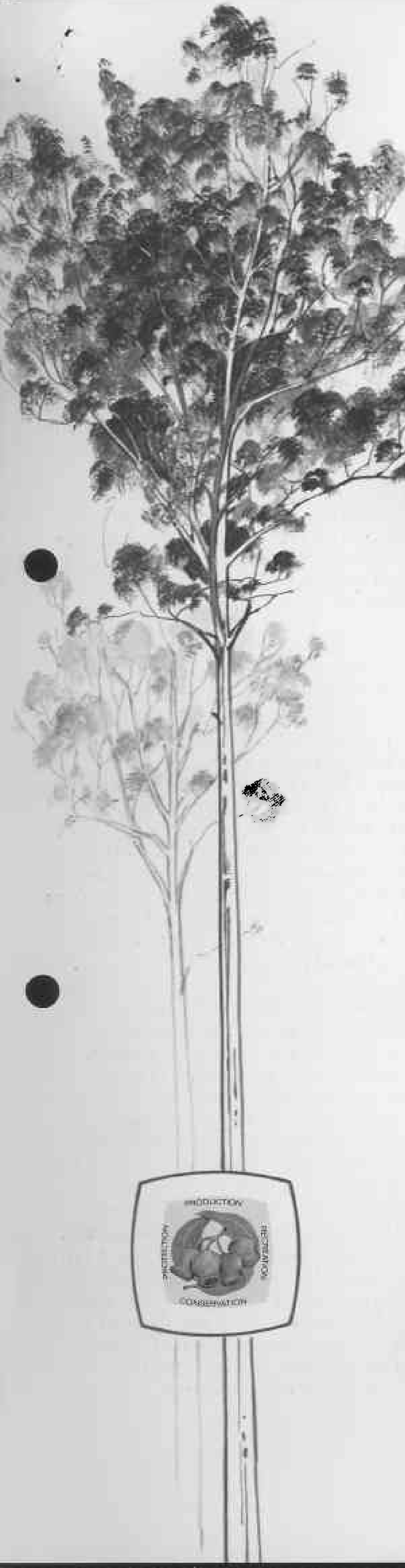

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# SILVICULTURE OF *Pinus radiata* IN AN AGROFORESTRY MANAGEMENT SYSTEM

by
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## SUMMARY

Data were drawn from a thinning experiment and two spacing experiments to examine the silvicultural problems in radiata pine (*Pinus radiata* D. Don.) plantations posed by a wide-spacing silvicultural system that permits continued grazing under the trees. Radiata pine in such an agroforestry system can produce high-quality sawlogs and veneer-quality timber if pruning up to a height of 10 m on the bole is strictly timed to prevent the formation of excessively large knots.

## INTRODUCTION

Integration of livestock grazing and pine silviculture is extensively practised in State radiata pine (*Pinus radiata* D. Don.) plantations in Western Australia (McKinnell and Batini, 1978), especially those located on former farmland in the Blackwood Valley.

This management system offers many advantages to the plantation manager. With careful control of grazing it is possible to reduce the fire hazard in the plantation, to reduce competition from the grass for water and nutrients, and to improve tree nutrition through the accession of livestock manure or fertiliser applied to improve herbage yields. Appropriate grazing can also improve the clover (*Trifolium* species) component of the pasture, which increases site fertility.

Against these advantages must be set the disadvantages of increased complexity of management, some tree damage, and some soil compaction at the stock camp-sites.

Grazing over most of the plantation area in Western Australia is random, utilising pasture persisting under young pine stands. In the future a proportion of the plantation will be managed under a silvicultural regime of very wide spacing, with closely grazed pasture under the pines throughout the rotation; these areas will serve as a fuel-reduced fire buffer for fire control. It is, however, essential that there is no serious decrease in tree production and that wood quality is not reduced to a significant extent under this regime.

This paper firstly considers the effect of thinning on yield by examining the data from part of a long-term thinning experiment that closely approximates the silviculture proposed for the fuel-reduced buffer areas. Secondly, the influence of tree spacing on branch size, which is a major determinant of wood quality in radiata pine, is discussed on the basis of data from two spacing experiments.

## METHOD

The pines in the thinning experiment were planted in 1957 on a repurchased farm at Mungalup, near Collie. The site has a deep red-brown soil that had carried improved pasture for some years. Thinning was begun in 1965, with four 0.08 ha replicate plots of each of 6 thinning treatments. All trees were low-pruned at age 5 years, and given an initial high pruning to 5 m at age 7 years and a second high pruning to 7.5 m at age 12 years.

The experiment included 6 different thinning regimes, but only 2 of these are considered here: the one with the least thinning and the other with the most severe thinning. In Treatment 1 initial stocking of 1100 stems per hectare (spha) was maintained until age 19.5 years, when stocking was reduced to 500 spha. For Treatment 6, the first thinning at age 8.2 years reduced 1100 spha to 500 spha; the second thinning at age 12.6 years reduced stocking to 250 spha; at age 19.5 years the plots were thinned again, leaving only 125 spha. Finally, standing volume on all plots was measured at age 20.5 years. All volume data quoted represent wood volume under bark; this was calculated from a tree form model constructed from samples of trees taken from all main Western Australian *P. radiata* plantations.

Since no observations of branch development were made in the Mungalup trial, data were drawn from two spacing trials of different ages. The first was planted in 1968 at Bussells plantation on a high-quality pastured site very similar to the Mungalup site. The spacings were 1.8 x 1.8 m, 2.4 x 2.4 m, 3.0 x 3.0 m and 3.6 x 3.6 m in four replicate plots of 0.08 ha in a Latin square design. All trees were low-pruned to 2.1 m at age 5 years but were not high-pruned. At age 10 years, five dominant trees randomly selected in each replicate plot were felled, and the base diameter over bark of all branches greater than 1 cm in diameter over the 2.1 to 10 m section of the stem was measured.

TABLE 1

Comparison of yield data,
Treatments 1 and 6, Mungalup experiment

| Age | Treatment 1 | | | Treatment 6 | | |
|---|---|---|---|---|---|---|
| | spha | Yield ($m^3 \cdot ha^{-1}$) Pulp | Saw | spha | Yield ($m^3 \cdot ha^{-1}$) Pulp | Saw |
| 8.2 | 1108 | - | - | 500 | 76.6 | - |
| 12.6 | 1108 | - | - | 250 | 133.1 | - |
| 19.5 | 500 | 114.5 | 59.3 | 125 | 18.0 | 196.4 |
| Standing volume at age 20.5 years ($m^3 \cdot ha^{-1}$) | | 110.0 | 429.3 | | 17.5 | 304.0 |
| Total volume produced ($m^3 \cdot ha^{-1}$) | | 224.5 | 488.6 | | 245.2 | 500.4 |

The second spacing trial was unreplicated, with initial stockings of 250, 500 and 750 spha in plots approximately 1 ha in area. The trees were planted in 1973 on a high-quality pastured site in the Blackwood Valley. Tree growth was so good that low pruning to 2.1 m was possible in mid 1977. Basal diameter over bark of all pruned branches was measured for ten randomly selected sample trees on each plot.

It should be noted that the term sawlogs refers to logs produced from second thinnings or later fellings in stands older than 16 years that have a small-end minimum diameter under bark of 20 cm. Peeler logs are sawlogs suitable for rotary peeling to produce veneer. Pulpwood is the part of the tree between the 20 cm and 7.5 cm diameter points, and is used in Western Australia for particle board manufacture. Some overlap of these log classes occurs in practice; for example, a log greater than 20 cm in diameter may be downgraded to pulpwood owing to crookedness or excessive branch size.

## RESULTS

### Volume production

For Treatment 6 the first thinning at age 8.2 years produced only logs of pulpwood size (Table 1). A first thinning at this age is unusually early, even for radiata pine; however, growth was such that the codominant height on the experimental area at this age was 18-19 m, and this is the normal stand height at which first thinning should take place to ensure good stability against wind and to avoid growth losses due to moisture deficiency.

At age 12.6 years the second thinning produced a useful yield of pulpwood, and by age 19.5 years, the stand was able to yield both high-quality sawlogs and a small quantity of pulpwood.

At the final measurement at age 20.5 years, there remained standing 304 $m^3 \cdot ha^{-1}$ of sawlog-sized material and 17.5 $m^3 \cdot ha^{-1}$ of pulpwood. The total volume of timber produced over the 20.5 years was therefore 745.6 $m^3 \cdot ha^{-1}$, giving a mean annual increment of 36.4 $m^3 \cdot ha^{-1}$.

In Treatment 1 the first thinning at 19.5 years yielded 114.5 $m^3 \cdot ha^{-1}$ of pulpwood and 59.3 $m^3 \cdot ha^{-1}$ of sawlogs, and the standing volume at age 20.5 years was 110 $m^3 \cdot ha^{-1}$ of pulpwood and 429.3 $m^3 \cdot ha^{-1}$ of sawlogs. The total volume production was 713 $m^3 \cdot ha^{-1}$, virtually the same as that from the most severe thinning treatment.

TABLE 2

Branch development between 2.1 m and 10 m on the bole, Bussells plantation spacing experiment

| Spacing | Stems per hectare | Mean branch basal diameter over bark (cm) | Mean branch basal area ($cm^2$) |
|---|---|---|---|
| 1.8 x 1.8 m | 3086 | 2.08 | 3.65 |
| 2.4 x 2.4 m | 1736 | 2.45 | 5.06 |
| 3.0 x 3.0 m | 1111 | 2.85 | 6.93 |
| 3.6 x 3.6 m | 772 | 3.06 | 8.45 |

For all practical purposes, these two very different approaches to silviculture did not differ with regard to the total volume of timber produced and the proportion of pulpwood to sawlogs. Clearly, managing radiata pine on a regime of wide spacing such as this will not result in an overall loss of production, at least under the climatic and soil conditions of Mungalup.

However, although Treatment 1 produced a similar volume of sawlogs to Treatment 6, the value of this volume was much lower. Treatment 1 produced no logs large enough to be classified as peeler logs, which attract a considerably higher stumpage than ordinary sawlogs, whereas 38.1 $m^3 \cdot ha^{-1}$ of the sawlogs produced at age 19.5 years in Treatment 6 were peeler size. Mean sawlog volume per tree at age 20.5 years for Treatment 1 is only 0.86 $m^3 \cdot ha^{-1}$, compared with 2.43 $m^3 \cdot ha^{-1}$ for Treatment 6. As a further point of comparison, mean tree diameters over bark at breast height at age 20.5 years were 33.4 and 48.4 cm respectively.

## Branch development

In the 1968 spacing experiment, the mean number of branch whorls per tree and the number of branches per whorl did not vary appreciably between treatments, but there were marked differences in branch size, which was measured by branch diameter over bark and by basal area (Table 2).

Mean branch diameter over bark increased with increased spacing between the trees. Branch diameter for the 3.6 m spacing was approximately 50% greater than that for the 1.8 m spacing, but the differences in diameter were statistically significant ($p = 0.05$) for the two extreme spacings only. Using radiata pine grading rules (Radiata Pine Association of Australia, 1977), the classification of average knot size was therefore increased from medium to large. It must be expected that the observed differences in branch size would increase with time, in the absence of pruning. Very wide tree spacing (approximately 5 m x 5 m), which is necessary to maintain pasture vigour in agroforestry, will result in even greater branch development. The position is exacerbated when the pasture has a high legume component, leading to a high nitrogen status in the soil; this has been observed to promote branch development in *P. radiata* (Will, 1971; Will and Hodgkiss, 1977).

The data in Table 2 refer to mean branch diameter over bark between 2.1 m and 10 m above the ground. Close examination of the data indicated that the relative branch diameters were the same over the whole section of the bole.

For each spacing the rankings of mean branch diameter over bark by whorls were compared using Kendall's coefficient of concordance (Siegal, 1956). The coefficient W was 0.928 ($p < 0.01$). We may conclude that the relationship between branch diameter and spacing is deterministic.

The 1973 spacing experiment, although crude in design, suggests that spacing will not seriously affect branch size in the zone of low pruning, between 0 m and 2.1 m above the ground (Table 3).

This difference is probably because up to the stage of low pruning the trees were all virtually free-growing at these spacings. Branch size at that stage of growth was more likely to be influenced by site factors such as nitrogen availability than by spacing. Although the branches were not large (Table 3), they certainly would have grown much larger had they not been pruned: in radiata pine plantations, it is common for the edge trees, which frequently do not receive pruning, to be completely unusable as sawlogs, owing solely to excessive branch size.

## DISCUSSION

The Mungalup thinning experiment has shown that managing *P. radiata* according to an agroforestry management system need not reduce total timber yield compared with that of a more conservative silvicultural system. However, the yield in the experiment is probably greater than would be obtained elsewhere since the site was of very high quality. A poorer site might produce similar yields if the pasture received regular applications of fertiliser. However, there was no attempt to encourage the pasture in this experiment, nor was there any planned grazing, even though the pasture returned to the site after the first thinning and remained present thereafter.

It is often held that a very high growth rate is undesirable, particularly in pines, as the wood produced is of low quality, having low wood density and therefore poor strength and relatively high shrinkage. In fact, this is not so except for the central core of juvenile wood that occupies the first 10 to 12 growth rings from the pith at any point on the tree bole. Juvenile wood is intrinsically of low quality, for it has marked spiral grain, low density, high shrinkage and low strength. These properties are affected in a minor way by rate of growth. The quality of mature wood is not affected by rate of growth (Turnbull, 1947; Sutton and Harris, 1974).

The butt logs from the 19.5 year thinning of Treatment 6 at Mungalup were sent to a plywood factory and rotary peeled for veneer, yielding veneer of a very acceptable face quality. The remaining sawlog-sized logs were sawn into boards and framing timber. Unfortunately, since no grade study was carried out on this material, it was not possible to confirm the detrimental effect of the silviculture on knot size that was suggested by the results of the 1968 spacing experiment.

Nevertheless, it is clear that the natural response of the trees to the greater growing space, which is a feature of an agroforestry management system, is increased branch development. Branches will grow vigorously for perhaps 10 years instead of the usual 3 to 4 years, thus inevitably forming larger knots on the bole. In terms of their effect on timber strength, knots are equivalent to a hole in the timber, hence the larger the knot the greater its effect on wood quality. Therefore, strictly timed pruning of the limbs on the lower part of the bole, up to approximately 10 m from the ground, is necessary to produce high-quality wood. Since this is far higher than

TABLE 3

Branch development in the low-pruned zone (0 m to 2.1 m)
Blackwood Valley trial

| Spacing | Stems per hectare | Mean branch basal diameter over bark (cm) | Mean branch basal area ($cm^2$) | Mean number of branches |
|---|---|---|---|---|
| 6.3 x 6.3 m | 250 | 2.15 | 4.73 | 38 |
| 4.5 x 4.5 m | 500 | 2.36 | 5.77 | 38 |
| 3.6 x 3.6 m | 750 | 2.10 | 4.79 | 33 |

the present level of high pruning in Western Australia, techniques for pruning to such heights need to be developed.

There have been many theoretical studies of the value of pruning and the possible yields of clear timber (for example, Rowan, 1963). Undoubtedly, the production of some clear timber is worthwhile as there is always a market for a good product, but in recent years it has been realised that the cost of intensive pruning in conventional pine silviculture cannot be justified only on the grounds of production of clear timber. The real value of pruning lies in the prevention of the formation of large knots and especially of loose knots (Brown, 1974). In agroforestry the situation is somewhat different. High pruning is necessary, or otherwise the timber will certainly contain excessively large knots. An additional benefit from this pruning will be a tendency towards wood of higher density (Cown, 1973).

High pruning is also necessary for optimum pasture production in agroforestry, since light intensity at the ground surface is an important factor influencing pasture production in this management system.

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