Sawmilling Trial Of Agroforestry And Conventionally-Grown Radiata Pine

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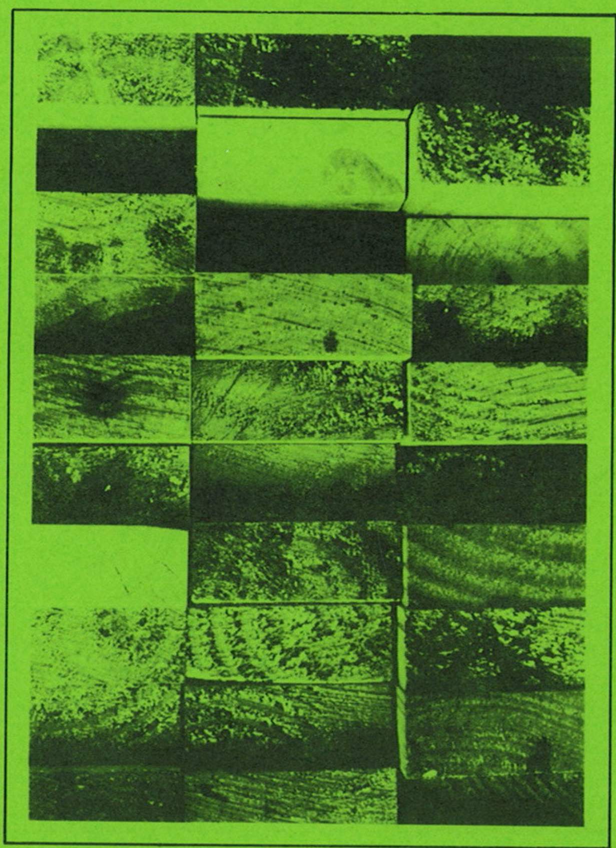

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CONTENTS

SUMMARY

A sawmilling trial of radiata pine (*Pinus radiata* D.Don) was designed to produce mainly structural timber. The logs came from an agroforestry trial, a fuel reduced buffer, three conventionally grown Departmental plantations and a private plantation. Log size distribution from each area was similar. The sawn graded recoveries and percentage of F5 stress grade timber produced were similar for each treatment. However, there was a high percentage of docked F5 lengths in the fast-grown pine, with the main factor involved being the large proportion of juvenile wood.

A further sub-sample of logs not making the current Departmental log specifications was milled, producing sawn graded recoveries similar to those from specification logs. A sub-sample of specification logs cut exclusively into boards indicated the advantages of milling young agroforestry logs for this product.

The trial included a comparison of visual stress grading and mechanical proof grading, showing that the latter method was less conservative.

INTRODUCTION

Radiata pine (*Pinus radiata* D.Don) is the major exotic timber species grown in Western Australian plantations. The silvicultural schedules followed by the former Forests Department and now the Department of Conservation and Land Management (CALM) are intended to produce sawlogs in a rotation length of 30 years.

In recent years Government policy changes have resulted in a decreased Departmental pine planting program and in moves towards an increased private resource. Agroforestry and share-farming schemes have been promoted to provide part of this resource. The CALM agroforestry research program has concentrated on growing pines at wide spacing in conjunction with agricultural activities, and silvicultural schedules for agroforestry stands are now available.

In the Western Australian environment, fire protection is of major concern, and part of the protection strategy is the use of fuel-reduced buffers with trees comparatively open-grown and grazing of grasses by stock to reduce the fire hazard. The growing conditions of pine in fuel-reduced buffers are therefore similar to those of agroforestry pine.

However, there are limited data on wood quality and sawn graded recoveries of radiata pine grown in agroforestry stands. The present trial was designed to compare sawn graded recoveries from an agroforestry stand with those from a fuel-reduced buffer, from a range of older conventional plantations, and from a single private plantation. Recoveries from samples of logs outside sawlog specification requirements were also assessed. A further aim was to obtain data to compare visual stress grading and machine proof grading.

MATERIALS AND METHODS

The sawlogs used in this sawmilling trial came from the following sources:

(i)	agroforestry	- Ewart Road agroforestry trial Kirup District (13 years)
(ii)	fuel reduced buffer	- Ferndale plantation, Kirup District (14 years)
(iii)	conventional forest	- (a) Hills plantations
	ex pasture -	Mungalup, Collie District (28 years)
	ex bush -	Mungalup, Collie District (25 years)
		(b) Harvey Coast plantation
		Coast Plot 2, McLarty, Harvey District (21 years)
(iv)	private plantation	- Murray Location 210, Dwellingup District (17 years)

The silvicultural history of these areas is given in the Appendix. In the Hills plantation, forest managers are aware of substantial differences in growth rates between 'ex pasture' areas that were pastured before pine plantations were established, and 'ex bush' areas that were native forest. The previous regular fertilizing of pasture gives these sites a considerable growth advantage.

A complete trip of mill logs (25-30 m^3) was supplied from each area to CALM's Wood Utilisation Research Centre (W.U.R.C.) at Harvey, where the sawmilling trial was done. Each log was measured and identified on arrival at the mill landing.

The logs were then graded to the Department's current pine sawlog specification. Briefly, the major requirements were :

- 20 cm minimum small end diameter under bark (s.e.d.u.b.)
- no excessively large knot whorls
- maximum sweep of 30 mm in any 2.1 m section of the log.

The logs were separated into three groups : (i) specification logs (ii) logs with excessively large whorls, and (iii) logs with excessive sweep.

Each area and log class was identified by painting both ends of each log to follow that material through the sawmill. The logs were milled into mainly structural timber, except for ten specification logs from each of agroforestry, fuel reduced buffer and ex pasture plantations which were set aside for milling into appearance grades only (i.e. boards).

The milling was done in two stages for more efficient scheduling of the overall research program at W.U.R.C. The first stage included the agroforestry, fuel reduced buffer, ex pasture plantation, and the private plantation material. The second stage included ex bush plantation and Harvey Coast plantation.

The initial breakdown of the logs was on the twin edger, to produce a 100 mm thick centre flitch. Resawing was done on a breast bench. The major size milled was the nominal 90 x 35 mm, with some 70 x 35 mm. Boards of nominal dimensions of 90 x 19 mm and 70 x 19 mm were cut when the larger dimensions were not feasible.

The seasoning of the timber was by high temperature drying using the standard schedules for heart-in structural timber of radiata pine (Radiata Pine Association of Australia 1979). The schedule involves seasoning under restraining weights of 980 kg/m^2 on top of the stack, with presteaming for at least four hours to plasticise the lignin in the timber, eight hours of drying at 120°C, then a post drying steaming for stress relief for at least four hours.

The structural timber was visually sorted using standard grading rules (Standards Association of Australia 1986) to separate out pieces which would not make F5 stress grade. The major defect in each piece was recorded. The timber was then mechanically proof graded using a 'Hilleng' machine. The visual F5 material was graded first, then the visually reject material that just failed to make the specification. Some pieces obviously had no chance of being upgraded, and were classified as structural appearance grade.

The appearance grade material was also graded according to the relevant standard (Standards Association of Australia 1973), and the major defect in each piece noted.

RESULTS AND DISCUSSION

The data for log distribution in 5 cm small end diameter classes are given in Table 1. Sample size for specification logs was considered satisfactory with at least 45 logs in each treatment. The specification logs had a reasonably similar distribution of log sizes, which is an advantage in making comparisons of sawn graded recoveries from different silvicultural treatments. The Harvey Coast specification logs included 9 per cent whose small end diameter was just under the nominal 20 cm s.e.d.. Logs which did not make specification because of excessively large knot whorls or excessive sweep, also included a proportion with less than the nominal 20 cm s.e.d..

Sawn graded recoveries are given in Table 2. As stated in Materials and Methods, age varied from 13 years for agroforestry logs to 28 years for Hills plantations on an ex-pasture site. The major results in the Table are the overall recovery percentages and the percentage making F5 stress grade material.

The recovery from specification logs ranged from 27.4 per cent for the private plantation material to 32.5 per cent for the ex-pasture site. The recoveries from non-specification logs were similar to those from specification logs, which indicates that the log specification (particularly for sweep) could be reassessed, by taking into account both the recovery and the wood quality.

The percentage making F5 stress grade in specification logs varied from 62.2 per cent for the ex pasture site material (which would be expected to have a large juvenile core), to a very satisfactory 86.6 per cent for the Harvey Coast material. The agroforestry and fuel reduced buffer material gave a satisfactory result, with 66.3 and 74.5 per cent respectively.

The variation in results can be largely explained by the considerable age differences and perhaps site and silvicultural variations, although log size distributions were reasonably similar. The proportion of the log cross-section make up of juvenile wood (up to 10 years) varied considerably. Juvenile wood has comparatively low density, shorter tracheids, higher micellar angle in the cell walls, and higher spiral grain than does mature wood (Hillis 1975). The fast growth in the agroforestry stands, fuel reduced buffers, and ex pasture sites results in large juvenile cores. The combination of low density and knots is generally recognized as the major reason why heart-in structural timber (i.e. occurring within a 50 mm radius of the pith) is less likely to make F5 stress grade.

Table 1. Log distribution by small end diameter class in different treatments (%)

Treatment	Total No. Logs	Log diameter class (cm) <20	21-24	25-29	30+
Agroforestry					
Specification*	53	-	24.5	47.2	28.3
Large knot whorls	41	36.6	48.8	14.6	-
Excessive sweep	17	29.4	41.2	17.6	11.8
Fuel reduced buffer					
Specification	49	-	22.4	59.2	18.4
Large knot whorls	45	17.8	44.4	26.7	11.1
Conventional Dept. plantations					
Hills:					
Ex pasture (Spec)	110	-	28.2	40.0	31.8
Ex bush (Spec)	120	-	40.8	50.0	9.2
Harvey Coast:					
Specification	139	9.4	46.0	39.6	5.0
Large knot whorls	37	21.6	62.2	13.5	2.7
Excessive sweep	17	5.9	35.3	52.9	5.9
Private Plantation					
Specification	45	-	20.0	46.7	33.3

* Specification logs: 20 cm min.

Table 2. Sawn graded recoveries of structural timber

Treatment	Age (yrs)	Log Volume (m^3)	Volume Recovery (m^3)	Recovery (%)	F/Length F5 Recov. (%)	Docked F5 Recovery (%)	% F5 Total	Struct. Appear. (%)	Board Recov. (%)
Agroforestry									
Specification logs	13	13.94	4.06	29.1	52.1	22.4	74.5	21.0	4.5
Large knot whorls	13	6.59	2.00	30.3	41.6	29.0	70.6	15.3	14.1
Excessive sweeps	13	3.46	0.96	27.7	30.2	12.0	42.2	48.7	9.1
Fuel Reduced Buffers									
Specification logs	14	13.29	3.96	29.8	48.9	17.4	66.3	30.4	3.3
Large knot whorls	14	10.79	2.83	26.2	42.0	23.1	65.1	30.7	4.2
Conventional Plantation									
Hills:									
Ex pasture(Spec)	28	29.98	9.75	32.5	51.3	10.9	62.2	29.8	8.0
Ex bush (Spec)	28	27.69	8.94	32.3	79.4	3.8	83.2	5.1	11.7
Harvey Coast:									
Specification	21	33.39	10.49	31.4	85.2	1.4	86.6	1.8	11.6
Large knot whorls	21	6.82	2.24	32.8	84.7	3.1	87.8	0.8	11.5
Harvey Coast									
Excessive Sweep	21	5.25	1.72	32.8	73.4	15.9	89.3	1.1	9.6
Private Plantation									
Specification logs	17	15.05	4.12	27.4	57.5	17.4	74.9	20.9	4.2
Large knot whorls	17	5.58	1.81	32.4	46.0	13.2	59.2	35.4	5.4

The variation in total F5 production is an important factor, but the proportion of that total made up by docked lengths must also be considered. The timber producer may have problems in selling docked lengths, particularly lengths of less than 2.4 m. From Table 2, the proportion of F5 made up by docked lengths from specification logs is:

agroforestry	- 30.1%
fuel reduced buffer	- 26.2%
ex-pasture	- 17.5%
ex-bush	- 4.6%
Harvey coast	- 1.6%
private	- 23.2%

These data indicate that the ex bush site in the Hills plantations and the Harvey Coast site produced better quality timber than the faster-grown stands. The ex pasture site results were disappointing, considering the age of the stand.

In general, the economics of pine plantation management should be taken into account as a corollary to any sawmilling studies, although it is outside the scope of this report. The indications are that the substantial reduction in time to produce a sawlog of given size, by managing the forest for fast growth, more than compensates for the lower wood quality, with the higher percentage of docked F5 and of structural appearance grades.

The silvicultural history of the different stands is given in the Appendix. The comparative lack of silvicultural treatment in the private plantation would explain the high percentage of pieces that needed docking. The fuel reduced buffer sites in the Hills require very strict timing of pruning operations to keep branches and hence knots to an acceptable size.

The recoveries of boards from wings (one sawn face) ranged from 5.3 per cent cut from the fuel reduced buffers to 11.7 per cent from the ex bush material. These boards are a minor component, and comment is not considered necessary on the recoveries although defects in the boards are discussed later.

Table 3 gives recovery figures for the 10 log sub-sample of specification logs, from each of the agroforestry, fuel reduced buffer and ex pasture sites, which were milled entirely into boards. The recoveries were higher than those from the larger sample milled to produce mainly structural timber, with increases of 4.7, 0.8 and 1.5 per cent respectively. The data suggest that milling of agroforestry timber into boards rather than structural timber should be considered.

Table 3. Sawn graded recoveries of appearance timber (boards) from specification logs

Treatment	Age (yrs)	Log Volume (m^3)	Volume Recovery (m^3)	Recovery %
Agroforestry	13	1.48	0.50	33.8
Fuel reduced buffer	14	1.21	0.37	30.6
Conventional plantation (ex pasture)	28	2.41	0.82	34.0

The defects in structural timber (Table 4) are predominantly knots, again indicating the relationships between silvicultural treatments and wood quality. While considerable variation in face, group, and margin knots exists between the different sites, a noticeable result is the high percentage of loose (i.e. bark-encased) knots from the ex pasture site. A high percentage of resin or bark pockets occurred in the ex pasture and ex bush material from specification logs. Changed pruning practices could explain the variation in this defect when comparing specification and non-specification logs from agroforestry and fuel reduced buffer sites. Other types of defect were comparatively minor.

The high incidence of knots indicates the need to consider dimensions in milling heart-in structural material in particular. For a given knot size, 90 x 35 mm material will have substantially less of the cross section taken up by the knot than would 70 x 45 mm cross-sections i.e. 90 x 35 mm has a lower knot area ratio than 70 x 45 mm material.

Table 5 lists the defects in boards from wings milled primarily for structural timber. Obviously there were no problems with included pith. There was a reasonable variation in the occurrence of knots in boards from specification logs (30.2 per cent from agroforestry material to 52.3 per cent from the private plantation). Wane was the major fault in several treatments, and the trends indicated a variation in milling practices between the first and second stages of the trial, a variation which occurred again with undersized pieces.

In the logs milled for appearance grades only, the range of defects in the boards was similar to those milled from the wings (Table 6). Knots were the major defect, with wane the next most important. There was a higher incidence of resin and bark pockets in the agroforestry material than in the fuel reduced buffer and the ex pasture.

Table 4. Defects in structural timber (%)

Treatment	Face	Group	Knots Margin	Edge	Arris	Spike	Loose	Resin on bark pocket	Pith	Wane	Sloping Grain	Bow	Spring	Twist	Planer Damage
Agroforestry															
Specification	23.1	15.4	30.8	-	11.5	-	-	7.7	-	11.5	-	-	-	-	-
Large knot whorls	19.0	23.8	23.8	-	-	-	-	4.0	-	4.8	4.8	4.8	-	-	-
Excessive sweep	11.9	22.4	10.4	-	9.0	-	1.5	29.8	6.0	3.0	3.0	3.0	-	-	-
Fuel reduced buffer															
Specification	14.9	37.2	14.9	-	5.3	-	1.1	9.5	4.3	8.5	1.1	3.2	-	-	-
Large knot whorls	10.5	29.8	10.5	-	8.8	-	-	22.8	14.1	3.5	-	-	-	-	-
Conventional plantations															
Hills:															
Ex pasture (Spec)	8.6	11.7	8.0	-	7.4	-	20.2	20.2	4.9	16.6	0.6	1.8	-	-	-
Ex bush (Spec)	10.6	7.1	16.4	5.9	10.6	-	-	28.2	5.9	5.9	3.5	2.4	-	-	3.5
Harvey Coast:															
Specification	-	11.8	30.9	5.9	14.7	1.5	-	13.2	11.7	4.4	2.9	-	1.5	-	1.5
Large knot whorls	12.5	12.5	26.3	-	10.5	5.3	-	5.3	21.0	-	6.3	-	-	-	6.3
Excessive sweep	14.3	28.5	14.3	-	14.3	-	-	14.3	14.3	-	-	-	-	-	-
Private plantation															
Specification	22.5	24.2	17.2	-	6.9	-	3.4	8.6	5.2	10.9	2.2	2.2	-	-	-
Large knot whorls	6.5	34.7	17.4	-	2.2	-	4.3	10.9	8.7	3.4	3.4	5.2	-	-	-

Table 5. Defects in boards from wings of logs milled primarily for structural timber (%)

Treatment	Knots	Knot & cone holes	Resin & bark pockets	Season-ing surface checks	Season-ing checks in knots	Pith	Needle trace	Bow	Spring	Twist	Stain	Wane	Under-size	Want	Planer damage
Agroforestry															
Specification	30.2	-	14.0	-	-	-	-	-	-	-	-	53.5	2.3	-	-
Large knot whorls	29.2	-	4.9	-	-	-	-	-	-	-	-	61.0	4.9	-	-
Excessive sweep	20.0	-	-	-	-	-	-	-	-	-	-	80.0	-	-	-
Fuel reduced buffer															
Specification	37.8	10.8	2.7	2.7	-	-	-	-	-	2.7	-	40.6	2.7	-	-
Large knot whorls	62.8	5.7	8.6	5.7	-	-	-	2.9	-	-	-	14.3	-	-	-
Conventional plantations															
Hills:															
Ex pasture (Spec)	37.8	6.7	12.2	-	-	-	-	-	-	-	-	34.5	4.4	-	4.4
Ex bush (Spec)	31.5	1.1	22.5	-	3.4	-	1.1	1.1	-	-	1.1	11.3	18.5	6.2	2.2
Harvey Coast:															
Specification	39.5	2.2	19.3	-	2.2	-	1.8	-	-	1.3	3.1	2.2	23.3	3.7	1.3
Large knot whorls	55.5	5.6	11.1	-	5.6	-	3.7	-	-	-	-	-	13.0	3.7	1.8
Excessive sweep	22.5	-	20.0	-	2.5	-	2.5	5.0	-	-	7.5	5.0	30.0	5.0	-
Private plantation															
Specification	52.3	1.4	2.9	1.4	-	-	-	1.4	-	-	-	40.6	-	-	-
Large knot whorls	43.8	-	3.1	-	-	-	-	-	-	-	-	50.0	-	-	-

Table 6. Defects in boards from logs milled for appearance grades only (%)

Treatment	Knots	Knot & cone holes	Resin & bark pockets	Season-ing surface checks	Season-ing checks in knots	Pith	Needle trace	Bow	Spring	Twist	Stain	Wane	Under-size	Want	Planer damage
Agroforestry	38.8	1.2	17.7	3.5	-	5.9	-	5.9	-	-	-	22.3	3.5	-	1.2
Fuel reduced buffer	52.3	1.0	3.6	1.0	-	1.0	-			1.0		33.9	2.7		4.2
Conventional plantations															
Hills:															
Ex pasture	48.4	0.6	2.5	0.6	-	8.1	-	-	-	-	-	28.6	8.7	-	2.5

The trial included a comparison between visual stress grading and machine proof grading of structural timber, by proof grading the pieces that were visually rejected from F5 stress grade (Table 7). In general, the results indicated the conservative nature of visual stress grading. With one exception, proof grading of the visual rejects gave a range of 65.9 per cent to 91.8 per cent F5. Pieces that successfully passed through the proof grader but deflected excessively were regarded as not making F5. The anomaly was material from specification logs in fuel reduced buffers, in which only 16.7 per cent of visual rejects made F5. The basic data indicate that the major cause was a high incidence of face knot combinations. The proof grading results indicated that there are advantages in using the 'run-of-the-mill' approach when a particular source of timber is above average quality, taking into account the price differential between F5 and structural appearance grades. It is important that the pieces of timber have satisfactory stiffness as well as bending strength to satisfy the requirements of stress grading, and any piece that deflects excessively should be rejected. Experience will indicate when pre-sorting before proof grading is essential.

Table 7. Comparison of visual stress grading and machine proof grading of structural timber

Treatment	No. pieces F5 visual reject	F5 by MPG (%)
Agroforestry		
Specification	80	60.0
Large knot whorls	24	88.9
Excessive sweep	31	66.7
Fuel reduced buffer		
Specification	100	16.7
Large knot whorls	67	68.4
Conventional plantations		
Hills:		
Ex-pasture (Spec)	232	91.8
Ex bush (Spec)	308	67.9
Harvey Coast:		
Specification	320	65.9
Large knot whorls	84	82.1
Excessive sweep	55	72.7
Private Plantation		
Specification	72	85.7
Large knot whorls	54	89.3

In summary, the results of this sawmilling study indicated that sawn graded recoveries from fast grown logs from agroforestry or fuel reduced buffers were similar to those from more conventional plantations. Log size distribution was similar in all treatments. The major difference was the high percentage of docked F5 stress grade material in the fast-grown pine, indicating that wood quality is poorer. The reason is the large proportion of juvenile wood in the younger trees (13 years old for the agroforestry treatment, and 14 years for the fuel reduced buffer).

From the forest production point of view, the current log specification criterion that sawlogs must have a minimum small end diameter of 20 cm could be increased in the case of fast-grown pine, to enable a reasonable volume of mature wood to be grown over the juvenile core produced in the first ten years and decrease the proportion of juvenile wood in the log. Agroforestry logs grown to 18 years (the age at which sawlogs are currently produced from second thinning operations) will have substantially larger logs with improved wood quality and greater recoveries. If younger logs must be harvested to satisfy demands there is an argument for a reduced royalty to compensate for the reduction in wood quality.

Improved recoveries appear possible by producing appearance grade material but the comparatively limited demand make this unattractive in the present market environment.

The trial included a small sub-sample of non-specification logs, which produced similar recoveries to specification logs. This indicated a need to review the current specifications for pine sawlogs, particularly in the limitation for sweep. A review has commenced.

From the economic viewpoint, there is strong evidence that the advantages of fast growth would more than compensate for the reduction in wood quality due to the large juvenile core in logs which just make the 20 cm s.e.d. limit. Future research could include a comparison of sawn graded recoveries from logs of the same age grown under different silvicultural regimes.

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APPENDIX

History of areas logged for sawmilling study

Agroforestry	Ewart Road Plots, Kirup District (Plot 1) (Research Working Plan 15/73) 1973 Planted 250 s.p.ha 1977 Culled to 150 s.p.ha, low pruned to 2.0 m. 1978 Pruned to 3.5 m (150 s.p.ha) 1980 High pruned to 7.5 m (150 s.p.ha) 1982 Thinned to 100 s.p.ha 1982 High pruned to 10 m (100 s.p.ha) 1986 Thinned to 50 s.p.ha
Fuel reduced buffer	Ferndale Plantation, Kirup District 1972 Planted (2.4 x 2.4 m) 1978 Culled to 750 s.p.ha, low pruned to 2.1 m 1979/80 High pruned to 5 m (300 s.p.ha) 1981 Thinned to 250 s.p.ha 1985/6 High pruned to 7.5 m (150 s.p.ha)
Conventional ex pasture:	Mungalup Plantation, Collie District Compartments 9,10,11 1958 Planted (2.4 x 2.4 m spacing) 1963/5 Low pruned to 2.1 m (when trees at 8.9 cm d.b.h.o.b.) 1966 High pruned to 4.0 m (250 s.p.ha) 1969 Lightly thinned to produce baulk logs for Harvey mill 1970 High pruned to 6.7 m (250 s.p.ha) 1974 Thinning to 300 s.p.ha completed by this year and some second thinning on better areas 1986 Third thinning on better areas to 200 s.p.ha
ex bush	Mungalup Plantation, Collie District 1961 Planted (2.4 x 2.4 m spacing) 1966 Low pruned to 2.1 m 1968/71 High pruned to 4.0 m (250 s.p.ha) 1975 Thinned to 400 s.p.ha 1986 Second thinning to 250 s.p.ha
Harvey Coast	Coast Plot 2, McLarty Plantation, Harvey District 1965 Planted (2.4 x 2.4 m spacing) 1971 Low pruned to 2.1 m 1973 High pruned to 4.5 m (200 s.p.ha) 1980 Thinned to 250 s.p.ha 1986 Second thinning to 125 s.p.ha
Private	Murray Location 210 (7 km east of Dwellingup) 1969 Planted (2.4 x 2.4 m spacing) Low pruning of crop trees (year unknown) 1984 Thinned 1986 Second thinning (low pruned or fine branched trees selected)