long log was normally cut to yield two 16 ft short logs, but occasionally it would be cut to yield three shorter logs. This prevented exact correlation
between log-height classes up the tree, and a number of logs could 
not be included in the results because they came in intermediate log-
height classes. This explains the differences in the numbers of logs 
quoted in each log-height class and the slight overlapping in the heights 
quoted in the log-height column of table 1. Results from some logs 
had to be discarded owing to loss of boards in the mill. A total of 160 
short logs was examined, but results from only 141 logs, yielding 
14,445 bd.ft of timber have been used. Shatter of tree lengths during 
the windthrow, together with the points mentioned above, reduced to 
25 the number of whole tree lengths for which results are complete.

The timber was graded according to specification (New Zealand 
Standard Specification 169); the size and grade of each piece, the 
nature of the critical defects, and the upgrade due to pruning was 
recorded. For the purposes of the study, such degrade as was due to 
imperfect sawing and sapstain was ignored. Boards that could be 
graded as either Dressing or Factory grade were always graded as 
Dressing grade. The timber listed as degraded because of cone-stem 
holes was degraded by that cause alone, although these defects also 
were sometimes present in other pieces that had more serious defects, 
such as bark encasement of the knots. A comprehensive, critical review 
of the current grading rules, which also contains full specifications of 
each grade, has been published (Ward, 1957).

Ideally the occurrence and position of every defect causing degrade 
should be noted. Such a procedure would allow the data to be used 
despite any future changes in the grading rules, but study methods 
were restricted by normal mill working and precluded such an 
approach.

Results of Grade Study

The actual yield of each grade and the major causes of degrade 
within each log-height class are given in table 1. The overall timber-
grade recovery from the stand is given in table 2; this assumes that 
equal numbers of each log-height class are sawn. (In the study, the 
lower-log-height classes were sampled more heavily and corrections 
have been made for this.) The effect of each major cause of degrade 
on the overall timber-grade recovery is given in table 3; this too is 
based on an equal number of logs from each log-height class. The 
width of the cant cut from each log small-end-diameter (s.e.d.) class is 
given in table 4.

The overall recovery of Dressing grade, and the effect of cone-
stem holes is illustrated in fig. 1.

Major Causes of Degrade

It is convenient to elaborate here on the major causes of degrade, 
for in any study of timber grading the local variables (such as cutting 
pattern and silvicultural history) have a considerable effect on the 
results.
Pith. When equal numbers of logs from each log-height class were sawn, 20% of all the timber was degraded, owing mainly to the presence of pith. The rapid growth rate of radiata pine gives rise to a pith of usually 0.6-0.75 in. diameter (sometimes up to 1.0 in.).

Fig. 1. Grade-study results showing production of Factory and Dressing grade and the effect of cone-stem holes.
<table>
<thead>
<tr>
<th>Log-height Class</th>
<th>Number of Logs Sawn</th>
<th>Total</th>
<th>Box</th>
<th>Bark-encased</th>
<th>Knots</th>
<th>Other</th>
<th>Total</th>
<th>Merchantable</th>
<th>Cone Tight Encased</th>
<th>Knots</th>
<th>Other</th>
<th>Dressing Factory</th>
<th>Clear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt (0.5 - 18.0 ft)</td>
<td>31</td>
<td>41.5</td>
<td>15.5</td>
<td>18.5</td>
<td>7.5</td>
<td>23</td>
<td>0</td>
<td>10.5</td>
<td>12.5</td>
<td>3.5</td>
<td>30</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Second (17.7 - 33.7 ft)</td>
<td>27</td>
<td>42.5</td>
<td>20</td>
<td>20</td>
<td>2.5</td>
<td>24</td>
<td>4.5</td>
<td>11</td>
<td>8.5</td>
<td>11.5</td>
<td>21.5</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Third (34.8 - 50.3 ft)</td>
<td>30</td>
<td>41.5</td>
<td>23</td>
<td>16.5</td>
<td>2</td>
<td>32</td>
<td>21.5</td>
<td>7</td>
<td>3.5</td>
<td>15</td>
<td>11.5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Fourth (51.5 - 66.3 ft)</td>
<td>25</td>
<td>34.5</td>
<td>22</td>
<td>8.5</td>
<td>4</td>
<td>45.5</td>
<td>37.5</td>
<td>5</td>
<td>3</td>
<td>19</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Fifth (66.0 - 79.9 ft)</td>
<td>18</td>
<td>33</td>
<td>25</td>
<td>1.5</td>
<td>6.5</td>
<td>49.5</td>
<td>43</td>
<td>2.5</td>
<td>4</td>
<td>16</td>
<td>1.5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sixth (83.0 - 95.1 ft)</td>
<td>10</td>
<td>42</td>
<td>31</td>
<td>0.5</td>
<td>10.5</td>
<td>44</td>
<td>44</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 2: OVERALL TIMBER-GRADE RECOVERY
Percentages of Overall Cut

<table>
<thead>
<tr>
<th>Log-height Class</th>
<th>Box</th>
<th>Merchantable</th>
<th>Dressing</th>
<th>Factory</th>
<th>Clear</th>
<th>Overall Total Volume Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt</td>
<td>11.5</td>
<td>6</td>
<td>1</td>
<td>8</td>
<td>0.5</td>
<td>27</td>
</tr>
<tr>
<td>Second</td>
<td>10</td>
<td>5.5</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>23.5</td>
</tr>
<tr>
<td>Third</td>
<td>7.5</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>18.5</td>
</tr>
<tr>
<td>Fourth</td>
<td>5</td>
<td>6.5</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>14.5</td>
</tr>
<tr>
<td>Fifth</td>
<td>3.5</td>
<td>5</td>
<td>1.5</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Sixth</td>
<td>2.5</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>6.5</td>
</tr>
<tr>
<td>Overall</td>
<td>40</td>
<td>32</td>
<td>12.5</td>
<td>15</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Actual 1960 average*</td>
<td>77</td>
<td>12.5</td>
<td>10.5</td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

The figures are based on the recovery of an equal number of logs in each log-height class.

* These figures have been adjusted by ignoring the cut of framing timber; they probably understate the production of the lower grades.

TABLE 3: DEGRADING DEFECTS
Percentages of Overall Cut

<table>
<thead>
<tr>
<th>Log-height Class</th>
<th>BOX GRADE</th>
<th>MERCHANTABLE GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pith</td>
<td>Bark-encased Knots</td>
</tr>
<tr>
<td>Butt</td>
<td>4.30</td>
<td>5.10</td>
</tr>
<tr>
<td>Second</td>
<td>4.75</td>
<td>4.12</td>
</tr>
<tr>
<td>Third</td>
<td>4.24</td>
<td>2.91</td>
</tr>
<tr>
<td>Fourth</td>
<td>3.19</td>
<td>1.23</td>
</tr>
<tr>
<td>Fifth</td>
<td>2.51</td>
<td>0.13</td>
</tr>
<tr>
<td>Sixth</td>
<td>1.90</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>20.89</td>
<td>13.49</td>
</tr>
</tbody>
</table>

Deviation in the straightness of a log can result in a “wandering” pith, and on many occasions pith can occur in more than two boards cut from the centre of a log. Owing to the very high percentage of timber degraded by pith it is necessary to discuss the alternative cutting patterns available to a frame mill which would avoid cutting wide boards containing, and hence degraded by, pith.

Table 4 shows the relation between log diameter, cant size, and number of pieces cut from the cant in frame saws. Fig. 2 shows diagramatically the cutting pattern used, and the alternative methods of sawing that are possible.

Pattern 1 would be to cut the centre of the log to large baulk sizes such as 6 X 6 in., 6 X 8 in., and 8 X 8 in. for sale as heavy beams and columns in temporary construction work. Within the limits of market demand, such a solution is adopted, but in relation to the annual
**TABLE 4: RELATION BETWEEN LOG SIZE, CANT SIZE, AND 1 in. TIMBER PIECES CUT IN LOG-FRAME SAWS**

<table>
<thead>
<tr>
<th>Log Small-end Diameter</th>
<th>Size of Cant</th>
<th>Full Cant Face</th>
<th>No. of 1 in. Full Pieces Cut*</th>
<th>No. of 1 in. Full Pieces Degraded by Pith†</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>4</td>
<td>4(\frac{3}{4})</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>5(\frac{3}{4})</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>5(\frac{3}{4})</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>6</td>
<td>6(\frac{3}{4})</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
<td>7(\frac{3}{4})</td>
<td>6-7</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>8</td>
<td>7(\frac{3}{4})</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>8(\frac{3}{4})</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>10</td>
<td>7(\frac{3}{4})</td>
<td>7-7</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>9(\frac{3}{4})</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>12</td>
<td>8(\frac{3}{4})</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>12</td>
<td>10</td>
<td>8-9</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>12</td>
<td>11(\frac{3}{4})</td>
<td>10</td>
<td>2</td>
</tr>
</tbody>
</table>

**Note:** The saws used at Conical Hill Mill have a kerf of \(\frac{3}{8}\) in.

*These figures are maxima, as in practice deviation in straightness would often occur, and pieces would need edging.
†These figures are minima - the pith frequently wanders and can occur, on occasion, in three or more boards.

Timber cut, the demand is insignificant and provides no solution to the pith problem.

Pattern 2 consists in cutting the centre of the log to a 2 in. thick piece to yield 4, 6, 8, 10, and 12, \(\times\) 2 in. timber, such timber having the pith (if it is straight) in the centre. (In New Zealand there is only a limited market for timber 5, 7, 9, and 11 in. wide, whether 1 in. or 2 in. thick, and these sizes are not considered in the discussion.) This solution is of little use for 6 in. and 7 in. s.e.d. logs, as the centre will yield a piece of \(\frac{4}{2}\) in. with pith right through it. On the current grading rules this could be graded above Box grade, depending on the incidence of other defects, but the timber would be wholly fast-grown, low-density corewood, of little intrinsic worth. The 8-10 in. s.e.d. logs would yield a central piece of 6 \(\times\) 2 in. which, depending on the incidence of other defects, would be either No. 2 Framing grade or Box grade. The piece of framing produced from 11 in. s.e.d. and larger logs could, on the grading rules, be placed in No. 1 Framing grade despite the presence of a central core of wood of low strength. Unfortunately there is very little demand for 2 in. thick timber more than 6 in. wide.

Pattern 3 consists in overcutting the cant by \(\frac{5}{4}-\frac{7}{8}\) in. to allow for re-ripping to two narrower boards, one of which may not contain degrading pith. (Any solution involving recutting requires more machinery, further provision for waste disposal, and higher cost of production; this may be justified in higher returns from enhanced
PATTERN 1
CUTTING LARGE BAULK SIZES
6x6" AND LARGER

PATTERN 2
CUTTING 4", 6", 8", 10" AND 12"x 2"
CONTAINING CENTRAL PITH

PATTERN 3
OVERCUTTING 1" BOARDS TO
PERMIT RE-RIPPING

PATTERN 4
CUTTING A 2" PIECE AND
RE-RIPPING FOR FRAMING

PATTERN USED IN SAWING
WIDE 1" BOARDS

Fig. 2. Frame-saw patterns for cutting cants which contain pith.

grade recovery.) This pattern was tried on occasions at Conical Hill mill, but the very frequent presence of spike knots often degraded the pith-free piece. The result was usually a slight loss on the financial side, as the cost of the extra handling, the loss on conversion, and
losses due to breakage of timber at spike knots running across the boards, exceeded the value of upgrading from Box grade.

Pattern 4 is to overcut the cant, and to cut a 2 in. piece from the centre for subsequent re-ripping. This again, involves the use of further machinery. An overcut 6 × 2 in. could yield only Box grade if ripped to two 3 × 2 in. pieces, for pith is not permitted on the nailing faces of timber of this dimension. The same objection occurs in the cutting of two 4 × 2 in. from an overcut 8 × 2 in.; of two 5 × 2 in. from an overcut 10 × 2 in., and of two 6 × 2 in. from an overcut 12 × 2 in. The overcut 10 × 2 in. can be ripped to yield two 4 × 2 in. and a central 2 × 2 in. (used as fence battens); in practice the 2 × 2 in. would be worthless. The pith-free pieces of 3 × 2 in. or 4 × 2 in. timber re-ripped from overcut 10 × 2 in. and 12 × 2 in. are not necessarily of No. 1 Framing grade; such pieces, being quarter-sawn, would usually contain spike knots running through their wider axes. As Framing grades are defined primarily in terms of the cross section occupied by defects, these spike knots are serious defects and would degrade the pieces below No. 1 Framing grade.

Unfortunately, lack of suitable machinery prevented the adoption of the pattern 4 alternative at Conical Hill mill, although some form of it is often adopted in larger, more elaborately equipped North Island mills. The simplest form of machinery required would be a breast-bench saw taking the centre 2 in. pieces cut by the cant-frame saw. This recutting would improve grade recovery, and it might not be essential to overcut the 10 in. or 12 in. cants if the pith were included in a piece of 2 × 1 1/2 in. or 2 × 2 in. cut centrally from the larger pieces. The financial results of cutting are revealing:

Cutting 1 in. boards, as in the study, yields:
Two pieces of 12 × 1 in. Box grade, worth 0.87 shillings per lineal ft.

Cutting 2 in. piece, and re-ripping, yields:
One piece of 4 × 2 in. No. 1 Framing, worth 0.39 shillings per lineal ft.
One piece of 4 × 2 in. No. 2 Framing, worth 0.31 shillings per lineal ft.
One piece of 3 × 2 in. Box, worth 0.19 shillings per lineal ft.

Total 0.89 shillings per lineal ft.

These grade figures are biased in favour of the 2 in. cutting, and moreover assume that the 3 × 2 in. piece contains all the pith, and is salable, which are both optimistic assumptions. It is evident that such an alternative cutting pattern is justified only if 10 × 1 in. or 12 × 1 in. Box grade is unsaleable, and if a mill has difficulty in cutting all the framing timber it requires. The framing pieces cut would be quarter-sawn, and owing to the variation in density, and to the different shrinkages of heartwood and sapwood, would have a strong tendency to distortion by crook. Flat-sawn framing would tend to distort by bowing, which is less objectionable as it is much easier to correct.

The question of pith and its associated defects has been dealt with
at perhaps exhaustive length, because it is too often dismissed as being due to faulty cutting patterns. Pith causing degrade does not occur in most other timbers, but is a very important and largely unavoidable defect in radiata pine. The ideal sawmill solution, apart from integration with a pulp mill as given by Entrican (1957), is to saw all the timber obtained from the centre of radiata pine logs on a simple breast bench, carefully working round the core-wood. Such a solution remains theoretical, as the current and foreseeable trend is towards larger and more fully automated mass-production sawmills for milling exotic softwoods.

To summarise: when frame-saw mills are used to convert the material the total degrading effect of pith can probably be reduced to below the 20.9 percent recorded here, but it is doubtful if it could be reduced below 12-15 percent. The latter figures were the best among those obtained from a series of minor studies carried out on 14-17 in. s.e.d. logs at Waipa Mill, which is fully equipped to carry out any recutting sawing pattern. To state that all the degrade is due to pith is a convenient oversimplification; it is due to the combined effect of the pith itself, the low-density wood around it, and the inevitable presence of spike knots in quarter-sawn pieces.

**Size of Intergrown Knots.** Excess knot size was a minor cause of degrade, although this is not readily apparent from the results. The current grading rules permit an intergrown knot to be up to one-half of the width of the piece in Dressing grade. Only in 4 X 1 in. and 3 X 1 in. timber were these limits approached. Knots were generally of 1.2.5 in. diameter, although there is usually a very wide range of knot sizes in radiata pine.

**Bark encased, Partially Intergrown and Tight Encased Knots.** The term "partially intergrown" knot is defined in the grading rules as "a knot, part of which has not more than half its perimeter separated from the surrounding wood by a crescent of bark". Tight encased knots are also permitted, these being "... so fixed by growth or position that [they] will firmly retain [their] position in the piece". In practice they are usually small knots which are partially intergrown on one side of a piece and encased on the other. The percentage of degrade follows the anticipated pattern – most occurring in the butt and second logs, and becoming progressively less further up the tree. The slight difference between butt and second logs, in favour of the former, can be ascribed to the effect of low pruning. It is not until the fourth log is reached at about 50 ft that the percentage drops from 16-20 percent, to about 8 percent. The incidence of degrade due to tight encased knots in Merchantable grade parallels that of the bark-encased knot degrade of Box grade, decreasing higher up the tree.

The degrade due to bark-encasement of the knots would be much higher if Factory grade were not recovered. This grade was formulated to encourage utilisation of the clear internodes of radiata pine.
by allowing the recovery of short clear-cutting lengths. The intervening defects between these lengths are such that the timber would otherwise be graded as Box, or occasionally as Merchantable grade. In table 1 it is evident that if the Dressing and Factory grade recoveries are combined (the timber is of equal price), the highest grade recovery is in the lowest logs, and recovery of good grades decreases with height up the tree; this is the opposite of the grade-recovery pattern found in poorly tended Corsican pine (Fenton, 1960). The recovery of Factory and Dressing grade, and the effect of cone holes is illustrated in fig. 1. A characteristic of radiata pine is the irregular size of the branches and the variation in branching pattern. Logs that contained whorls of small secondary branches yielded poorer grades of 1 in. timber than logs with well defined annual whorls of branches. These small branches died early and degraded the wood. Similarly, the small branches of a whorl died first and caused more serious defects than larger branches that were still alive at the time of felling. Hence encased knots were present even high up in the green crown.

Cone-stem Holes. Tables 1 and 2 and fig. 1 show the important nature of this defect; a total of 17.4 percent of all timber sawn was degraded from Dressing grade to Merchantable solely by the presence of cone-stem holes. The current price differential between these two grades varies from 10 shillings to 30 shillings per 100 bd. ft, depending on the width of the piece, but if an average differential of 20 shillings per 100 bd. ft is assumed, then the cost of the degrading effect of cone-stem holes was more than £100 per acre in the stand studied. The effect on grade recovery of the decreasing incidence of branch encasement from butt to top log was largely nullified by the increasing incidence of the cone-stem holes.

Other Defects. The main causes of other degrade in Box grade were: large spike knots; large resin and bark pockets, some of which were the result of damage received by the trees during thinning; and, in the butt logs, heavy resin pockets both above and below pruned branches – the result of faulty axe pruning.

Summarised Study Results

One fact that emerged from the study was that a very small percentage of the timber cut was graded as Clears. The main defects of radiata pine, in addition to the encased knots common to most softwoods, are cone-stem holes and the combination of pith, low-density wood, and spike knots – which are either absent, or of less importance, in other species. These additional defects will complicate future tending, and must be recognised as serious sources of degrade when silvicultural schedules for this species are being considered. If stands are to remain untended, then Factory grade is of great importance in final-crop grade recovery.
Type of Tree Required

Before attention is given to the silvicultural systems and schedules necessary to promote optimum timber-grade recovery from radiata pine, it is relevant to consider what type of final crop tree is desirable, bearing in mind the defects found in the timber-grade study. Bannister (1959) has pointed out that the objects of selection are still rather poorly defined, and the authors agree with this contention.

Pollock (1952) states “The best type is tall, usually straight, clean, lightly branched and foliaged, and with whorls set well apart. The poorest type is the reverse, with high percentage forked or multi-leadered”. Reid (1953), while acknowledging the value of individuals which have groups of knots at infrequent intervals, favours the multi-nodal form, particularly for framing, round produce, structural timber, and some board sizes for full-length uses. Thulin (1957) states “It appears that the highest-quality timber is cut from trees with light, multinodal branching, straight stem form, and high heartwood content”. Entrican (1957) requires that “the geneticist must persevere with his efforts to produce a better-form tree with fewer and smaller laterals”, and thus requires the selected trees to have fewer branches. Weston (1957) states “The most desirable trees are vigorous and straight, free of stem cones, and with widely spaced whorls of relatively few fine branches, nearly at right angles to the stem” — he introduces the importance of branch angle into the requirements for selected trees. Bannister (1950) noted that individual trees can be found which have both low branching frequency and small branch size, and that a better aim of tree selection would be to reduce the mean size of branches, while the frequency remains constant. He also points out that a small dead knot could be a more serious defect than a large live one. Fielding (1960) showed that, in the stands of the Australian Capital Territory which he studied, the uninodal trees tend genetically to produce fewer cones, to have more acutely angled branches, to be less straight stemmed, and to show more abrupt change in taper than trees of multinodal branching type. He found that branch size was under weaker genetical control than these other characters. Fielding also reported that the present Australian preference is for multinodal types of tree.

The following are the points that the authors feel are of premier importance in selecting final-crop trees in stands of radiata pine.

(1) The trees must be as straight as possible; there is no dispute over this point. The pruning of curved, butt-swept or crooked trees results in boards which contain clear wood for part of their length, and which then, as the plane of sawing is parallel to the pith, contain knots from the central core. A similar result is obtained when boards are sawn from the zone of intergrown knots, which further along the piece, pass into an encased-knot zone. The obvious grain deviations
resulting from sawing bent trees, and the sharp drop in sawmill conversion factors are also important reasons against their retention. Too often small, butt-swept trees are pruned, and one is assured that “the kinks grow out”, the implication being that the final log will be cylindrical; this may be, but the knotty core will extend across the zone of clear wood, and a poor grade recovery will be the result.

(2) The range, as well as the mean, of branch diameters must be as small as possible. Very small branches, about the size of a pencil, are often left on the pruned portion of a stem, their significance as a source of degrade not being properly understood. Their effect is to degrade a Clear to Factory grade; in the unpruned green crown, these branches die early and reduce potential Dressing grade boards to Merchantable.

The size of the branches is of greatest importance in the part of the stem that is going to be pruned. Few quantitative data are available in New Zealand, but we have seen nothing to contradict overseas findings that the rate of occlusion of large-diameter branches after pruning is much slower than that of small branches. The occlusion of larger branches is often associated with elongated resin pockets which in effect increase the diameter of the knotty or defective core. It also costs less to prune off small branches. In the part of the trunk above the pruned level the inter-relations between the size and condition (alive or dead) of branches, cone-stem holes, and timber grades are complex, but trees with long crowns of small live branches should be retained in the crop.

(3) Branch angle should receive the full attention of marking staff. Experience has shown that many of the branches that are at an angle of between 45° and 30° with the trunk, and almost all those that are more acute than 30°, have an extensive resin or bark pocket along their upper edge, which gives rise to serious defect in both board and framing timber. Trees with such branches should remain in the crop only if they possess long internodes capable of yielding Factory grade; they could then be removed in the final or penultimate thinning.

(4) The full advantage of pruning the lower log-height classes will be lost if trees having marked nodal swellings are chosen as final-crop trees. In radiata pine, the base of the branch nodes can extend for more than an inch outside the main line of the trunk; if such trees are pruned, the diameter of the central core is increased by two inches. It is also likely that occlusion over such stubs would be slower than over stubs which lack nodal swelling.

(5) The selected trees should not, up to at least the 50 ft level, have cones on the trunk; ideally they should be very high up, and be uncommon on the trunk. The importance of stem cones is often ignored; they frequently remain on the pruned portions of final-crop trees.
Tree vigour was once the major factor in the choice of final-crop trees, but we strongly represent that, if the object of management is to produce saw-logs, vigour alone should not be allowed to predominate over the criteria of quality already given. Throughout New Zealand any current pruning operation is now being linked with thinning, the intensities of which, by the standards of ten or even five years ago, are extremely heavy; it is unlikely that the co-dominant of superior form will now be overtopped by a vigorous, coarse-grown dominant. Such an outlook could possibly be regarded as academic, but with the general prospect of the first thinning being to waste, and considering the massive standing volume of low-grade timber represented in the first rotation stands, we can see no merit in retaining, purely by reason of their vigour, trees which would yield low-grade timber. Nevertheless there is obviously a limit to the extent to which trees which are not dominants should be selected for optimum silvicultural treatment; the guiding principle should be the ultimate production of large-diameter butt logs with a small and uniform knotty core.

The authors would hesitate to join in any controversy about the choice of uninodal as against multinodal trees. Any forester who has marked stands of radiata pine and has satisfied the conditions outlined for straightness, small and even branch size, branch angle (branches approaching the horizontal), absence of stem cones and of nodal swellings in the sections to be pruned, and reasonable vigour, will probably have very few trees remaining on any one acre. By this stage, the question of uninodal or multinodal trees will possibly have solved itself. There is, however, a curious dilemma for New Zealand foresters, in that their current tending schedules (which are discussed later) result in such heavy and early thinning as to make the choice of final-crop trees with good characteristics problematical. The responsibility of an officer who marks for tending is heavy at any time, but when marking radiata pine he is dealing with a tree that, despite its exuberance of growth, presents more problems, and places more obstacles in the way of producing high-grade timber than any other exotic softwood grown in New Zealand. It is only by pains-taking attention to the points outlined that the yield of better timber grades will be increased. We hope that the foresters who mark trees will respond to the challenge made by Bannister (1960), when he writes “... often he [the forester] seems apathetic towards the principle of artificial selection by silvicultural methods.”

This inventory may well be completed by listing some additional criteria for elite trees, which are the concern of the geneticist. These are:

(a) an increase in the density of the timber;
(b) the reduction of the extent of the low-density core (this could, of course, concern the forester);
Fig. 3. Thinning schedules.

(c) an increase in the juvenile-wood-fibre length and overall fibre length;
(d) resistance to unseasonable frost;
(e) resistance to *Sirex* and other pathogens;
(f) more shade tolerance and ability to retain deep green crowns;
(g) freedom from excessive spiral grain;
(h) strong apical dominance;
(i) control of tendency to form heartwood. (With the development of the wood-preservation and pulp industries, the earlier demand for more heartwood has probably been reversed.)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed site index</td>
<td>72 ft</td>
<td>76 ft</td>
<td>76 ft</td>
<td>90 ft</td>
<td>90 ft</td>
</tr>
<tr>
<td>(Lewis, 1954)</td>
<td></td>
<td>700-1,210 per ac.</td>
<td>1,210 per ac.*</td>
<td>1,000 per ac.*</td>
<td>Base of green crown, 10 ft minimum</td>
</tr>
<tr>
<td>Initial stocking</td>
<td>1,210 per ac.</td>
<td>1,210 per ac.*</td>
<td>1,210 per ac.*</td>
<td></td>
<td>6-7</td>
</tr>
<tr>
<td>Low pruning, to</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300-350</td>
</tr>
<tr>
<td>at top height</td>
<td>8 ft</td>
<td>8 ft</td>
<td>7 ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>at age</td>
<td>43 ft</td>
<td>25 ft</td>
<td>15 ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>number per ac.</td>
<td>13 years</td>
<td>8-10 years</td>
<td>5-7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First thinning</td>
<td></td>
<td>Malforms removed</td>
<td>To 250-350 per ac.</td>
<td>To 200-250 per ac.</td>
<td>To 300-350 per ac.</td>
</tr>
<tr>
<td>Intermediate pruning</td>
<td>Nil</td>
<td></td>
<td>At intermediate pruned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High pruning, to</td>
<td>16 ft</td>
<td>18 ft</td>
<td>16-18 ft</td>
<td></td>
<td>20 ft</td>
</tr>
<tr>
<td>at top height</td>
<td>114 ft</td>
<td>41 ft</td>
<td>40-45 ft</td>
<td></td>
<td>40-45 ft</td>
</tr>
<tr>
<td>at age</td>
<td>38</td>
<td>12-16</td>
<td>8-10</td>
<td></td>
<td>8-10</td>
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<tr>
<td>number per ac.</td>
<td>80-120</td>
<td>up to 180</td>
<td>150 per ac.</td>
<td></td>
<td>150-200 per ac.</td>
</tr>
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<td>Second thinning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at top height</td>
<td>75 ft</td>
<td></td>
<td>90-95 ft</td>
<td>90 ft</td>
<td>at extra-high pruned</td>
</tr>
<tr>
<td>at age</td>
<td>22</td>
<td></td>
<td>25</td>
<td>20</td>
<td>190</td>
</tr>
<tr>
<td>number per ac.</td>
<td>289</td>
<td></td>
<td>120</td>
<td></td>
<td>32 ft</td>
</tr>
<tr>
<td>Extra-high pruning, to</td>
<td>Nil</td>
<td></td>
<td>32 ft†</td>
<td></td>
<td>60-70 ft</td>
</tr>
<tr>
<td>at top height</td>
<td>Nil</td>
<td></td>
<td>15-17</td>
<td></td>
<td>13-15</td>
</tr>
<tr>
<td>at age</td>
<td>Nil</td>
<td></td>
<td>50</td>
<td></td>
<td>40-80</td>
</tr>
<tr>
<td>number per ac.</td>
<td>Nil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Third thinning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at top height</td>
<td>102 ft</td>
<td>76 ft</td>
<td>115 ft</td>
<td>Nil</td>
<td>100 ft</td>
</tr>
<tr>
<td>at age</td>
<td>33</td>
<td>18-22</td>
<td>35</td>
<td></td>
<td>20-22</td>
</tr>
<tr>
<td>number per ac.</td>
<td>150</td>
<td>240-260</td>
<td>80†</td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>Probable final crop</td>
<td>not defined</td>
<td>50</td>
<td>50</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>number per ac.</td>
<td>80-100</td>
<td>80-120</td>
<td>80</td>
<td></td>
<td>80</td>
</tr>
</tbody>
</table>

* In areas which are naturally regenerated, all schedules call for a reduction in stocking to the figure given at about age three.

† These are further reductions in this schedule; these are given in the text.
Current Thinning and Pruning Practice

New Zealand experience in the thinning and tending of exotic softwood has been limited in area to a few tens of thousands of acres, and in time to just over two decades. Published results of early work are very few, and one of the first comparative accounts of our practice was written by a visiting forester and has been published only recently (Penistan, 1960). It is scarcely surprising that thinning schedules for our forests are still tentative, but Penistan’s paper serves as a landmark from which the direction of our practice can be followed. Without doubt, over the last decade our thinning schedules have become more and more severe. Although in most conservancies the approach has been empirical, the resultant thinnings are as heavy as, or even heavier than, those of South Africa.

Fig. 3 shows the following six thinning schedules:

(a) That actually given to compartment 9a, Dusky.
(b) That proposed in the 1953 Pomahaka Working Plan; this is comparable (Penistan, 1960) to the schedule developed and in use in South Australia.
(c) The current prescriptions evolved by C. H. Brown in the 1960 revision of the Pomahaka Working Plan.
(e) The revised Rotorua prescription, made by J. Ure, and currently in use in the 1960 revision of the Murupara Working Plan, which covers the greater part of Kaingaroa Forest.
(f) The South African Forest Service schedule for radiata pine (after Penistan) has been included for comparison.

Table 5 shows the complete pruning and thinning prescriptions for the New Zealand regimes. The figures for top height, age, and number of stems per acre for any operation are not rigidly prescribed, and in many cases we have had to make minor compromises with the data; for example, the top heights specified in the 1953 prescriptions vary slightly from those which would follow from the yield table (Lewis, 1954). The 1953 Pomahaka Working Plan prescribed in terms of ages (which are given in table 5) and not top height. These slight variations are inevitable as the yield table was not published until a year after both the 1953 prescriptions were written. We do not consider that the slight amendments found necessary have misrepresented the various prescriptions.

The further details that should be added to the 1953 Pomahaka Working Plan regime are: at age 26-32 years, top height 100-105 ft, thin to 150-180 per acre; at age 36-42 years, top height 115-118 ft, thin to 80-100 per acre.

In the prescriptions given in table 5, the thinning and pruning operations have been bracketed together wherever these operations have coincided.

Southland and Rotorua Conservancies possess very different conditions for tree growth, and for log markets, but there have been marked changes in thinning prescriptions in both areas during the period between 1953 and 1960.
Estimated Timber-grade Production from Final-crop Trees in Southland

TABLE 6: ESTIMATED TIMBER-GRADE YIELDS FROM FINAL-CROP TREES IN SOUTHLAND

<table>
<thead>
<tr>
<th></th>
<th>Butt</th>
<th>Second</th>
<th>Third</th>
<th>Fourth and higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade study: percentage of overall cut</td>
<td>27.0</td>
<td>23.5</td>
<td>18.5</td>
<td>31.0</td>
</tr>
<tr>
<td>Future crop: estimated percentage of overall cut</td>
<td>30.0</td>
<td>25.0</td>
<td>19.0</td>
<td>26.0</td>
</tr>
<tr>
<td>Grade study: log diameter in., s.e., i.b.</td>
<td>15.2</td>
<td>13.9</td>
<td>11.6</td>
<td>—</td>
</tr>
<tr>
<td>Future crop: estimated log diameter, in., s.e., i.b.</td>
<td>18.5</td>
<td>16.9</td>
<td>15.0</td>
<td>—</td>
</tr>
<tr>
<td>Grade study: results as percentage of overall cut:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Box and Merchantable</td>
<td>17.5</td>
<td>16.5</td>
<td>13.5</td>
<td>25.5</td>
</tr>
<tr>
<td>Dressing</td>
<td>1.0</td>
<td>3.0</td>
<td>3.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Factory</td>
<td>8.0</td>
<td>5.0</td>
<td>2.0</td>
<td>—</td>
</tr>
<tr>
<td>Clear</td>
<td>0.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Estimated future grade outturn percentage of-

<table>
<thead>
<tr>
<th></th>
<th>Box and Merchantable</th>
<th>Dressing</th>
<th>Factory</th>
<th>Clear</th>
</tr>
</thead>
<tbody>
<tr>
<td>From Butt-logs</td>
<td>8.3</td>
<td>—</td>
<td>1.7</td>
<td>20.0</td>
</tr>
<tr>
<td>Second logs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>if all are pruned</td>
<td>8.0</td>
<td>—</td>
<td>2.0</td>
<td>15.0</td>
</tr>
<tr>
<td>if half are pruned</td>
<td>10.5</td>
<td>2.5</td>
<td>4.5</td>
<td>7.5</td>
</tr>
<tr>
<td>Third logs</td>
<td>11.0</td>
<td>6.0</td>
<td>2.0</td>
<td>—</td>
</tr>
<tr>
<td>Fourth logs and above</td>
<td>21.5</td>
<td>4.5</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>For all logs, total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>if half second logs pruned</td>
<td>51.3</td>
<td>13.0</td>
<td>8.2</td>
<td>27.5</td>
</tr>
<tr>
<td>if all second logs pruned</td>
<td>48.8</td>
<td>10.5</td>
<td>5.7</td>
<td>35.0</td>
</tr>
</tbody>
</table>

Table 6 shows the timber-grade outturn from final-crop radiata pine stands in Southland Conservancy estimated to result if the 1960 prescriptions are applied. These estimates are conjectural, and are based on a number of assumptions, viz:

(1) The 1960 prescriptions apply to stands with a site index of about 75 ft at 20 years (Lewis, 1954), which gives a top height of 130 ft at the rotation age of 50 years. In unthinned stands, this would result in a mean d.b.h.o.b. of 19.2 in.; from the 1960 Pomahaka Working Plan estimates of final-crop yields, the mean d.b.h.o.b. is 23.5 in. An additional 4 in. in diameter from thinned as against unthinned stands seems extremely modest, particularly as high basal areas (about 350 sq.ft. per acre) can be attained in Southland at this age. The average log sizes are then taken from the taper tables (Duff and Burstall, 1955).
The taper tables show that 75 percent of the cubic volume to a 6 in. top of a 130 ft tree is contained in the first 50 ft of trunk. The conversion factors for the large logs from the lower log-height classes are much higher than for top logs, but a conservative difference of 8 percent has been made, allowing 26 percent of the sawn timber to come from sawlogs cut above 50 ft and 74 percent from the lower logs.

The knotty core has been assumed to occupy an 8 X 8 in. central baulk, which allows for some tending mishaps. A further allowance has been made in assigning some of the boards in the clear zone to Factory grade to allow for long occlusion scars. The prescriptions envisage three-stage pruning to 16 ft and our allowances are probably pessimistic for the butt log; they are probably correct for the second log-height class.

For the sake of simplicity, the 8 X 8 in. central core has been assumed to yield only Merchantable and Box grade. This, too, is pessimistic.

The estimates of the yield from pruned logs have been made from drawings of cutting patterns. The smallest-sized timber allowed for has been 3 X 1 in.; it seems likely that smaller sizes would be salvaged from such logs.

Estimates of the grade outturn from unpruned second logs have been made on the assumption that a third of the final-crop trees would yield a high proportion of Factory grade, and that the deep green crowns which would presumably result from the heavy thinning would increase the amount of Dressing grade recovered in comparison with the results from comparable log-height classes of the grade-study trees.

Timber-grade outturn from the third log-height class has been assumed to have improved in comparison with that in the grade study, by reason of the greater persistence of green branches. Degrade from cone holes has been assumed to be the same as that found in the grade study.

No improvement in estimated grade recovery has been allowed for the logs from the fourth and higher log classes. There would probably be very limited encasement of the knots, but branch size may increase considerably, and cone-stem holes will still be present in these logs.

Natural Pruning of Radiata Pine

Brief mention must be made of natural pruning of radiata pine grown in forest stands in New Zealand. Small areas, or relics of former larger areas, were examined at Tapanui and Hanmer Forests in South Island, and at Waiotapu and Whakarewarewa Forests in North Island. These stands ranged from 48 and 55 years of age,
and were the oldest forest stands of the species known to us; thinning, if there had been any, had been very light. *Sirex* mortality and wind-throw had been effective in reducing stocking to about 70-100 stems per acre in the North Island stands.

The average branch length of the South Island trees is considerable (Weston, 1957, photo 1), and their branches have not apparently been reduced to any degree in either extent or number. The North Island stands appear to be far more advanced, in that the branches are mainly restricted to stubs 3-9 in. in length. These stubs are, however, persistent. Pruning by falling trees has been considerable, as has been consequent damage to the trunk. The outstanding feature of old trees is the very persistent stem cones. The Waiotapu Forest stand, planted 1906 and situated in an area possessing a peculiarly moist microclimate, had the cleanest stems of all, and some stems were clean of most branches up to 20-40 ft, but they were not clean of stem cones. It appears that these cones will eventually rot off at about two-thirds of their length, leaving their stalks and basal scales still on the tree. Considering the current bark thickness, the length of the remaining branch stubs, and the relatively low rate of diameter increment, it will be decades before these trees produce clear timber. Therefore it is useless to wait for natural pruning when there is normal stocking of radiata pine, and in North Island at least, mortality caused by *Sirex* will prevent maintenance of a very high initial stocking.

**DISCUSSION**

An account of a timber-grade study has been presented, and the limitations and qualifications of the results have been given. The results showed the relative importance of the various defects that occur in radiata pine, and also the effects of a conservative tending regime. The requirements for final crop trees were then outlined, if the known causes of degrade were to be reduced to a minimum. Typical past and present tending regimes have been presented, and a forecast made of the probable future timber yield from one of them. The discussion that follows is based on these three main themes.

It is apparent from table 2 that the tending of compartment 9a has not resulted in any marked improvement of the overall timber-grade yield, when a comparison is made between the grade-study results and the overall grade yield of the mill, which is based mainly on logs from untended stands. References dating back to 1928 mention the urgent necessity of the thinning of our exotic forests, and there seems to have been a belief that any thinning is better than none. Entrican (1957, page 9) states "... with few exceptions, silvicultural operations have been carried out at a heavy net charge against the forest. Little attempt has been made to justify the expenditure by speculative estimates of the improvement to the value of
subsequent thinnings and the final crop..." He also says that the early silvicultural attempts were to be regarded as experimental, and were to provide information for future management. Interpreting the grade-study results in this spirit leads to the conclusion that tending is a waste of money if it is mistimed and too light in intensity. The speculative estimate of future grade returns made here shows, at the very least, that the recent tending schedules will result in the production of a high proportion of clear timber.

The greatest difficulty hitherto encountered in growing good-quality radiata pine has been lack of fundamental knowledge of the factors affecting timber grade, although these have been pointed out, for example by Reid (1953). This ignorance leads to delay in carrying out a first thinning until a top height of over 40 ft (or in order to gain a market, of over 60 ft) has been reached. Such delays are so detrimental to the stand that much of any subsequent tending will inevitably be second rate. In closed stands, radiata pine with a top height of over 40 ft will have 5-15 ft of the crown in dead branches. When the first thinning is delayed to 60 ft, the dead-branch zone can reach 25-30 ft, since the rate of death of the lower crown is accelerated during this period of rapid height growth. Attempts to overcome this rapid death of the lower crown by pruning selected final-crop trees only leads to a disappointing stand when thinning has been delayed, as the pruned trees are often suppressed by vigorous trees of poor form. The intense competition and early death of the lower crown between 20 ft and 50 ft top height make heavy and early thinning essential. The grade-study stand was thinned too late and too lightly, and deterioration of the quality of the butt and second log had already begun.

It is misleading to discuss the tending of radiata pine without linking pruning and thinning operations. We agree with what has been expressed often before (Reid, 1953, et al.), that the great merit of the species lies in producing large volumes of clear wood in a relatively short time. In the grade-study stand the low pruning to 8 ft was about 6 years too late; the branches were dead and the diameter growth rate of the butt logs was slowing down, the combined effect being an unnecessarily wide knotty core, which contained encased knots and was likely to occlude relatively slowly. The 1960 schedules for Southland should give a much improved result with a knotty core to 7 ft of less than 6 in. diameter.

The second and third thinnings of the grade-study stand are generally acknowledged to have been too light, and are not worth much comment. It is of interest, however, to see that the proposed thinning in the 1953 Pomahaka Working Plan does not differ very greatly from those given to the grade-study stand; the stocking at 45 ft is 15 percent less; at 80 ft, 11 percent less, and at 105 ft 10 percent greater. It seems likely that this schedule would lead to a repetition of the grade results achieved in the first-rotation stand studied.
The two 1960 thinning schedules (Rotorua and Southland) show much earlier thinning, linked with low or intermediate pruning, which will result in the retention of a green crown down to the top of the pruned zone—a sensible objective. The considerable divergence between the two schedules is of interest as it reflects the differences in market available to the two areas. The Rotorua schedule has been able to exploit a market for pulp logs by thinning at about 65 ft, whereas the Southland schedule has an earlier and heavier first thinning, and delays (to about 86 ft) the second thinning, in order to obtain sawlogs. The 1960 Rotorua schedule has at least 50 percent fuller stocking than the 1953 schedule, but calls for thinning to this level at 12 ft lower top height.

The principal objection to the heavy early thinnings called for by both the 1960 schedules is that the chance to select trees will be limited; the trees will be only 20-30 ft high at the first major thinnings. In Southland site conditions, particularly wind, have presumably led to the requirement for spacing equivalent to 6 × 6 ft for the original stocking, compared with 6 × 8 ft in Rotorua. The South African practice of starting with a stocking of about 530 per acre is followed on occasions in New Zealand where stem form is sufficiently good.

The 1960 schedules would seem to be relatively conservative once the trees reach a top height of 90 ft. It is possible that final-crop stockings of less than 80 stems per acre will be retained at this stage.

One method to achieve satisfactory selection of stems to produce the important second and third logs (important because they will not necessarily be pruned) would be: a poison thinning to be accomplished at the height prescribed for first thinning in the 1960 schedules, and further poison thinnings at intervals thereafter of not more than two years. The aim of these subsequent regular poison thinnings would be to liberate those trees selected to provide satisfactory second and third logs from the competition of coarse, poor form stems which would otherwise achieve dominance. Radiata pine grows from 20 ft to 90 ft within 15-18 years or, putting this in another way, produces a new length of saw-log every three years. The scheme outlined here is idealistic, but would have an advantage in retaining an intermediate crop which could be extracted if markets became available.

Olsen (1961) proposes to overcome the problem of improving the third log-height class by calling for pruning to the 50 ft level. The presence of stem cones complicates grade returns from the third log, and despite thinning schedules devised to maintain long green crowns, Dressing grade may not be produced. The upgrade by pruning from Merchantable to clear, instead of Dressing grade to clears, may justify this operation.
Entrican (1957) has already given the final answer to the problem of utilising the top logs of radiata pine, which as he points out are much more suitable for pulp logs than for sawlogs. Unfortunately, at present this solution applies only to the three integrated mills; although these mills currently produce between 40 and 45 percent of the total exotic-timber cut. Outside the pumice lands of North Island, the exotic forests are too small to present full scope for large, integrated utilisation plants. Grainger (1961) has calculated that in the year 2050 70 percent of all logs will still be required as sawlogs. These scattered forests will continue to be utilised by relatively small mills cutting up to 15,000,000 bd.ft. each year. The disposal of low-grade timber from such units will be a difficult problem.

For forests supplying non-integrated mills, the question of cone-stem holes in the green crown is relatively straightforward: if tending is delayed and branches die the resultant timber will be suitable only for framing; if tending is correctly timed, the trees will retain deep, green crowns and may or may not possess degrading small branches or stem cones. It will still be necessary, as for Corsican pine (Fenton, 1960), to thin to maintain the deep crowns, but careful tree selection, in line with that outlined earlier, must be made in the later thinnings in order to maintain grade quality. Death of the branches of the lower crown in the last 10 to 15 years of a tree’s life will not be a serious matter, as the affected portions of the log will be removed in a sawmill.

Further industrial developments, such as the expansion of production of finger-joined boards, may swing preference for tree types back to the uninodal form. Basically the short clears produced in Factory grade are of the highest quality and much superior to Dressing grade. Because we face an extreme shortage of clear wood in the next four decades it may be preferable to obtain an interim production of admittedly high-cost clears to maintain the market, while the clear timber aimed at by the 1960 schedules is actually growing.

The grade which causes most complaints in radiata pine is Dressing grade, and as Ward (1957) has pointed out, this grade should now be defined more rigorously. Undoubtedly the maximum admissible knot size must decrease, and a ruling to govern the maximum number of allowable defects must be introduced.

It appears that New Zealand foresters are adopting heavy thinning schedules with extensive pruning in the belief that production of clear wood is the logical final product of the management of radiata pine.

In contrast with South African development, we have reached this stage empirically, as a result of our experience; there has been no deliberate attempt to set out to grow trees of a certain type or size. It must be frankly admitted that we do not know many of the important variables involved in following these regimes. The most important unknowns are the effect of pruning green branches on growth rates of
individual trees under our exceptional conditions, the development of branch size and condition in heavily thinned stands for the vital stage of growth between 6 and 20 years, and the subsequent development of diameter increment on selected final-crop trees. We grow a species with a phenomenal growth rate which still produces a remarkably versatile timber. This same growth rate prohibits any timid or half-hearted tending – defects appear within two years of mistimed tending. We cannot afford to let our second rotation go untended, or to wait for perfect data to guide our silviculture; but we have the compensation that sawmill results will show within two decades whether the new schedules will be successful.

The New Zealand forester has in the past been too much concerned with producing stands of high volume; he is only now beginning to learn how to grow this remarkable species, and it is now time for him to change the emphasis to growing timber of good quality.

REFERENCES