DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

A Report on Second Rotation (2R) Studies in Western Australia

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SUMMARY

This report summarizes existing second rotation (2R) trials and makes recommendations on 2R establishment techniques, based on interim results from current experiments.

The Victorian and South Australian studies with *Pinus radiata* on 2R sites have shown that on poor sandy soils nutrient depletion when slash is burnt leads to a decline in productivity. If crushing slash is practised instead of burning slash, better 2R growth is achieved. This is due to the mulch created, which conserves the organic matter and nutrients and improves the soil moisture conditions.

Data from existing *P. radiata* trials in Western Australia are not available yet. However, if burning slash is generally conducted on poor sandy soils similar to the Victorian and South Australian ones, it is envisaged that decline in productivity is likely to occur. Part of the Sunkland and the Harvey Coastal Plantations are in this category, having poor sandy soils.

From interim results of a major 2R trial established in 1985 at Myalup, W.A., in three year old slash (slash left *in situ* for three years prior to planting), survival of *P. radiata* seedlings is seriously affected. If the three year old slash is furrow lined (i.e. removed in the planting lines) good survival is achieved. With one year old slash there were no survival problems.

On fertile loamy soils in the Hills Plantations, it is unlikely that losses in productivity will take place. Broadcast burning is not a current practice in these areas. The standard technique is to heap and burn slash, producing a mild burn compared with hot broadcast burns.

With *P. pinaster* the other species dealt with on the Coastal Plain north of Perth, a long term study is in progress to compare first and second rotation growth on plots side by side, planted simultaneously. Other 2R experiments at Gnangara are also in progress and will enable a study of growth under different types of site preparation treatments.

INTRODUCTION

In Western Australia pine plantations managed by the Department occupy about 60 000 ha. *Pinus radiata* the major species in terms of total planted area, occupies some 34 000 ha mainly on fertile soils of the South West of the State. *Pinus pinaster*, second in importance to *P. radiata* in terms of total planted area, occupies over 28 000 ha including 20 000 ha of plantations on poor sandy soils of the Coastal Plain north of Perth.

Some of the early plantations, established from the 1920's onwards, have already been clearfelled and replanted, but there are still large plantation areas of stands now reaching the economic rotation of thirty years.

In 1966 a decline in productivity with successive rotations of radiata pine plantations was reported in the Eastern States, where burning of slash was conducted on poor sandy soils. As a result of these findings, in the 1970's studies were initiated in Western Australia to find out whether a similar problem existed in our plantations, and if so, to find the means of correcting it.

In Victoria more recent work has shown that the decline in productivity was due to nutrient depletion by burning slash and that when slash was crushed, better second rotation growth was achieved. This was due to the mulch created which preserved the organic matter and nutrients and improved the soil moisture conditions on poor sandy soils.

In 1982 further second rotation studies were initiated in Western Australia, and several experiments were established to compare and complement the Victorian and South Australian studies.

This report summarizes the experiments established in Western Australia to study the second rotation problem and makes recommendations on second rotation establishment techniques based on interim results from the experiments.

SECOND ROTATION (2R) EXPERIMENTS

W.P. 29/71 - Gnangara Plantation and Grimwade

This was the major second rotation study designed in 1971 to study the long-term growth of *Pinus radiata* in the southwest (Grimwade) and *Pinus pinaster* in the plantations north of Perth (Gnangara).

Each study area had two principal objectives:

1-To ascertain whether there was a decline in productivity occurring in all W.A. pine plantations and if so,

2-To find the means of preventing or minimizing the decline.

The first part of the experiment consisted in carrying out stem analysis on mature trees of a stand, clear fell and replant using the original establishment techniques (same seed source, similar spacing and fertilizer) as the previous stand. In addition, improved techniques would be used (pedigree stock, optimum spacing and fertilizer) in another adjacent plot. A comparison of growth between the two rotations could then be made using stem analysis data from the previous crop and measurement of growth of the current crop.

The second part consisted of modifying the microenvironment of a mature stand to benefit the next crop. This was done by thinning a stand during the last five years of the rotation and crushing or burning the resulting slash, sowing a N-fixing crop (clover or lupins) and heavily fertilizing the stand. It was expected that any decline in productivity would then be counterbalanced by the treatments mentioned above.

The Gnangara experiment was seriously affected by poor survival of *P. pinaster* seedlings, following replanting of the first part of the experiment. Delay in clear felling the second part of the experiment (five years after the treatments were applied) has also adversely affected the reliability of the experiment (effects of treatments presumably would have dissipated over more than five years). However, preliminary results for the first part of the experiment are now available, comparing 2R growth at age six with that of the 1R through stem analysis data.

At Grimwade the first part of the experiment (one plot replanted in 1973 with the original techniques; one plot sown with clover, left for seven years and then replanted in 1980) is still viable. Other plots were destroyed by fire. No

establishment problems were recorded and the plots were replicated on good and poor quality sites. In addition, a stand of naturally regenerated *P. radiata* of comparable age (the previous stand was clearfelled in 1972), equivalent to a stand planted in 1973, was available for comparison with growth on the good site. Apart from the stem analysis data from previous stands, there are no measurement data for these plots. The second part of this experiment has become limited due to ineffectiveness of treatments applied. Presence of large hardwood slash reduced the efficiency of the crushing treatments, while broadcast burning was inefficient because there was no uniform distribution of slash to produce a hot burn.

RESULTS

Gnangara Experiment - *P. pinaster*

The following results for the first part of the experiment were possible, comparing 2R growth with that of the previous stand at the same age (six years). For the first rotation stand (1R), height at age six was derived from stem analysis carried out on 100 predominant trees per hectare. For the second rotation stand, height was a result of direct measurement carried out on 250 trees.ha-1.

	1R	2R
Sample size	40	160
Mean Height (m)	5.00	5.37
S.D.	-	0.38

Results show that height growth for the 1R and 2R at age six is similar. The value for 2R height was obtained combining both treatments ("original techniques" and "improved techniques"). There was a difference of 9% between the two treatments. This could be partly attributed to better genetic stock on the "improved techniques" treatment, since differences in growth between routine and pedigree stock in progeny trials are of the order of 10-15%. Higher levels of fertilizer applied in "improved treatment" may also explain, in part, the better growth observed in this treatment.

W.P. 22/85 - Effect of site preparation and fertilization on survival and growth of *P. radiata* on 2R sites, yellow sands at Myalup, Harvey Coastal Plantation.

The study was part of a combined research-management project to study the long term growth of *P. radiata* on 2R sites, under different types of site preparation techniques - crushing slash, burning slash and slash left untreated. It was also intended to test the effect of a rotary rake which windrows logs, large branches and tops onto the fire break, retaining the needles and smaller branches *in situ*. A N-fixing crop (clover) to possibly improve the nutrient status of the soil and pine growth was used.

Furrow lining as a technique to improve survival of seedlings was tested in a separate experiment. The aim of furrow lining is to open V-shaped trenches to concentrate moisture in the planting lines.

Thirty six hectares were prepared for replanting, with about 18 ha of three year old *P. pinaster* slash (slash left *in situ* for three years after clear felling) and about 18 ha of one year old *P. pinaster* slash (slash left *in situ* for one year after clear felling). Some *P. pinaster* stands on the Harvey Coast growing on yellow sands were clearfelled for particle board material and replanted to *P. radiata* because the latter species grown on suitable sites provides a much greater economic return than *P. pinaster*.

The experimental design consisted of a split-plot randomized block design of the following treatments.

1- Main plots

Burning slash - a hot broadcast burn was achieved.

Crushing slash - with a dozer drawn vibrating roller, fitted with blades to achieve a crushing effect.

Control - slash left untreated.

Raking was carried out with a Symonds rotary rake towed by a D7 dozer, removing the large material (logs and branches) and retaining the needles and smaller branches. This treatment was conducted in one year old slash only and it was not part of the overall experimental design.

2- Sub-plots

Establishment of legume species and fertilization - the type and variety of legume species used and rates.ha-1 were as follows.

-Hykon rose

-Tornafield medic

-Nungarin subclover

Rate: 12 kg.ha-1 (16 kg.ha-1 with lime pelleting), 2:2:1 respectively, broadcast sown. Fertilizer used was coastal super 200 kg. ha-1 and super Cu Zn Mo no.2 200 kg.ha-1 broadcast, prior to planting.

Fertilization (no clover) - coastal super 200 kg.ha-1 and super Cu Zn Mo no.2 200 kg.ha-1 broadcast, prior to planting.

Nil - no fertilizer or clover.

Replication - There were two replications of the main plots with the subplots consisting of 160 trees.

Planting was carried out in July 1985, by hand, each seedling receiving 150 g of Agras no.2 with minerals (N 12%, P 10.4%, Cu 0.33% and Zn 0.33%) as initial fertilizer, speared in , 15 cm from the stem.

The furrow lining experiment consisted of a split-plot randomized block design of the following treatments.

1-Main plots

Burning three year old slash

Crushing three year old slash

2-Sub-plots

Furrow lining slash with a furrow line plough, running in between the old rows of stumps to a depth of 15-20 cm.
No furrow lining.

The sub-plots consisted of three rows of 10 trees and there were 5 replicates for each main treatment. There were no buffers.

RESULTS

Survival of *P. radiata* seedlings under several site preparation and fertilizer treatments, 8 months after planting a 2R site at Myalup.

Slash age	Burn	Crush	Nil	Clover	Fert.	Nil
3 year old slash	77[a]	36[b]	37[b]	40[b]	57[b]	52[b]
1 year old slash	68[a]	69[a]	59[a]	53[b]	69[a]	74[a]

Values having the same superscript are not significantly different at $p \leq 0.05$.

Effect of furrow lining on crushed or burnt 3 year old slash on the survival of *P. radiata* seedlings.

Treatment		Height Inc.	Survival
C	Furrow	25	79
R		**	**
U	No Furrow	18	32
S			
H			
B	Furrow	26	87
U		n.s.	*
R	No Furrow	23	72
N			

n.s. difference not significant at $p \leqslant 0.05$.
* significant difference at $p < 0.05$.
** significant difference at $p \leqslant 0.01$.

Results have shown that there is a clear detrimental effect of clover on the survival of *P. radiata* seedlings on sandy soils at Myalup. Clover, particularly the variety 'Hykon rose',established well on these sandy soils and competed strongly with the planted seedlings. It was essential to chemically control clover in the planting lines, before planting to avoid these competitive effects.

There was also a deleterious effect in three year old crushed or untreated slash on the survival of *P. radiata* seedlings, not observed in one year old slash, when the effects of clover were excluded.

It was also apparent that by removing this three year old slash through furrow lining, survival and growth improved substantially.

It is not known exactly what was the primary effect in the three year old slash on survival of *P. radiata* seedlings.

Preliminary investigations showed that although there were some weed species widespread throughout the area, these were not competing to any extent with the planted pines. The three year old slash treatment did not appear to have any more weed species than the one year old slash treatment. Planting technique was satisfactory and did not appear to be a contributing factor.

Several hypotheses to explain the poor survival in three year old slash are plausible. They include:

1 - A phytotoxic effect (allelopathy), with the release of chemicals that are antagonistic to survival and growth of *P. radiata* seedlings.

2 - Presence of a pathogen in decomposed slash.

3 - Soil moisture relationships in three year old decomposed slash. This slash may absorb (and trap) moisture more readily than the less decomposed one year old slash, therefore delaying the wetting of the mineral soil.

In general, results from this experiment suggest that unless three year old slash is furrow lined to remove the slash in the planting lines, survival of *P. radiata* seedlings is very poor. Clover should be controlled in the planting lines, before planting, to avoid competition with the planted pines.

The raking treatment proved to be efficacious in terms of survival of seedlings. It was also safe and less physically demanding on planters as access was eased (as opposed to operating on ground with large pieces of slash, sometimes slippery.

Although burning slash also gave satisfactory survival rates, the long-term effect on growth and productivity is not known.

W.P. 7/82 - Efficiency of crushing versus burning slash.
Gnangara Plantation, Section B,
Compartment 49.

This experiment was designed to study *P. pinaster* second rotation growth in crushed or burnt slash (residue after clear felling the first rotation crop), to complement the Victorian and South Australian studies.

The unthinned section of compartment 49 (4.8 ha) was affected by drought in 1977 in which most trees had perished; these were clearfelled and left on the site. The remaining standing live trees were clearfelled in 1982 and slash was either burnt or retained unburnt and crushed. The experimental design of split-plot randomized block included the major plots burning or crushing slash and the minor plots fertilizer P + N or P only. Size of the major plots was 100 x 60 m and the minor plots 60 x 25 m.

The experimental area was ploughed with a furrow line plough running parallel to the old rows of stumps, one week prior to planting. The planting operation was carried out in July 1982, using hand planting spears, with 4 x 2.5 m spacings. Fertilizer was applied in accordance with the treatment layout. Each seedling receiving the 100 g of "Agras" (P + N), had it applied broadcast to one side 15 cm away from the stem. The other seedlings, receiving 60 g of superphosphate (P) had it broadcast across the plant.

RESULTS

Several visual inspections after planting showed good survival. However, in January 1983 a quantitative survival assessment contrasted with the earlier inspections. Widespread mortality averaging 37 per cent was occurring.

Treatments	Mortality
Site Preparation	
Crush	38a
Burn	35a
Fertilizer	
(Agras) P + N	43a
(Super) P	31b

Same superscipt indicate difference not significant at $p \leqslant 0.05$.

There were significant differences (at $p \leqslant 0.001$) between mortalities for the two fertilizer treatments, but no significant differences (at $p \leqslant 0.05$) between any of the other treatments. However, the high mortality rates could not be attributed solely to the "Agras" fertilizer. There may have

been some toxic effect from the nitrogen-fertilizer mix, but widespread mortality only became apparent in January 1983 and most seedlings were healthy prior to their death.

Several factors are possibly involved in the poor survival.

They include:

- Hydrophobic soils
- Allelopathic effects
- Soil pathogens
- Poor nutrition
- Alterations in the microflora and fauna
- Methods of site preparation
- Hand planting technique
- Presence of weeds
- Soil compaction
- Root system development

In 1983 the dead seedlings were removed and replanted. Soil wetting agent was applied prior to replanting to one half of the replanted seedlings (in paired plots i.e. one replanted seedling with wetting agent, one replanted seedling without wetting agent). There were large numbers of weed species in the 1983 planting and they may have strongly competed with the planted pines. A weedicide (Roundup) was applied, but this presumably was too late because the seedlings were already stressed, and only a very small number of the replanted seedlings survived.

This experiment is still in progress, and in the long-term it will enable a comparison of growth of *P. pinaster* under different types of site preparation treatments.

The follow-up fertilizer treatment is to be applied in 1986/7:

1)-Treatment 1 - 250 kg.ha-1 super to the seedlings which received 60 g of super (P) at planting time.

2)-Treatment 2 - 250 kg.ha-1 super + 150 kg.ha-1 urea to the seedlings which received 100 g of Agras (P + N) at planting time.

Initial survival was reported in C.A.L.M. Research Paper no.1.

W.P.25/83 - Comparison of first and second rotation stands side by side, planted simultaneously, on marginal and good yellow sands at Yanchep.

This experiment enables a direct comparison of 1R and 2R plots side by side, established at the same time - 2R plots by replanting old pine pilot plots and 1R plots by clearing native vegetation surrounding each pilot plot.

Earlier 2R studies compared the growth of a stand with that of the previous one on the same site. This does not account for annual climatic differences which occur between rotations, while the silvicultural practices of the day and the genetic stock may change from one crop to another. This study also includes crushing or burning slash and encompasses site variation within the yellow sands as eight pilot plots covering marginal to good yellow sands were planted.

Each pine pilot plot was harvested and adjacent native vegetation was cleared and heaped. Site preparation in 1R plots included burning the heaps ploughing and then furrow lining. In each 2R plot pine slash was crushed (one half) and burnt (the other half) and the plot furrow lined parallel to the old rows of stumps. Some plots had the site preparation work done prior to the one done for the others because of availability of machinery in the designated areas. Planting, however, was done at the same time for all plots in July 1984, and very good survival after planting was achieved. Initial heights were measured three months after planting, and a survival assessment was carried out twelve months after planting when a very high survival rate was recorded for all plots (97 per cent).

W.P.20/79 - Experiment at Margaret River Plantation.

The aims of this experiment were to investigate the effect of various site preparation treatments (crushing, burning) on site productivity, and to test a machine to crush slash.

The treatments were:

1 - Crushing slash, sowing clover and planting pines.
2 - Double crushing, sowing clover and planting pines.
3 - Double crushing and planting pines.
4 - Crushing slash and planting pines.
5 - Total cleanup (control of regrowth, slash windrowed and burnt), sowing clover and planting pines.
6 - Minimum disturbance (regrowth controlled, large size pine and hardwood slash heaped and burnt), sowing clover and planting pines.
7 - Minimum disturbance with no clover.

The larger hardwood slash prevented an effective crushing treatment. The hot burning effect was also unsatisfactory. Another impediment which affects the statistical analysis of this experiment is that the three replications of treatments 5 (burning slash) are located together, on a single site type different to all the sites for other treatments.

There are no data available for this experiment. However, the experiment can be used as a demonstration of different site preparation treatments for 2R establishment.

W.P.10/83 - Effect of incorporation of soil wetting agents and other soil amendments on the survival of *P.pinaster* Gnangara Plantation.

This experiment was a short-term trial to investigate the effects of soil wetting agents, water absorbent gels, red mud, fly ash, etc.,on the survival of *P. pinaster* seedlings.

Previous 2R establishment failures may have been due to poor soil moisture conditions. By incorporating soil wetting agents and other amendments it was expected to reduce the soil hydrophobic character, with the effect of maximizing survival.

RESULTS

The mean mortality at the end of summer was 18 per cent. No significant differences in mortality rates between the different treatments were recorded.

This experiment is now terminated and has been reported in C.A.L.M. Research Paper no.1.

W.P.11/83 - Effect of furrow lining versus non furrow lining crushed slash on the survival of *P. pinaster*, Gnangara Plantation.

Poor survival in previous 2R studies may have been due to an adverse effect of furrow lining. This type of site preparation technique exposes mineral soil in the planting lines and reduces the effect of the mulch.

This experiment also tested the effect of P + N and P fertilizers, because P + N (Agras), may have also contributed to high mortalities in an earlier experiment. The treatments were applied in a split-plot randomized block design.

RESULTS

Survival and height growth of *P. pinaster* seedlings seven months after planting

	Survival%	Height Inc. (cm)
Furrow lining	97a	8a
Control	92b	10b
P + N	95a	9a
P	93a	9a

Same superscript shows difference not significant at $p \leq 0.05$.

Results from this trial showed that furrow lining is not detrimental to good survival of seedlings, it gave significantly better survival rates than the control. Also, the P + N fertilizer (speared in 15 cm away from the seedling), gave better survival rates then P only although the difference was not significant.

This short-term experiment is also terminated and has been reported in C.A.L.M. Research Paper no.1.

Legume trials on the Harvey Coast

Several trials were established on the Harvey Coastal Plantation on second rotation areas using legume species as an alternative to inorganic fertilizers.

Legume species used were:

-Lupins

-Clover (several varieties)

-Medics

-Serradella

Most of these trials failed due to poor survival of *P.radiata*, thus suggesting a strong competitive effect between legume species and the planted pines. With lupins for example, even when chemically sprayed, they regenerated and competed with the pines.

On Coastal sandy soils at Myalup moisture appears to be a critical factor for pine survival, especially during the first summer. If legume species are to be established on such soils a thorough chemical control in the planting lines is required.

Suitable species have been recommended in Hingston's report for W.P. 17/82.

DISCUSSION AND RECOMMENDATIONS

Second rotation experiments with *P. pinaster* at Wanneroo are still in progress and are expected to provide long-term answers on any productivity changes between rotations.

With *P. radiata* only limited information is available from the existing trials. However, if slash is burnt, decline in productivity is likely to occur, especially on poor sandy soils similar to the Victorian and South Australian ones, due to nutrient depletion and poor soil moisture conditions.

On Coastal Plantations, after clear felling the 1R crop, it is recommended that slash be kept unburnt (crushed). The best technique to retain slash tested so far, was to rake with a Symonds rotary rake. This involved the windrowing of logs and large branches onto the break, retaining small branches and needles *in situ*.

At Myalup trials showed that slash should not be left *in situ* for three years (three year old slash) prior to replanting because this may contribute to poor seedling survival. Areas with three year old slash not yet replanted should be furrow lined (removing three year old slash in the planting lines) prior to replanting to avoid poor seedling survival. In one year old slash no survival problems have occurred.

Due to the presence of old rows of stumps on 2R sites, access of planting machines is difficult. Hand planting into crushed slash is physically demanding and the risk of poor planting is high. Hand planting has to be carefully conducted to ensure a reasonable depth of planting as well as a tight soil-root contact in transplanted seedlings.

On fertile loamy soils in the Hills plantations it is unlikely that losses in productivity will take place. Broadcast burning is not a current practice in these plantations. The standard technique is to heap and burn slash producing a mild burn compared with hot broadcast burns. However, the best technique to establish the 2R crop on these sites should have into account that burning of slash on steep terrain may cause erosion problems in addition to the possible nutrient depletion problem. In terms of the optimum management solution each situation should be judged on its merits.