FOREST RESEARCH INSTITUTE SYMPOSIUM ON
PRUNING AND THINNING

R. N. JAMES, J. R. TUSTIN and W. R. J. SUTTON*

SYNOPSIS

A symposium to discuss pruning and thinning was held by the Forest Research Institute, Rotorua, in March, 1970.

Future wood requirements were predicted to double from the year 1970 to 2000; during this period the proportion of sawlogs would decline from 74% to 51% of total wood production, while pulpwood would increase from 24% to 47%. It was stressed that New Zealand must consider carefully the types of forest products to be exported. To meet the range of specifications for different end products, advantage should be taken of the two extreme tree types in radiata pine — the unimodal and multimodal.

The economics of pruning are greatly affected by the timing of all operations. The result of any pruning is the production of considerable quantities of clear cutting grades.

Forest managers have often paid insufficient attention to markets in formulating production thinning prescriptions, and have frequently not defined adequately what was meant by an "economic" production thinning. The effect of thinning on main crop values should be studied in any such evaluation. Many delegates favoured production thinning on tractorable country, but there was general agreement that the difficulties of steep country thinning were best avoided by the use of a silvicultural regime which concentrated on clearfelling. Overseas trends towards complete mechanization in harvesting are expected to have only a small impact on New Zealand practice.

Basic in the determination of tending schedules are the end use objective, overall profitability, and recognition of the manipulative possibilities of initial spacing, pruning, thinning and tree morphology. For example, an optimum regime for production of boards is one with wide spacing and early heavy thinning to ensure maximum diameter growth on final crop trees with well-pruned butt logs and, where possible, unimodal second logs. It was not resolved whether satisfactory production of framing and board grades could be achieved by the same regime.

Efficient implementation of silvicultural schedules requires an objective method of programming stands for treatment, and a skilled, motivated labour force in balance with supervisory staff. Control systems should include well-defined, easily-assessed quality standards and be directed towards the

*Scientists, Forest Research Institute, Rotorua.
achievement of overall management goals. The latter should be well thought out and clearly stated.

The symposium revealed a substantial diversity of opinion on how man-made forests of exotic conifers should be grown and tended. It did emphasize, however, that if future markets could be defined, positive pruning and thinning operations could play a major role in the achievement of quality and profitability objectives.

INTRODUCTION

The New Zealand Forest Research Institute held a second symposium on pruning and thinning at Rotorua during the week 16-20 March 1970. The proceedings were attended by 124 delegates representing State and private forestry and utilization interests, and included 10 delegates from Australia and two from South Africa. Fifty-six papers were tabled for discussion together with the collated replies to a questionnaire circulated prior to the meeting to all participating organizations. As well as the discussions, field trips to Kairanga Forest and the Timber Industry Training Centre sawmill were arranged. Discussions during the symposium, predominantly on radiata pine, were lengthy and covered all aspects of pruning and thinning. The proceedings will in due course be published in the FRI Symposium series. The intention here is to present a summary of the more important points. In a condensed version such as this it is inevitable that a good deal of useful discussion and data are left out. The authors apologize for any omissions or misrepresentations of statements by participants.

The discussions were divided into five sessions:

A. Future requirements and quality specifications
B. Silvicultural aspects of pruning and thinning
C. Economic aspects of pruning and thinning
D. Review of silvicultural schedules
E. Methods of implementation and control

This summary follows that sequence.

Changes Since the Previous Symposium in 1963

As a prelude to the discussions, R. T. Fenton briefly reviewed the major changes that had occurred in New Zealand forestry since the previous symposium. These included a greatly increased planting rate and increasing emphasis on radiata pine. The average annual planting of radiata pine in State forests during the period 1964-68 was 15,065 acres (71% of total area planted), which is three times the mean area for the period 1958-63. No data were available for private planting. In 1965 a needle disease caused by Dothistroma pini was discovered. This affects radiata, Corsican and ponderosa pines. It is controllable, but while Corsican and ponderosa pines are susceptible throughout their life, the fungus attacks
radiata pine only up to about 14 years of age. This confirms radiata pine as the major species for future afforestation.

Development of pruning has paralleled that of planting; both the area pruned and the emphasis on radiata pine have increased. In State forests pruning is now concentrated on the butt log (to 18 ft) and there is an increasing tendency for this work to be done under contract, especially in larger forests. Thinning to waste is now carried out predominantly by power saws rather than axes or by poisoning. Extraction thinning of pine stands of 100 ft top height or less is still limited, the quantity of radiata pine thinnings produced being less than 2% of total production from State forests.

The structure of the forest utilization industries is still basically the same as in 1963. Three large concerns dominate: two pulp and paper companies producing largely complementary products, and the State. Production of pulp and paper has risen steadily since 1963, annual production in most categories having increased between 50% and 75%. Production of panel products remains low in comparison with that of other industrialized countries, and plywood and veneer production has actually fallen since 1963. Production of Douglas fir sawn timber has increased substantially, and radiata pine saw timber is now produced at about 420 to 470 million bd. ft per annum. Douglas fir is still sold ungraded. Figures for radiata pine timber production by grades are not available nationally, but data from the largest mills (40% of total cut) indicate that the breakdown by grades is:

<table>
<thead>
<tr>
<th>Grade</th>
<th>% of Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1 Framing</td>
<td>30%</td>
</tr>
<tr>
<td>No. 2 Framing</td>
<td>10%</td>
</tr>
<tr>
<td>Box (1 in. and 2 in.)</td>
<td>40%</td>
</tr>
<tr>
<td>Factory and Dressing</td>
<td>10%</td>
</tr>
<tr>
<td>Merchantable</td>
<td>10%</td>
</tr>
</tbody>
</table>

A noteworthy development is the production of sawn baulks for Japan. Timber price control was lifted in December 1965.

Perhaps the most outstanding development since 1963 has been the log trade with Japan; this has grown rapidly from 9.7 million cu. ft in 1963 to 59 million cu. ft in 1969. It is highly profitable to the forest grower and provides a yardstick for comparison with other markets for wood.

The problem of an increasing supply of small sawlogs and their high cost of conversion has not been solved. Nor have tolerances for poor log form been economically defined.

Progress in research has included developing a uniform system of grade studies as a research tool, and defining by log height class the relative cost of production of some board-veener, pulp and other regimes. Economic analysis by the budget approach has defined the relative importance of all direct variables in costs and returns for a number of management regimes.
FUTURE WOOD REQUIREMENTS

Quantities and Types of Product

G. J. Yska outlined forecasts of future wood requirements up to the year 2000. The total volume required from exotic plantations in New Zealand is predicted to rise from 229 million cu. ft per annum in 1970 to 464 million cu. ft per annum in 2000. Of even greater interest to forest growers was the predicted change in end use. The proportion of the total cut required for sawlogs would decline from 74% to 51% by 2000, but pulpwood, which in 1970 would comprise only 24% by volume, was expected to rise to 47% of total cut in 2000. It was stressed that these forecasts rest on two major assumptions: that present trends towards greater industrial processing would continue, and that export markets are assured. Neither of these assumptions can be taken for granted, and in fact after 1980, when current plans for the expansion of the pulp and paper industry expire, the emphasis could conceivably change. No regional breakdown was attempted, but replies to the questionnaire indicated wide regional variation in expected wood usage. Log exports were predicted to decline to 2 or 3% of exotic forest production by 1980.

There was considerable discussion about wood products New Zealand should aim to export. Fenton produced data showing prices for ply logs (up to 57c NZ per cu. ft) and pulpwood (14c to 18c per cu. ft) in the U.S.A., pointing out the relatively low value and abundance of pulpwood. He suggested that the rapid growth rate shown by radiata pine in New Zealand could best be utilized by growing clear timber — a commodity he claimed would be in increasingly short supply overseas. It was argued that a high degree of industrial processing was in the national interest, but this was challenged. P. F. Olsen, obviously speaking with a good deal of support from forest growers, suggested that forest owners would be poor businessmen indeed if they did not sell their wood for the best price; this could mean selling logs to Japan or for veneer to the U.S.A. rather than to a local sawmiller. The discussion proved inconclusive, and delegates admitted that they were “equally unhappy” over the questions of future markets for their wood and of which products they should be trying to grow.

Quality Specifications by Product

An attempt was made during this part of the symposium to define tree and log characteristics desirable for the production of various products. Sawlog specifications were outlined in a paper given by B. Lonn. He stated that dimension and form influence the quality of logs, particularly for peeling; they also affect the cost of sawing. A common cause of degrade is large knot size; intergrown knots of 4 in. diameter were permitted in dressing grade, 3 in. for finishing, but only 1.33 in. for 4 × 2 No. 1 framing. For veneer production, tolerances depend on grade, but for individual grades the maximum
allowable size is 1.5 in. or greater. A paper by T. R. Cutler outlined the opinions of the Commercial Division of the N.Z. Forest Service. He stressed the importance of quality and cost of sawn timber in competition with substitutes. This led to a discussion of the unsatisfactory record of New Zealand framing timber exports to Australia. Poor kiln drying techniques with associated high costs, price competition from green Oregon and hemlock imports and green indigenous hardwoods, and lax New Zealand framing specifications were all blamed by different speakers. The permanency of present specifications for No. 1 framing was questioned. Work by the Economics section of FRI has indicated that trees yielding a high proportion of No. 1 framing, as defined at present, will be expensive to grow. It was pointed out by I. D. Whiteside that grading rules are always a compromise between what is produced and what the market requires; the rules would be altered if future supplies contained knots predominantly greater than the maximum allowed at present. This opinion was strongly contested on the grounds that New Zealand framing specifications are not now especially strict, and that relaxation of them would encourage substitution from other materials, and place further restraints on exports.

Log specifications for producing clear timbers were discussed and further marked divergencies of opinion were revealed. Production of clear timber by recutting and finger-jointing was advocated by J. Murphy, while W. R. J. Sutton advocated using early pruning regimes. Sutton stated that pruning would add only about 2c per cubic foot to the cost of the crop. In the U.S.A. the current usage of clear timber is 4,500 million bd. ft — a colossal quantity in comparison with New Zealand's future potential production. In view of this, exports of clear timbers seem assured.

Data which confirmed Lonn's observations on tree form were presented by Sutton, showing that the larger the log, and the shorter its length, the less a given amount of sweep will affect recovery. The questionnaire returns showed that many organizations feel forks can be tolerated at harvest if they are above the first two log lengths. However, forked trees are always a bad risk in plantations as they are liable to wind damage. Although log size was recognized as the most important single factor in influencing the cost of sawing, no precise definition of the optimum sawlog size could be given. It was also recognized that every set of equipment has an optimum sized log, and conversely that equipment could be designed to fit a specified log size. The limited data presented indicated that sawing costs are relatively high for logs less than 10 in. s.e.d.

Quality specifications for pulpwood were outlined by R. L. Bryant. He considered that groundwood will continue to be produced by the stone grinding process for some time; disc refiners produce a stronger pulp, but this is outweighed by the higher cost of production. Stone groundwood requires a compromise in wood density characteristics; a high density results in a higher pulp yield, but a lower-quality pulp.
low heartwood content is essential in order to minimize resin content and to give a lighter-coloured pulp. Small branches, rather than large, are preferred; they have better grinding characteristics and contain less resin. Log diameter should be between 6 in. and 14 in. The implications of this analysis are that trees for groundwood should be young, and thus rotations should be short.

Specifications for kraft pulp vary with the end use (paper bags, containers, etc.), but these are controlled during the pulping process, and therefore log specifications can be less strict than for groundwood. The main need is for uniformity of raw material supply.

R. T. Fenton expressed disappointment at the way in which wood properties for the two main pulp types had been defined. He said that, although it was forecast that half of New Zealand's annual exotic wood production would be pulped by 2000, no information had been given which indicated the relative costs of wood, power, chemicals, depreciation or labour per ton for any pulp type. It was considered that these data were essential for rationalization of pulpwood silviculture.

There has recently been an increase in production of re-manufactured wood products in New Zealand. Structural members such as laminated beams or roof trusses require high quality timber, but bonded-board and other similar products can be made from much poorer material. These two products are to some extent complementary and, if made in the same plant, log supply presents no problems.

The use of panel products is as yet relatively minor in New Zealand. There is, however, a potential market in the U.S.A. for baled veneer. Plywood logs should be straight and from 15 in. to 18 in. s.e.d. inside bark. Logs for the manufacture of particle board should have a high moisture content, a density of 23 to 28 lb/cu. ft, and be free from rot or stain.

SILVICULTURAL ASPECTS OF PRUNING AND THINNING

During this session discussion concentrated on the silvicultural and pathological considerations which could limit the size, shape or quality of trees in the crop, and the extent to which crops could be manipulated in order to achieve set objectives.

Criteria for Selecting Crop Trees

The relationship between tree morphology and desirable characteristics for the various end products was outlined by C. J. A. Shelbourne. Two distinct morphological types of radiata pine can be recognized; multinodal and uninodeal. The multinodal type, with smaller branches, is suited to products requiring a small knot size such as framing, groundwood and some veneers; while the uninodeal type, which is characterized by long internodes of clear timber between annual whorls (particularly in the second log section — 20 to 40 ft), is more suitable for producing factory grade boards
and clear veneers. Control of branch characteristics can be obtained over the bottom log of either tree type by pruning. Fundamental to both types of tree, and for all products, is that the stem should be free of malfunction, and should be straight, and that the tree should be fast growing. The order of economic importance of these characteristics was outlined in a paper by J. M. Valentine and J. R. Tustin. Studies by the Economics Section of FRI have shown that, for sawlog production from trees pruned on time, about 70% of the gross value is contained in the first 40 ft of stem. Selection of trees for the final crop should therefore be based on the characteristics of this section of the stem. It is considered that first in importance is stem straightness, secondly tree vigour, and thirdly a clearly dominant leader (especially if selection is undertaken before the full second log is formed). Where sufficient trees are available, further selection should be for either a strongly multinodal or uninodal type, since trees with intermediate branching patterns produce less satisfactory grades for both framing and boards.

Some surprise was voiced at the ranking of vigour as only the second most important selection criterion, because of loss of dominance following pruning. However, evidence from FRI thinning trials in radiata pine was produced to show that vigour could be induced and maintained in the pruned crop by thinning release.

The importance of even spacing of crop trees has possibly been over-stressed in the past. The number of acceptable crop trees, and the degree of malfunction, vary with site. Data from permanent sample plots of radiata pine were presented. At 18 ft top height, in stands planted at 6 ft × 6 ft, the number of acceptable trees on coastal sand sites was 450 per acre, but only 250 per acre on pumice soils in the central North Island. There is also variation with terrain; in Kaingaroa Forest the highest number of acceptable stems is found on steep slopes, and the least on flat areas. It was generally agreed that, where stands are planted at 8 ft × 6 ft spacing, sufficient crop trees could be found on all sites. There were some suggestions that, in many cases, fewer trees could be planted.

Establishment, Stocking and Dominance

The effect of establishment practices was discussed in a paper by J. M. Valentine. He concentrated on "tree effectiveness" and the practice of blanking, or replacing trees which die after planting. Blanking is carried out in order to maintain a uniform high initial stocking. Reasons for the practice have been: to provide enough trees for adequate crop selection; to control branch growth on crop trees; to provide intermediate yields; to control weeds by canopy closure; and to provide insurance against losses. Recent investigations have shown that in some circumstances blanking has achieved none of these. Crops are normally blanked one year after the initial planting, when site conditions offer greater competition.
Blanked stock is sometimes one year younger (1/0 instead of 1½/0 or 2/0 seedlings) than the originals and therefore smaller. Blanking is also often carried out at the beginning of the planting season with insufficiently hardened trees, and mortality can be high. Height growth lags behind the originals, and therefore any crop selection with vigour as an important criterion tends to reject blanked trees. Attempts to determine whether blanked trees affect branch growth of the original planting gave inconclusive results. Some indication of the effect of stocking on branch size has been obtained from a thinning trial in natural regeneration, with an original stocking of 6,500 s.p.a. Three plots were thinned as follows:

(a) to 600 s.p.a. based on uniformity of height.
(b) to 960 s.p.a. based on uniformity of height.
(c) to 960 s.p.a. based on vigour

Five years after thinning, 100 dominants per acre were measured in each plot. Mean size of the largest branch per tree in (b) was 1.17 in., but (a) and (c) had the same mean branch size (1.36 in.). This suggests that the 360 additional trees in (c) lagged so far behind the dominants that their influence on the crop was negligible. It is suggested that, as a general rule, trees only one-half to two-thirds the height of dominants have little or no influence on the branch development of crop trees. The Chairman said that they might as well not be there.

Changes in dominance during the early life of radiata pine stands were documented for Woodhill and Kaingaroa, respectively, by I. P. Armitage and W. R. J. Sutton. In both areas it was found that up to about 30 ft top height there is a tendency for co-dominants and sub-dominants to move into higher crown classes; thus, during this early period the number of dominants per acre increases. Armitage found indications that, where stands are pruned, the tendency of pruned co-dominants to move up into the dominant class is proportional to the density of pruning. There is, however, a suggestion that after 30 ft top height competition becomes stronger and the number of dominants per acre decreases. Armitage suggests that an increase in the number of stems pruned to 8 ft may ensure that subsequent selections will always be from pruned stems. A more direct approach would be to thin out all unpruned stems and remove the threat of competition to the pruned trees.

*Genetic Improvements in Tree Quality*

A paper by C. J. A. Shelbourne outlined the extent to which genetic improvement could increase the number of acceptable trees. Use of control-pollinated progeny from seed orchard clones resulted in trebling the number of acceptable stems, in comparison with normal tree stocks from bulk seed collections. The major gains were in stem straightness, freedom
from butt sweep, and absence of forks. There was little improvement in branch size. Results from similar studies in Australia are similar, according to A. Brown (FRI, Canberra). On this basis it appears that initial stocking could well be reduced by the use of superior stock, but replies to the questionnaire revealed there was a good deal of disagreement as to how low it would be practical to go — estimates ranged from 150 to 500 s.p.a. for radiata pine.

No information was available about cuttings, but indications of their characteristics were obtained from a limited comparison between grafted stock and normal seedlings by W. R. J. Sutton. The grafts examined had less taper and fewer branches per whorl, but more whorls and more branches per unit of length. Branch diameters were smaller but there were many more stem cones. Stem deviation and malformation were negligible. Serious doubts about the quality of wood from trees grown from cuttings was expressed. The presence of stem cones low on the stem rules out production of high grade boards; there are indications that pruned stem cone holes do not readily occlude. If cuttings were planted at wider spacings to take advantage of improved form, the maximum branch sizes would still be large enough to reduce the production of high grade framing timber.

E. H. Bunn emphasized that, if increased tree acceptability permitted a reduction in initial stockings, the other reasons quoted for maintaining high stockings must be rationalized. These are discussed in the following sections.

**Stand Density Considerations**

Branch size can be controlled in two ways — by pruning or by close spacing. Branch size before pruning could affect the cost of pruning and the size of occlusion defects. This was of concern to H. A. Luckhoff (South African Forest Service). However, experience in New Zealand suggests that any increased cost will be small, since if pruning is carried out early (for example, to 6 ft at less than 18 ft top height), variation in branch size will be small whatever the stocking. According to a paper by J. A. Thomson, provided the tool used is of adequate capacity, the cost of pruning was more in proportion to the number than to the size of branches. There was no information about the necessity to plant at close spacing in order to control branch size if pruning to 18 ft is carried out on time. However, in their reply to the questionnaire, H. Baigent and Sons Ltd. prescribed an initial stocking range of 500 to 750 s.p.a. specifically to control branch size for production of framing timber. Work by Sutton shows that branch size is greater at lower stockings, but there is also a good deal of variation between sites. This holds good for 12 spacings in 6 forests. An examination of the mean diameters of the largest branches 15 ft to 20 ft up the stems of dominants in stands planted at 8 ft × 8 ft spacing showed the following:

<table>
<thead>
<tr>
<th>Forest</th>
<th>Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodhill Forest, Auckland Conservancy</td>
<td>1.35 in.</td>
</tr>
<tr>
<td>Eyrewell Forest, Canterbury Conservancy</td>
<td>1:38 in.</td>
</tr>
</tbody>
</table>

33
Ashley Forest, Canterbury Conservancy 1.50 in.
Kaingaroa Forest, Rotorua Conservancy 2.55 in.

An important observation is that even at extreme rectangular spacings (up to 24 ft × 6 ft) between-row and within-row branches are the same size. For such spacings, the mean branch size is the same as for square spacings of equivalent area. This finding is important since significant economies can be made both in initial establishment and in subsequent tending operations if rectangular spacing is adopted. It is also apparent that branch size control may be lost when the stand is thinned. A study by R. N. James and J. R. Tustin showed that, in one case involving a very heavy thinning in radiata pine, branches responded to the release by an increase in diameter after their growth had been checked. The response, which occurred in most of the larger, lower branches which were alive at the time of thinning, was of the order of ½ in. Other work indicated that final branch diameter in thinned stands is likely to be smaller than if stands have been established at a spacing equivalent to that produced by thinning. Response of branches to fertilization of the crop was not clear, and some observers considered it resulted in elongation rather than in increased diameter.

Another reason given for high initial stocking is to obtain intermediate yields. Both M. Hall (Australian Paper Manufacturers Pty., Australia) and M. Calsaferrì confirmed that this was their aim in establishing forests at 7 ft × 7 ft spacing. The forests concerned are both close to the processing plants, and the cost of wood from alternative sources is high. A solution proposed by N. A. Barr was to obtain intermediate yields from animal grazing under stands established at wide spacing.

Following planting, the growth of weed species such as gorse and blackberry can restrict access for tending operations. Solutions proposed by some organizations were bonus payments to workers (N.Z. Forest Products Ltd.), clearing vegetation by tractor (Nelson Conservancy), or growing a crop that does not require pruning (H. Baigent & Sons Ltd.). Grazing within the stand may also be effective, but for this, as for tractor clearing, wide spacing between rows is generally necessary.

Pathological Considerations

There are no absolute pathological limitations to silviculture, according to C. Bassett. Because of the presence of *Dothistroma pini*, New Zealand forestry has turned further towards monoculture of radiata pine. He propounded the hypothesis that pruning the infected crowns in August and September could prevent *Dothistroma* from spreading to other parts of the same tree, and thus reduce the general level of the disease. *Sirex noctilio* populations tend to build up in areas where pruning or thinning to waste has been carried out in summer. However, at the moment *Sirex* populations are very low, especially in the North Island, and are of no con-
cern. Damage to residual crop trees is widespread in stands that have been production thinned; the significance of this, particularly the damage to the thin-barked upper stems, in terms of grade and value loss, has not been determined.

**Effects of Wind**

Two papers, by C. G. R. Chavasse and K. C. Chandler, dealt with the effect of wind on stands. Chavasse concentrated on “toppling” in young stands. In some cases up to 70% of trees were affected. Toppling leads to butt sweep, and in one case, at Ashley Forest, first thinning yield was reduced by 27% because of this. Toppling is related partly to soil conditions, and partly to the quality of planting, especially distribution of roots. Chandler outlined wind damage in older stands. In his studies the critical height, above which trees are susceptible to windthrow, was 50 ft to 60 ft. Stability of stands can be increased by early heavy thinning, but this must be carried out at least two years before the critical height is reached, to allow time for the stand to stabilize. During discussion it became apparent that the larger the diameter of the tree in relation to height, the more stable it is. However, another way of avoiding windthrow is to refrain from any thinning, although the small diameter trees resulting from this would be less valuable. Where deep rooting occurs, as on sands, breakage is more common than windthrow, and trees damaged in this way are more difficult to salvage than those uprooted. Chandler did not find any evidence that the main cause of resin pockets in timber was due to exposure to wind. This may conflict with earlier findings in Canterbury.

**Fire Protection**

Fire protection is often quoted as one of the reasons for 100% low pruning. It was reported that in Australia fires had reached the crowns via isolated unpruned trees. One major New Zealand forest owner has adopted this practice, partly for fire protection, while another prunes all trees in the two outside rows adjoining all roads. In State forests 100% pruning is adopted only adjoining areas where the public have access — for example, near the beach front in sand dune areas.

**Yield and Stem Form**

Yield prediction was discussed in two papers by J. Beekhuis and A. G. D. Whyte. Beekhuis outlined modifications he is currently incorporating into his original variable density yield tables. These include the use of multiple regression techniques, to replace graphical methods, and in order to incorporate additional variables; a stand index to permit estimation of the effect of malformation and of losses due to felling damage; use of the Beta distribution for analysing diameter distributions; and standardized height/diameter curves. These will permit estimations of extractable yield and piece size.
The advantage of the variable density yield table approach is that it can be used to project yields for any age, and for most thinning regimes. However, recently proposed heavy thinning regimes fall outside the data on which present studies are based, and the method does not cover thinnings other than the orthodox “from below” type. Whyte, in his paper, indicated some dangers in using methods based on stand averages, and suggested that stand table projection methods might be more accurate in predicting final piece size and diameter class distributions.

Evidence that severe thinning may influence the distribution of volume along the stem was given by Fenton. Detailed log measurements taken from sawing studies of radiata pine have revealed significant departures from taper tables derived from unthinned stands. Total stem volume remains much as predicted, but the proportion of the volume in the lower sections of the stem is greater. From the financial point of view this is desirable. Deviation from predicted taper was greatest in large trees.

**ECONOMIC AND PHYSICAL ASPECTS OF PRUNING**

**General Considerations**

In a background paper to this subject Fenton reported “. . . that up to 1966 only 22% of the area pruned in State forest was of radiata pine. . . . Pruning from 1967 onwards can often be anticipated to give better results, though most regimes proposed envisage production thinning and consequently 40 to 100% longer rotations than the minimum necessary to produce 23-24 in. d.b.h. trees. Hence little exotic clearwood will be available for over thirty years, unless stands on high quality sites, pruned to 18 ft by a reasonable schedule, are allowed to grow faster [in diameter], whereby clearwood yields may be available in twenty years’ time”.

Second log pruning, which was shown to be of doubtful economic value, even for radiata pine, at the 1963 symposium, has in some places continued. “From 1966, second log pruning has been concentrated mainly in the South Island . . . [where] 900 acres of Corsican pine . . . and 1,112 acres of radiata pine [have been pruned] . . . as against 272 acres of radiata pine in the North Island.”

**Objectives of Pruning**

Most organizations considered that the primary objective of pruning was the production of clearwood, or the obviation of degrade. The exceptions would be some Australian States, where pruning is undertaken primarily for fire control. Secondary justifications are many, and these are discussed later.

**Improvement Resulting from Pruning**

Data from sawmill studies were presented by Fenton. The first product laid down on the stem after pruning is factory
grade. At least two, and up to nine (or occasionally more) 1 in. boards sawn immediately outside the knotty core include some defect, but have long clear cuttings. The more belated the pruning, the lower the yield of full length clears and the higher the proportion of factory grade. Even with reasonably well-pruned logs, the factory grade proportion is still high. Results from sawing large dominants, pruned a little late by today's standards, from Compartment 28, Waiotapu Forest, were:

<table>
<thead>
<tr>
<th>Butt logs</th>
<th>Whole tree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(5 logs)</td>
</tr>
<tr>
<td>Clear</td>
<td>37%</td>
</tr>
<tr>
<td>Factory grade</td>
<td>32%</td>
</tr>
<tr>
<td>Dressing grade</td>
<td>11%</td>
</tr>
<tr>
<td>Merchantable</td>
<td>8%</td>
</tr>
<tr>
<td>Box</td>
<td>12%</td>
</tr>
<tr>
<td>Framing (2 in. sizes)</td>
<td>—</td>
</tr>
</tbody>
</table>

For the whole tree, the proportion of factory grade is thus almost twice that of full length clears, and even for the butt log the percentage of clears is only slightly greater than that of factory grade.

In discussion, the representatives of sawmilling and utilization organizations expressed concern at the high proportion of factory grade, claiming that it had a negligible market and was over-priced. Fenton's view was that this material was of high quality both in terms of its finishing properties and the yield of clear cuttings; the average clear cutting length in the butt log was 5 ft — well in excess of the minimum of 2 ft laid down in the grading rules. This material would be very suitable for finger-jointing and would certainly find a market, including exports — New Zealand was one of the few countries able to produce clears or clear cuttings in any quantity. Moreover, whether it was wanted or not, present pruning policy would result in a considerable yield of factory grade. Fenton did not consider factory grade was over-priced, and produced data from the U.S.A. which showed sustained price margins for this material over the last ten years.

Opinions varied as to what was the minimum tree size from which improved grade yields could be obtained following pruning. W. Robinson, from Queensland, considered that a tree of 12 in. d.b.h. would produce sufficient clears to offset the cost of pruning. From studies in New Zealand, negligible quantities of clears were produced from pruned trees of 14 in. d.b.h., and even trees of 17 in. d.b.h. normally produced less than 5% clearwood. Therefore pruning to upgrade trees likely to be removed in thinning is unlikely to be worth while in New Zealand. However, very little information is available on the optimum size of a pruned stem, either for sawing or peeling. Some results in New Zealand indicate that a mean d.b.h. of at least 22 in. is desirable, and that 24 in. or more would be preferable. The problem at present is that there are virtually no large trees with small knotty cores available for conversion studies.
On the importance of the size of the knotty core, Sutton presented results from a theoretical study, only partially supported from sawing studies, which indicated that, in order to obtain the same proportion of clearwood yield to compensate for an increase of knotty core diameter of 1 in., the final d.b.h. of the tree must be increased by 2½ in. This generally appeared to be consistent over the likely range of tree sizes in the final crop.

Low Pruning

Opinions varied considerably on how many stems per acre should be low pruned. T. W. Swale, advocating 100% pruning, claimed that it was as cheap as selection pruning, but this was challenged by D. A. Elliott on the grounds that work study had shown that the time element for walking and selecting trees, under normal conditions, was only one-fifth of the total pruning time. Representatives of Australian States claimed that 100% low pruning was necessary for fire protection, but Australian Paper Manufacturers, on the other hand, do practically no pruning. Among the justifications for low pruning large numbers of stems (400 s.p.a. or more) were: insurance against loss of dominance of pruned stems; improving conditions for mechanical harvesting; improving prospects for extracting post material; and the provision of employment for a minimum work force needed for fire protection during the fire season (Canterbury Conservancy). Where a small proportion of the stand is pruned (200 to 400 s.p.a.), selected trees are either clearly marked, or criteria for selection are well defined. In one forest low pruning is combined with thinning to waste all unpruned trees in one operation. Of the methods of selection, those based on the criterion of pruning all acceptable trees (normally all malform-free dominants and larger co-dominants) has merit. Of the systems in use, work by Sutton has shown that selecting the best two trees out of four was superior, but even this method would not ensure that every acceptable tree is pruned.

Studies by J. A. Thomson, in which all available tools for low pruning were tested, showed that Wilkinson pruners were superior for small branches, but where the maximum branch diameter was over about 1½ in. the No. 2 Porter pruner was the most effective tool. Saws are generally not favoured for low pruning.

Further Pruning of the Butt Log

Since the 1963 symposium there has been a move away from two-stage to three-stage pruning of the butt log. Reasons for the change are many, the important ones being: that a smaller knotty core is obtainable, the reduction being of the order of 2 in.; that with two-stage pruning two tools are usually required for the second lift, and thus there is little additional expense in making this two separate operations; that in some cases three-stage pruning may even be cheaper,
since the branches in the mid-log section are smaller than for two-stage pruning; and that the addition of another lift pro-
vides another opportunity for selection. The ladder and jack
saw method appears to be the most efficient way of pruning
these lifts. Pole saws, however, are still used extensively, and
have some support from contractors.

Second Log Pruning

Currently there are no organizations pruning second logs. Data presented to the 1963 symposium indicated that second
log pruning was not justified on economic grounds. However,
if short-rotation sawlog regimes are adopted, the larger
branches associated with heavy early thinning may result in
an undesirable increase in poorer grades in the second log,
and the position needs further study. An economic analysis
presented by Fenton showed that second log pruning for
this regime might be profitable.

“One-shot” Pruning

It was suggested by Bunn that selection of final crop trees
at a stand top height of about 35 ft, and pruning only these
to 20 ft in one operation, might save about $20 per acre. It
was not determined whether this estimated saving would com-
 pense for the poorer grade yields resulting from an esti-
mated increase of 3 in. in the diameter of the knotty core.
In practice, selection of final crop trees without low pruning
for access appears to be so difficult that the method is un-
likely to find favour.

Effects of Pruning on the Size of the Knotty Core, and
Subsequent Growth

Results from extensive pruning trials were presented by
W. R. J. Sutton and J. B. Crowe. These include relationships
from which to calculate the mean size of the knotty core
(defined as the diameter over pruned stubs) for any radiata
pine pruning schedule involving one, two or three lifts to
20 ft in planted stands. Results obtained by E. V. J. Purnell
from a similar trial in regenerated stands gave comparable
figures for all except the first lift, where the knotty core
diameter was about one inch smaller.

Sutton and Crowe also presented results on the effect of
pruning intensity on growth. In contrast with overseas find-
ings, they found that minimal removal of the green crown
resulted in some loss of both height and diameter increment,
but the losses were small. With the exception of very severe
pruning, normal increment of both height and diameter were
resumed within about 18 months. The effects of repeated re-
moval of the green crown are under investigation. Probably
more important than actual growth rates is the effect of prun-
ing on the dominance of pruned trees. Trials by the FRI
Economics section have shown that severely pruned trees
are capable of a considerable response to releasing by heavy thinning immediately after pruning, but it is not yet possible to assess the effects of loss of dominance on pruned trees in unthinned stands. Results from a Tasmanian trial were presented by M. Gilbert, which showed that, with severe pruning and no releasing, up to 84% of the pruned trees can lose dominance, compared with only 44% of lightly pruned or unpruned controls. The importance of this aspect is now being recognized, and an increasing number of schedules combine a thinning with the last pruning lift.

Priority of Pruning

When asked to express an opinion on what priorities should be given in pruning, Fenton replied that he would give priority to low pruning and the pruning of edge trees (the latter for all species). The economics of pruning on different sites have not yet been worked out, but pruning in Canterbury does not appear to be justified because of the small final tree size.

Species Other than Radiata Pine

According to N. A. Barr, there was a strong case for pruning poplars to 25 ft, in order to produce three 8 ft billets. Sutton presented results of a core size study which showed that Douglas fir would have similar core sizes to those of radiata pine, and that those of Corsican pine would be about one inch larger in diameter. Having regard to the small log sizes expected from these two species, this would probably rule out pruning on most sites.

ECONOMIC AND PHYSICAL ASPECTS OF THINNING

Non-commercial Thinning

Replies to the questionnaire showed that most slasher thinning of natural regeneration over the next five years would be confined to radiata pine in the central North Island. Current practices of the fourteen organizations involved in regeneration thinning vary widely. Residual stockings range from 400 to 1,600 s.p.a., and a number of selection criteria are used. Beekhuis reported on his research at Kaingaroa, and recommended slasher thinning to 960 s.p.a., with selection based on uniformity of tree height. He said treatment of stands when they reach man-height would keep the cost of the operation down, and further thinning at the time of low pruning would prevent loss of dominance in the pruned element. He had found that gains in diameter, resulting from either a selection for dominance or a reduction to lower numbers at the slasher thinning stage, tended to be offset by malformation in the larger diameter classes. In the discussion, Bunn said that part of the philosophy of adopting uniformity in height as the selection criterion was the possibility of adopting relatively low stockings. The branch sizes obtained on the dominant element in stands selected for uniformity could
only be achieved in stands selected on dominance characteristics by maintaining higher stockings, and this reduced the probability of growing all stems to merchantable size. Delegates generally agreed that stems which would never be merchantable should be removed as soon as they could be identified, but opinions varied as to when that stage was reached. One large organization prescribes thinning at age 6 when most small trees, and malformed stems, can be readily seen. The discussion exposed a general lack of confidence in natural regeneration, and a tendency to rely more on planting for re-establishment of exotic cutover.

In South Africa and Australia, because of easy country, shortage of wood, cheap extraction, and in some cases wide initial spacing, thinning to waste is rarely practised. Within New Zealand, when slasher thinning of regeneration is excluded, 85% of current thinning to waste is carried out by the Forest Service, mostly in radiata pine stands. Power saw felling is now the commonest method where stems are too large for slasher cutting. Poisoning has been discontinued owing to the introduction of light, robust power saws, which, together with the ready availability of capable contractors, have reduced costs of severance methods. The limited data available on comparative growth responses indicate more rapid basal area growth after power saw felling than after poisoning. Moreover, poisoning has proved unreliable. Crop trees have died in some cases, while poisoned trees have survived. It has recently been found that, in poison-thinned stands, apparently healthy residual stems have been affected by incipient decay and rot at the nodes. There could be a case for poison thinning where windthrow could be expected, as on very exposed sites, or in untended natural regeneration where thinning has been delayed. R. K. Usmar warned the few delegates that still favoured poison thinning to consider the effect of the thinning on the final crop values. He said this could far outweigh any cost saving on the actual thinning operation.

Commercial Thinning

According to J. J. K. Spiers, who chaired this session, there were two opposing schools of thought; on the one hand were those who believed in maximizing physical yield and on the other hand those who thought the main need was to maximize profit. The former believed the key to a satisfactory silvicultural schedule was the achievement of a production thinning, and they expected cheap mechanical harvesting to control costs. The latter believed the final crop was the key point, and on this basis there was a good case to forgo production thinnings. Spiers suggested that the best silviculture may lie somewhere between these two schools of thought, and asked delegates to decide on the criteria that should be used to measure the success of a silvicultural regime. There was no unanimity on this. B. J. Allison said his company had identified profit with volume. Fenton pointed out that no organization in New Zealand was trying to achieve maximum physical yield; if this was really the objective, it would be necessary
to adopt very close spacing and to utilize stumps. In fact, most silvicultural schedules in use in New Zealand had relatively few production thinnings, and some had reduced this to one. Fenton stated, however, that the concept of maximizing yield had been firmly and categorically rejected by economists in 1820, but foresters had taken no notice, an attitude which persisted in most forest services. The exception was Britain, where the Forestry Commission has adopted modern management techniques and a profitability criterion. Fenton quoted a reference to Scandinavia which said that there is no certainty that the costs incurred through maximizing volume production were more than matched by the additional net earnings provided by processing higher volumes. According to his calculations, as soon as a thinning paid a profit, the whole stand could pay a very big profit, and it was rather difficult on economic grounds to justify continuation of a rotation much past that production thinning. This view was challenged by P. F. Olsen, who said that commitment to a utilization plant could be a restraint on the application of economic criteria. Kaingaroa forest managers have had to adopt a mixed-product regime to improve the profitability of growing their groundwater commitment. In Australia, according to A. G. Hanson, State Governments take careful note of economic criteria; the intention is to maximize volume production provided the long-term Government bond rate can be met.

There was some discussion on what constituted an economic production thinning. It was suggested by some that a thinning is economic when the costs incurred in that particular operation are recovered. However, others contended that it would be unrealistic to ignore the effect of the thinning operation on final crop values, and on the profitability of the whole rotation. If high stockings are maintained with the object of obtaining a more profitable thinning, this will result in a reduction in size of final crop trees with a concomitant reduction in the proportion of higher grades, or a lengthening of the rotation. In Bunn’s view, this factor has been unrecognized by many forest managers. Other factors to consider are the costs of earlier roading for the extraction of thinnings, and the loss of productive areas in thinning roads and landings.

It is apparent that forest managers have paid insufficient attention to, or have misjudged, markets. Much of the silviculture in New Zealand has been prescribed on the premise that stable markets exist for posts and pulpwood. Frequently this market has not been maintained, and the stands have either been left unthinned, or belatedly thinned to waste. A delegate representing large-scale private forestry summed up the situation when he said: “If you cannot see your market, then don’t produce the stuff. It won’t disappear of its own accord”. Another large private forest grower was thinning to waste nine miles from a pulp mill, in order to produce a stem size of 10 to 20 cu. ft as quickly as possible for a pulpwood thinning, because it was considered economic to do so. Nevertheless, the situation could arise, according to Allison,
where there would be a shortage of wood, and when this stage is reached the price of wood may rise to cover the cost of extracting pulpwod thinnings. Fenton could not agree; in this situation there would be a strong argument for clear-felling rather than thinning, as crops would have a high opportunity cost.

Papers presented by J. R. Tustin and I. G. Trotman gave many data on the timber grade recovery from thinnings for sawlogs at about 20 years of age in tended radiata pine crops. These studies indicated that the combination of small log size, low grade outturn and high cost resulted in this operation being particularly unattractive financially. They suggested that in forests where sawlog thinnings were prescribed the silvicultural schedules should be re-examined. Spiers said that much of the material being produced from prescribed sawlog thinnings was currently being sold as pulpwod. In his view the silvicultural schedules being suggested by the FRI Economics section were particularly applicable to the management of forests where there was no pulpwod outlet. B. J. Allison stressed that there is a tendency to neglect the fact that each forest manager was faced with different circumstances. It was never correct to say that there is a right and a wrong regime, universally applicable, but to say “in these circumstances this is a better way than that”.

Papers presented by J. L. Wilson and R. H. Robinson dealt with machinery and methods for production thinning. They both agreed that mobility is essential for successful operations and that this is achieved with rubber-tyred equipment. Wilson thought that rubber-tyred tractors would in time be used on steeper country than that currently being worked, and that downhill logging would be adopted. In his view, forest managers need better data than approximations based on experience and intuition. Engineers can optimize equipment for any thinning operation if foresters can specify the job. They need to define precisely all the relevant parameters including mean tree size. Wilson pointed out that, while non-commercial thinning is a waste of a basic raw material, unless this material can be extracted economically, and successfully marketed, the thinning operation could be wasteful of other basic resources such as manpower and capital. He pointed out that in North America trees the size of thinnings in New Zealand are logged by mechanical harvesting techniques. The machinery used is generally restricted to clear-felling on flat or gently rolling country, and would have limited application for thinning the steep country characteristic of much of the area currently being planted in New Zealand. Topographic limitations on multi-purpose rubber-tyred tractors of the felling-bunching-delimbing type are accentuated each time another operation is added. Stem form and branch size in radiata pine crops in New Zealand could prevent effective mechanical delimbing. However, the key to achieving best results with new equipment is efficient management. It is important for forest planning to be geared to a production layout so that costs and problems are minimized. Extraction
equipment and techniques need to be integrated with loading methods, transport systems and handling in the mill yard for optimum efficiency. Chavasse said that Australian Paper Manufacturers' management was most impressive from this point of view. The whole forest layout and roading plan was geared to their extraction methods.

Answers to the questionnaire indicated that for tractor country most organizations, for reasons of economy and speed, favoured rubber-tyred machines. Two organizations considered that these were complementary to tracked tractors, and that they could both be used to advantage in combination or in close proximity. Both within New Zealand and overseas, hauler extraction of thinnings was purely experimental. Reports are discouraging, but Hanson described trials in Australia with a light skyline system which has proved satisfactory. He said that the main difficulty was finding men to work with wire rope systems, and for this reason present research was directed to tracking on steeper country for timberjack extraction. Robinson thought that thinning on steep country was a waste of time and money. He said that if there was a future for thinning steep country it lay in the development of contour tracking and suitable rubber-tyred skidders. Although Wilson described hauler machinery that he felt might be more suitable than that used in the past, there was no defender of thinning by hauler systems. There was general support for the opinion expressed by Spiers that on steep country no production thinnings should be prescribed, because costs have been high in the past, and he could not see them being any lower in future. Non-tractorable country was poorly defined at the symposium. The ideas of many delegates differed markedly, especially with regard to slope and ground conditions. There is a clear need for an acceptable terrain classification for New Zealand conditions, and for co-ordinated logging research. H. V. Hinds emphasized the need for development and research into operational efficiency. He said the problem was scarcely touched on in this country and noted, as a comparison, the reports published by the Swedish Logging Research Foundation.

Answers to the questionnaire on the relative cost of thinning versus clearfelling indicated that thinning costs on tractor country ranged from 10% higher to approximately three times as much as those of clearfelling. Background papers by T. Johnson and R. S. Wyatt discussed the factors which influence logging costs. Johnson thought that, for properly motivated thinning gangs, mean tree size was the most important variable influencing logging productivity. Topography, particularly when very steep, was the next most important. He did not think volume per acre especially significant unless it was combined with small sized trees. Tree scatter influenced only two elements in the work cycle (breaking out and bume men's walking time), but small tree size affected practically every element. Hence, larger trees could be spaced out without altering productivity very much, but smaller trees would have to be concentrated to maintain production and to control
costs. Referring to rubber-tyred tractors, he demonstrated
that load size was much more important than haul speed.
Logging productivity is determined by many interacting
variables and the effect of any one of them on the end result
is largely determined by which other factors are present
and to what extent. Lack of motivation in the labour force
can be an overwhelming factor, but in normal circumstances
greater production and lower costs can be achieved if man-
gagers aim to grow large-sized trees. Respondents to the ques-
tionnaire also consider piece size to be of prime importance,
although some qualified their answer by saying that volume
per acre became more important for short pulpwood opera-
tions. The attention of delegates was drawn to bunching by
hand or machine by A. W. Grayburn; this tends to overcome
the adverse effect of small tree size. Even so, according to
Allison, a large tree is always preferable to a small one, and
he felt that managerial effort should be directed to designing
a silvicultural schedule which would improve the piece size
as far as possible, with little or no sacrifice of volume pro-
duction. But, as Bunn pointed out, growth could be concen-
trated on relatively few trees.

One important point, according to Wyatt, was choosing the
right machine for the job. He considered that piece size, horse-
power, manoeuvrability, capital cost, economy in operation,
traction and speed need to be equated to both machine size
and the logging environment. Major gains could be derived
from the optimum solution. He added that the right balance
between labour and machinery could also greatly increase
efficiency, and contractors could often demonstrate what this
balance should be. The capital cost and operating expenses of
logging machinery were the major cost determinants in large-
scale operations, and Wyatt stressed that operating efficiency
was greatly affected by down time. Only when piece sizes
dropped below 12 cu. ft did the labour content of the opera-
tion tend to dictate productivity and costs. The stand variables
of average piece size and available yield per acre greatly in-
fluenced the size of the machinery used and its productivity
which, within reason, set the financial return for any given
operation, with the possible exception of short pulpwood.
When the number of residual stems exceeded 150 s.p.a., the
residual stand density became an important factor in in-
creasing thinning costs. However, at lower residual stockings,
with larger piece sizes and higher volumes per acre, thinning
costs approach clearfelling costs. N.Z. Forest Products Ltd.
do not impose production quotas on any contractors and
Grayburn considered this was a major factor in reducing
logging costs.

Ideal groundwood material for Tasman Pulp and Paper
Co. Ltd., according to M. Calsaferri, would be trees of about
10 cu. ft, but if these were from thinnings they would have
to be available at an attractive price. Mechanized thinning
would probably be needed to keep the price down, and he
wondered if this was feasible. Johnson said mechanization in
Sweden had been greatly facilitated by a much smaller and
more uniform piece size than is logged in New Zealand.
Sutton added that the percentage of total wood production in Sweden from clearfellings was expected to increase from 25% to over 75% during the following ten years. This change was mainly due to the difficulty of mechanizing production thinning in circumstances where the pressure to mechanize was considerable. In Australia, high production rates could be achieved with the Windsor Tree Harvester, but best results were obtained by row thinning. This harvester may cost between $40,000 and $60,000, and some delegates considered it an expensive machine to produce a low-value product. In addition, Bunn felt that mechanization developments in Australia could have only a small impact on New Zealand practice. Effective use of such machines depends on easy terrain, row thinning, and close proximity to a pulpmill.

There was some debate over logging productivity. Spiers considered that thinning costs could be improved in the future. He said that most effort had been expended on clearfelling, and this had led to reduced costs. He felt that with a concerted effort similar gains could be made in thinning. Fenton produced data for N.Z. Forest Service clearfelling gangs. He said that their productivity was, in his opinion, not high (two-thirds of a tree per man-hour) and felt there was room for considerable improvement.

REVIEW OF SILVICULTURAL SCHEDULES

Introduction

This session was chaired by E. H. Bunn, who discussed the factors to be considered in determining a silvicultural regime. He began by stressing that the old untended crop has supported the forest industry in New Zealand for some time, and will continue to do so for the next twenty years. For this reason we should have very good reasons for investing money in pruning and thinning. The steps to be taken in determining regimes were:

1. Define target or targets
2. Evaluate quality requirements with a view to retaining maximum flexibility
3. Minimize risks
4. Simplify operations

The incentive for pruning and thinning is, or should be, financial. Money spent on these operations is an investment in anticipation of enhanced future values and returns. Therefore the main target (to which all others are subordinate) is to maximize values and/or profits, not just at one time or for one operation, but for the enterprise as a whole. In the evaluation of quality requirements it is important to recognize the influence of size, form and uniformity, as well as quality, on particular end products. Analysis of desired qualities for
each product reveals that it will be difficult to satisfy all requirements from a single management regime. If we are to retain some flexibility it is necessary to group products which have common quality characteristics. For radiata pine, Bunn suggested two fairly logical associations. The first group includes quality finishing timbers, clearwood, face veneers, laminated members, kraft pulp board and chips for export. The second group included framing and construction timbers, structural plywood, stone groundwood and particle board.

Risks would be minimized, Bunn suggested, by shortening rotations and avoiding holding large uncommitted resources of mature timber "on the hoof" beyond their optimum financial or physical rotation. Management can be simplified by avoiding operations where possible, or simplifying by mechanization, research or manipulation of the stand.

Radiata pine is a very plastic species that allows considerable silvicultural flexibility. Bunn said that studies both in New Zealand and Australia have shown that within very wide limits merchantable volume of radiata pine stands is not greatly affected by thinning intensity. Also important was the significance of form — it had been shown that the two lower logs of the crop trees account for some 70% of the gross value of the crop.

Objectives

For most forests, the objective of the current schedules was not to produce for any specific end product or product group, but to attempt to produce a multi-purpose product. This was given support by the utilization representatives who claimed that sawmills cut to order regardless of what is economically desirable. But this ignored the evidence of grade studies which indicate that it is impossible to cut grades that simply do not exist. Untended radiata pine stands produce little or no dressing, finishing or clear grades, and our future stands, which have been pruned and thinned, will probably produce poor quality framing grades above the pruned butt log because of the increase in branch size consequent upon thinning. Representatives of the larger firms, or large State forests committed to supply major utilization industries, expressed the opinion that they had little control over rotations, and that there could thus be little or no flexibility. But, as Bunn said, this should not stop us from evaluating the rationale behind the regimes. However, while the larger forests (both private and State) were being managed for multi-purpose products, in smaller forests there was some attempt to manage crops for specific ends.

Opinions varied considerably on what was the optimum tree size for the major end products. In New Zealand, the aim in crops grown for boards was a tree size ranging from 20 in. to 28 in. d.b.h., with most about 23-24 in. Overseas, a smaller tree (15 in. to 20 in.) was specified. For framing, mean tree size specifications were less — generally below 20 in. d.b.h. Victoria was an exception — larger logs are there considered necessary because the Australian framing grading
rules specifically exclude all material within 2 in. of the pith.

In New Zealand, with some exceptions (for example, Nelson and Westland Conservancies), schedules include a production thinning even on steep country, although delegates generally agreed that in practice they would forgo thinning on steep land. Fenton claimed that an analysis of all State thinning operations over the past ten years has failed to show that the operation can be done economically, even on flat country, especially when full opportunity costs of damage to, and loss of, final crop trees, and the loss of increment consequent upon holding stands at high stocking (in order to get an economic thinning volume for extraction) are included.

Framing Regimes

Fenton presented a paper outlining four silvicultural alternatives for the production of framing grades. The first was a regime designed specifically for growing framing timber. In this, the initial and subsequent stocking had to be sufficiently dense to suppress branch diameter development, and preferably to kill the branches early over at least two log lengths. Results from sawing trials of radiata pine indicate that the critical initial spacing for production of No. 1 framing, for the central North Island and the east coast at least, is not wider than 6 ft × 6 ft or its equivalent. Little is yet known about branch diameter responses after thinning, but early results suggest that the larger branches, at least in the upper 25 ft of the crown, will respond. To enable branch size control over two log lengths (about 35 ft), stands must be held at their initial stocking until a top height of 60 ft is reached. If the stand is reduced to 150 s.p.a. at this stage, then crop trees would probably attain a mean d.b.h. of 19 in. at a height of 137 ft (age 34 yr for a site index of 95). Because of the lengthened rotation and relatively small log size, this is considered an expensive regime for quality framing production.

The second possible regime is one giving both framing and boards; this is equivalent to the current Kaingaroa Forest schedule — pruning in three lifts, thinning to waste at 40 ft top height to about 200-300 s.p.a., with production thinning at 60 ft and/or 90 ft, and a final stocking of about 80-90 s.p.a. The major drawbacks are a smaller final crop tree, higher costs, a relatively long rotation, while production of suitable framing grades from the second and third log has not yet been demonstrated. The third possibility is to adopt a board regime and produce framing by re-manufacture. The fourth possibility is to repeat the first rotation by planting the crop and leaving it untended. Fenton made the point that, for the foreseeable future at least, there were adequate supplies of framing timber from the present radiata pine crop, Douglas fir and other largely untended stands of other exotic species. It was expensive material because of long rotations and small piece size.

In opening the discussion, Bunn said that radiata pine framing could also be grown on low-fertility sites where
branches tended to be fine; but I. D. Whiteside said that production of high quality framing grades was not necessarily related to low-quality sites, and gave information of a recent study from stands in Golden Downs Forest, planted at 8 ft × 8 ft, where outturn of No. 1 framing was 55%. B. Keating said that similar stands in the Wairarapa produced a like proportion of No. 1 framing. Sutton, on the basis that Yska had shown that there was enough wood for all our internal needs, claimed that we should consider every additional acre planted as an “export acre”. What we grow should be that which has the greatest export potential. He contended that this was clear boards and not framing, for which our specifications were relatively low and for which our export record was uninspiring. But Whiteside considered that grade is not the limiting factor in the export of framing; if we could improve drying and stability we could export unlimited quantities. But Bunn felt that we could not meet the specifications from small logs or from trees with large knots. Whiteside claimed that this had never been proved or demonstrated, but Fenton challenged this and quoted work by Kinimmonth in New Zealand, and some Australian experience. The question of whether quality framing would be produced from unpruned second logs and third logs from stands that were thinned early and heavily was not resolved. Bunn noted that most Australian regimes did not prescribe any thinnings before top height 60 ft. He doubted if we could hold stands that long without risk of wind damage following thinning, and claimed that wind was one of the most important restraints on silviculture in plantations in New Zealand. Shelbourne, in a discussion about the contributions of tree breeding, stated that we could not expect a great reduction in branch size from selection.

Board Regimes

Fenton opened the discussion by re-stating the case for the short-rotation regime (published in N.Z. J. For., 13 (8), 1968). He outlined the problems and disadvantages of production thinning and claimed that maximum volume yield had not been achieved by extraction thinning. Analysis had shown that framing was difficult to grow and that at least 70% of the gross value of the tree was in the bottom two logs. Once we had control over the quality of those logs, then we could open up the stand and allow maximum diameter growth. The quality of the butt log could be ensured by pruning, and that of the second log either by selection on uninodal characteristics with long clear internodes, or again by pruning. Selection of final crop trees was possible at a height of 35 ft. The objective must be to maximize growth on these trees. Details of the suggested schedule, for a site index of 95 ft, are given in Table 1.

The increase in profitability over current regimes, with their scheduled production thinnings, is considerable — of the order of $100 per acre land expectation value equivalent (LEV) at 7% compound interest. Physical yields are about
TABLE 1: SILVICULTURAL SCHEDULE FOR SHORT-ROTATION SAWLOG REGIME FOR RADIATA PINE

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Mean ht (ft)</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>—</td>
<td>Plant at 12 ft × 6 ft spacing.</td>
</tr>
<tr>
<td>4 to 5</td>
<td>16 to 18</td>
<td>Prune best two trees out of four to 8 ft or half height, whichever is lower.</td>
</tr>
<tr>
<td>6</td>
<td>28</td>
<td>Prune 150 s.p.a. to 14 ft or half height.</td>
</tr>
<tr>
<td>8 to 9</td>
<td>34 to 36</td>
<td>Prune 80 to 90 s.p.a. to 18-20 ft. Thin to waste to 150 s.p.a</td>
</tr>
<tr>
<td>11 to 12</td>
<td>55</td>
<td>Thin to waste to 80 s.p.a.</td>
</tr>
<tr>
<td>25 to 26</td>
<td>118 to 120</td>
<td>Clearfell. Expected yield 9,000 cu. ft; expected mean d.b.h. 23.4 in.</td>
</tr>
</tbody>
</table>

the same as, or possibly higher than for regimes including production thinnings, as there is no loss of productive area in tracks and extraction bays.

In opening the discussion, Bunn said that the advantage of this regime was that it avoided the opportunity cost of delaying growth on the final crop trees. Evidence of the significance of this lost growth was accumulating. Usmar asked how we could resolve what appeared to be two regimes in conflict; on the one hand, regimes with one, and up to six production thinnings; on the other, the short-rotation sawlog regime with none. Both sides claimed their regime to be economic. In Allison’s view it all depended on whether or not one had control over the processing plant. If he was asked to give advice to a speculative planter he would recommend the short-rotation sawlog regime, but where the forest was only part of the business, the primary object was to grow wood as economically as possible; the profits are made in the processing. After much discussion, this conflict was not resolved.

Regimes for Douglas Fir

In opening the discussion on Douglas fir, Bunn stated that the target for this species is clearly structural timber. The basic question is — do we control branch size through manipulation of stand density, or do we have a wider initial spacing and prune and thin the crop? The general consensus of opinion was that pruning was not worth while. The minimum stocking to get good quality framing timber from Douglas fir is yet to be determined, but Whiteside said that evidence from stress grading studies had shown that, provided establishment was successful, there was little difference between trees from stands planted at 8 ft × 8 ft, and at 6 ft × 6 ft spacing. But J. M. Harris felt that this simplification would be misleading; intrinsic properties do play an important part, over and above visible defects like knot size and slope of grain. Bunn thought there was a strong case for pruning marginal trees; most schedules delayed first thinning until about top height of 90 ft, which meant that quality on at least the first three logs was controlled. But material from
thinnings was small and the cost of conversion correspondingly high. Most forest managers expect rotations of 50 years or more. The opinion was expressed that Douglas fir may be more windfirm than radiata pine. Douglas was considered by Calsaferri to produce good kraft pulp.

**Summing Up**

An attempt to arrive at a consensus was made by J. G. Groome in summing up this section. He suggested that most of the organizations delaying thinning beyond 50 ft top height, and/or retaining more than 200 s.p.a., were those with an assured market, or were a part of an industrial processing organization. There was a tendency elsewhere to take note of the case put forward by the FRI Economics section. A possible regime for radiata pine, producing about 67% of total volume as sawlogs, is given in Table 2.

### TABLE 2: BASIC SCHEDULES FOR RADIATA PINE

<table>
<thead>
<tr>
<th>Detail</th>
<th>Production Thinning (Tractor Country)</th>
<th>No Production Thinning (Non-Tractor Country)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial spacing</td>
<td>Rectangular</td>
<td>Rectangular</td>
</tr>
<tr>
<td>Minimum stocking per acre</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Pruning — first lift</td>
<td>At top height 16 to 20 ft; prune 500 to 500 s.p.a. to 8 ft.</td>
<td></td>
</tr>
<tr>
<td>Pruning — second lift</td>
<td>At top height 28 to 30 ft; prune 150 s.p.a. to 14 ft.</td>
<td></td>
</tr>
<tr>
<td>Pruning — third lift</td>
<td>At top height 35 to 40 ft; prune 100 to 150 s.p.a. to 20 ft.</td>
<td></td>
</tr>
<tr>
<td>Thinning</td>
<td>Not resolved, but probably less than 200 s.p.a. at time of last pruning</td>
<td></td>
</tr>
<tr>
<td>Final tree size (d.b.h.)</td>
<td>24 in.</td>
<td>24 in.</td>
</tr>
</tbody>
</table>

**IMPLEMENTATION AND CONTROL OF SILVICULTURAL OPERATIONS**

**Implementation**

Replies to the questionnaire indicated that most forest management plans contain a silvicultural schedule as a guide to crop treatment. Implementation of this schedule begins with the formulation of detailed annual programmes. However, the methods used by organizations to assess the silvicultural requirements of specific stands vary. A few rely on subjective judgment, others on stand age, and many on field assessment of the crop. In large organizations the work content of the job is systematically collected for setting incentive standards or contract rates. An essential requirement for
optimum tending practice is an objective assessment of stands to ensure that they are programmed for treatment at the prescribed stages of development.

The needs for successful implementation and control of large-scale silvicultural programmes were outlined by E. Kearns. Success depended on a skilled, flexible labour force and a proper balance of supervisory staff. Supervisor:worker ratios should not exceed 1:10 for wage workers or 1:8 for workers on bonus incentives, or for contractors. Inadequate supervisory staffing can lead to high labour turnover. New workers are often completely inexperienced, and, with insufficient staff, training and supervision of recruits can be inadequate; this leads to poor appreciation of the job, poor workmanship, inability to achieve targets, and disillusionment. The quality of the labour force is important, particularly as it affects the deployment of limited supervisory staff. A fairly high proportion of the forest labour force is unskilled, and this type of man could not be used effectively on all jobs; this was especially the case with men employed under the winter employment scheme. In a few cases women were being employed successfully.

Delegates were unanimous that adequate supervision of the labour force is essential for successful implementation of silvicultural programmes, irrespective of whether labour is employed on day wages, bonus work or contract. Day labour is still used by many employers, though the advantages of bonus and contract systems are being increasingly recognized. Large organizations tend to employ labour under all three systems, the proportions of each being dependent on the quality of the work force, the type of work, and the availability of supervisory staff. Some organizations found that quality control was more easily obtained if the labour force was employed under incentive schemes. Experience in Kaingaroa Forest is that successful bonus work is dependent on very good front-line supervisors and careful gang selection. The supervisor must be fully conversant with the work method, and have sufficient drive and initiative to make it succeed. Workers need to be carefully trained and screened to ensure their suitability for incentive work. Small gangs of two to four men, streamed for uniformity in skill and output, prove highly productive.

Within New Zealand, contract work is becoming increasingly popular. The contractors provide their own equipment, transport and housing. Supervisory staff can concentrate on planning and control of quality. In the Bay of Plenty two quite distinct methods of employing contractors are used. The first type is where the forest manager deals directly with a prime contractor, who in turn employs men on wages or sub-contract. The prime contractor is responsible for supervision of his employees. The second type is where the forest manager deals directly with individual co-operative contractors, who work in units of two to four men and share their earnings equally. Prime contractors are used successfully in large-scale private forests. They fulfil the role of hired supervisors
and are paid as such, often at considerably higher rates than supervisors in State forests. Prime contractors have been less successful in Kaingaroa Forest, where co-operative contracts are now preferred. Reputable prime contractors do not seem to be attracted by the contract prices offered by the State. However, competent prime contractors, if available, can greatly reduce the work load on understaffed stations, where the pressures due to trying to cope with large and expanding silvicultural programmes are considerable.

The forest manager needs to recognize the physical and psychological difficulties involved when new work standards and techniques are introduced into bonus and contract operations, according to T. E. Rogers. It behoves those who instigate changes to check thoroughly in advance any problems that may arise in the field, and to make allowances for them. Careful co-ordinated planning, to phase the new method into full-scale operations, can help to ensure that potential productivity increases are realized and that field staff are not brought into conflict with workers. Forest managers must retain the confidence of those involved at the work face. A smooth transition can be effected only with the whole-hearted support of the front-line supervisors and the labour force. He gave an example — the replacement of pole saws by ladders and jack saws for pruning the second lift at Kaingaroa Forest. After a six-week phasing-in period, difficulties arose which caused the forest manager to reduce the target in order to overcome poor performance and flagging gang morale. The solution was not ideal, but in the circumstances it was clearly necessary. The lesson for forest managers is that ideal solutions are not always present, but careful documentation of past experience may assist with the handling of similar situations in future.

Control

R. K. Usman said that control systems must work towards the achievement of overall management objectives. It is important that these objectives are well thought out and clearly stated. Woolly objectives lead to "whimsical prescriptions" and "over-reaction to ephemeral market conditions". Three papers were tabled which gave a comprehensive review of the control system used in a large company forest.

J. A. Church stated that incentive schemes and contract work tend to over-emphasize the quantity aspect of silvicultural work. Hence most supervisory staff effort should be directed towards quality control. Pruning quality checks at N.Z. Forest Products Ltd. are done by the supervisor, who is always accompanied by the contractor or gang foreman. One-tenth acre strip plots are laid down evenly over the stand to give at least a 2½% sample. Factors assessed are total number of stems pruned, stems not pruned which should have been, stems pruned which should not have been, and bad pruning (for example, unnecessarily long branch stubs, stem damage and insufficient pruned height). No selection or tally-
ing of prunable trees is carried out prior to pruning. Defects are pointed out to the foreman or contractor on the spot, so that the standards required are understood, and remedial action can be taken. Pruned tree tallies are adjusted by quality deductions (for wrong selection or bad pruning), and gangs are sent back over areas where the number of acceptable trees not pruned is excessive. These quality control measures help to ensure that quality standards are not sacrificed in favour of low costs for the employer or excessive earnings for the work force. It has been found that morale of the foreman or contractor and his crew is increased as a result of regular, objective assessments, and the elimination of false tallies and poor quality work.

The computerized thinning control system used by N.Z. Forest Products Ltd. was described in detail by C. R. McKenzie. The system has been designed to meet requirements of easy administration, to provide up-to-date information at all times, and to permit cyclical re-use of data. Information gathered for control of one thinning becomes the input for yield predictions for the next one. Currently, the system controls a thinning yield in excess of ten million cubic feet per annum, all produced by contract gangs. McKenzie thought that control of selective thinning gangs began with good marking, and the company employs a special six-man gang responsible for all marking for thinning. A marking quality check is linked with the gang's bonus scheme. Inspection of thinning operations is by a two-tiered system. Thinning supervisors inspect thinning operations daily, and forestry staff carry out random checks. All aspects of the operation are examined to ensure the following:

(a) All areas scheduled for thinning are treated
(b) Residual damage to crop trees is minimal
(c) Only marked trees are left standing
(d) All suitable material is cut to specification and stacked for extraction
(e) Extraction tracks are as narrow as possible, without contributing to damage to the residual stand
(f) Tracks connect and utilize gaps where possible, and any marked trees on extraction tracks are replaced by an unmarked stem wherever possible
(g) Road lines and dumps are placed where possible in gaps and areas of low stocking.

These points are subject to an objective inspection, or the standard is set by the best gang working under similar conditions. This criterion has proved both workable and enforceable. The prime contractor is the one person held responsible for the quality of the operation. This ensures that there is self-inspection within the gang at all times, and that the supervisor only has to deal with one person rather than many.
Penalties for sub-standard operations vary according to the circumstances. The foreman sets the penalties, and failure to deal with individual cutters can give the whole gang a bad report, thus risking suspension for a period or termination of the contract. Each thinning operation is recorded on a permanent computer file, which ensures an accurate and permanent record of the work done. It also facilitates multiple retrieval for constructing the different types of reports required by roading engineers, loggers and foresters.

Subsequent discussion on thinning and pruning control systems showed that, while the large organizations have defined quality standards and carry out systematic field assessments, small organizations tend to rely on close supervision and subjective assessment of quality. However, most delegates considered it desirable to have well-defined quality standards which are simple, objective and easy to assess. R. K. Usmar noted that, while check assessments are carried out in most forests after silvicultural operations, any action that stemmed from these assessments was seldom outlined. Hence, for many organizations, it is not possible to judge the extent to which deviations from silvicultural prescriptions are tolerated. Although it did not appear to be general practice, delegates agreed that data collected from quality control checks should be accumulated for all management purposes.

A detailed account of the clerical working plan system used by N.Z. Forest Products Ltd. was given by B. G. Twitchin. He emphasized that it is designed for the people who use it; it is accurate; and it is constantly updated. These features are essential to ensure that the plan is used, and that those who use it have confidence in the system. Aerial phytography and computers are the two major tools that have been used to streamline planning. Aerial photography is used frequently to check on the accuracy of information and to obtain a permanent record of stand condition at critical development stages. For example, it is used to record changes in stocking resulting from thinning. Computers currently facilitate fast, accurate analysis and storage of data, but in future they will also be used to extend planning facilities. A feature of the system, which is considered to be important, is that it has withstood the test of rapidly changing circumstances.

When the size of the forest programme dictates it, according to Usmar, large sophisticated control systems have to be adopted. This is a reflection of the impossibility of direct and continuous contact with the job by top managers. Small organizations can learn from these systems, but do not need to adopt them. Control methods need only be adequate for the scale of operations. However, any system can be taxed by expansion of the operational area. The multiplier effect of acreage, and an increasing spectrum of operations as an afforestation programme matures, can be enormous. Forest managers should realize this when they first design their overall control system.

On the question of control through financial estimates, W. J. Wendelken explained that a function of any head office
was to make resources available so that plans could be implemented. The capital available to the N.Z. Forest Service had to be divided between seven conservancies, each of which tended to think it had top priority! Capital is a scarce resource, and while no head office would wish to restrict development of the organization unduly, one head office function is to ensure that no one receives too much capital. On the other hand, it is necessary to ensure that conservancies receive enough to achieve targets, and this is to some extent outside head office control.