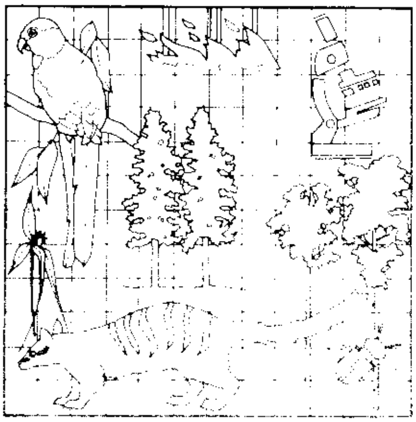
Research Paper



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Potential of *Pinus pinaster, P. radiata* and *P. elliottii* to rehabilitate dieback sites.

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SUMMARY

Four sites were planted to assess the potential of three *Pinus* species to rehabilitate areas on which the indigenous forest was affected by dieback disease. The pines were planted on a range of sites with two types of site preparation and six fertilizer treatments. *Pinus pinaster* grew better than *P. elliottii* or *P. radiata* on all sites, with the same type of site preparation and fertilizer application. Mounding was essential to survival of all species on wet sites. With minimal fertilizer application on marginal sites (initial application only, at planting time) *P. pinaster* still maintained good growth, whereas in *P. radiata* or *P. elliottii* growth declined without refertilization at age four years. On the best sites all species achieved very good growth irrespective of treatments.

INTRODUCTION

In the Darling Ranges disease caused by *Phytophthora cinnamomi* Rands, commonly known as dieback, has infected many areas of the native jarrah forest (*Eucalyptus marginata* Sm.). The reduction in vegetative cover has caused reduced transpiration and a consequent rise in the groundwater table. In some of the more easterly occurrences, such as at Mt. Cooke (about 65 km S.E. of Perth), salt was released from the large salt storage in the deep soil profile by the rising of the groundwater table. The usual consequence of saline seepage is further destruction of the vegetative cover. The principal objective in these eastern dieback sites is to lower the water table and retain salts in the subsoil by revegetating. Further benefits can be obtained from the revegetation by using commercial timber producing *Pinus* species for the rehabilitation, however, in water catchments timber production is a secondary consideration (Havel 1975a), water production being the primary one.

Early studies on pine nutrition by Kessell and Stoate (1938) indicated that pine establishment and good subsequent growth was possible on fertile red loamy soils in the Mundaring area. However, these soils occurred only in limited strips and the costs of managing such plantations were very high (Havel 1975a). On infertile wet sites establishment of pine and subsequent growth, including vigour (diameter and height) and form (stem straightness and butt sweep caused by the site conditions) were a problem. Site preparation treatments had to include ploughing and/or mounding for establishment and subsequent stability. On these infertile sites, comprising lateritic gravels which have a high phosphate holding capacity (Havel 1975c), growth was very poor unless heavy fertilization was applied (Keay *et al.* 1967).

This paper describes a study designed to test the effects of different site preparation methods and fertilization regimes applied during the first nine years of growth on three pine species, *Pinus pinaster* Ait., *P. radiata* D. Don and *P. elliotti* Engelm var. *elliottii*, planted on sites varying from wet to well drained sands and from gravels to moist sandy loams. The objective was to determine which of these species performed best overall on these degraded sites.

METHOD

Location

The study was conducted in the Mount Cooke area, at longitude 116° 18'E and latitude 32° 26'S, about 65 km south-east of Perth. The area is part of the Darling Range and the elevation ranges from 305-366 m (Havel 1975c).

The climate is typically mediterranean (Gentilli 1971), determined by its proximity to the Indian Ocean, by its latitude, and by local topographical configuration. There is a predominance of winter rains, when moist westerly winds drop moisture as they rise over the coast and the Darling Scarp: the average annual rainfall is about 1000 mm (Bureau of Meteorology 1966).

Churchward and McArthur (1980) described the landforms and soils of the area as sands and gravels. Havel (1975b and c), in a detailed study of the Darling Range, classified the following site-types within the study area:

Type AY - characterised by wet leached acid sands, waterlogged in winter, underlain by impermeable horizon (Site 1 in the present study).

Type B - leached humusoid acid grey sands, moist to wet in winter, rapidly drying out in summer (Site 2, parts of Sites 1 and 3).

Types H and J - extending from gravelly sands, through to pale yellow sands and into leached sands (Site 3).

Transitional Type BW - moist sandy loams, occurring to such limited extent that it could not be shown on broadscale maps (Site 4).

Procedure

The study was established to assess the potential of *P. pinaster*, *P. radiata* and *P. elliottii* to rehabilitate dieback affected areas using two site preparation methods and six different fertilizer treatments.

Four individual sites were selected, covering the range of site-types described above and having in common certain factors such as species and fertilizer treatments, so that the results could be integrated.

All the chosen sites were planted in June 1969, at a spacing of 2.4 x 1.8 m. The field layout consisted of blocks of basic square units of approximately 0.04 ha, each containing 88 trees. Only the inner 20 trees were measured, the remaining ones serving as buffer trees.

The experimental design consisted of a split-plot randomised block with treatments as outlined in Table 1.

TABLE 1: Basic treatments of the experimental design on each of the four sites.

	Site			
	1	2	3	4
	Types AY and B (wet sand)	Type B (moist sand)	Types H, J and B (well drained sands and sandy gravels)	Type BW (moist sandy loam)
Species	*P. pinaster*	*P. pinaster*	*P. pinaster*	*P. pinaster*
	P. radiata	*P. radiata*	*P. radiata*	N/A
	P. elliottii	N/A	N/A	*P. elliottii*
Soil type	Yellow grey sand, silty at surface	Moist sands	Yellow to gravelly sand	Moist sandy loam
			Yellow sand	
			Pale yellow - grey sand	
	Grey yellow silty sand, moist with iron mottling		Pale yellow - grey sand, moist	
Site Preparation (a)	Ploughed only (control)	Ploughed only (control)	Nil	Ploughed only (control)
	Ploughed and mounded	Ploughed and mounded		Ploughed and mounded
Fertilizer (b)	N/A	Nil P	Nil P	N/A
	60 g P/tree	60 g P/tree	60 g P/tree	N/A
	N/A	120 g P/tree	120 g P/tree	120 g P/tree
	N/A	240 g P/tree	240 g P/tree	240 g P/tree
	30 g N/tree	N/A	N/A	N/A
	60 g P + 30 g N/tree	N/A	N/A	N/A

(a) Site Preparation - Ploughing with a disc plough, to a depth of about [illegible] cm. Mounding with a bulldozer producing a mound 0.6 m high and 0.9 m wide at the base. Direction of the mounds north-south.

(b) Fertilizer - Superphosphate (P) in September 1969. Applied around the seedling within a radius of 15 cm.

- Urea (N) in September (mounded plots) and in October 1969 (unmounded plots), when no surface water was visible. Applied on the downhill side 15 cm from the seedling and about 10-15 cm deep, using a planting spear.

N/A - Not applicable.

Annual height measurements were taken and a survival assessment was carried out at the end of the first summer after planting.

Analysis of results was done for each site separately due to the small number of replications per site. The statistical method used was analysis of variance.

Limited soil sampling was carried out for chemical analyses, to confirm the variability in sites.

RESULTS

Survival and site preparation

Mounding was shown to be essential for survival of all species tested on the wet sands, plants on the non-mounded plots (ploughed only) failing totally, irrespective of fertilizer treatment (Table 2).

TABLE 2: Effect of site preparation and fertilizer on the survival of *P. pinaster, P. radiata* and *P. elliottii* seedlings on wet sands (Site 1).

Species	Fertilizer treatment	Block	Percentage of live seedings (end of first summer after planting)	
			Ploughed and mounded	Ploughed only (control)
P. pinaster	P	1	95	0
		2	100	0
	N	1	100	0
		2	35	0
	P + N	1	50	0
		2	100	0
P. radiata	P	1	100	0
		2	70	0
	N	1	80	0
		2	75	0
	P + N	1	80	0
		2	35	0
P. elliottii	P	1	100	0
		2	90	0
	N	1	100	15
		2	95	0
	P + N	1	95	20
		2	95	0

Analysis of variance obviously showed significant differences in survival between the ploughed and mounded and ploughed only treatments ($P \leq 0.05$) on these sites. The differences between blocks were not significant at $P \leq 0.05$ (because of the few degrees of freedom involved).

Also, there were no significant interactions. On the other soil types survival was satisfactory at about 95 per cent. Ploughing and mounding on moist sands (Site 2) were shown to produce better growth response than ploughing only, when data for all species were combined for analysis to compare the two treatments (Table 3). However, in the early years, it was observed that mounding did not have the same over-riding effect as on the wet sands, because the area was not waterlogged. The benefit observed at age 9 may have been due to concentration of top soil in the planting lines. On moist sandy loams (Site 4), although difference in survival was not significant, better height growth was achieved when ploughing and mounding had been carried out.

Growth and effect of initial fertilizer

Reference to the area of the wet sands (Site 1) in this section applies only to the ploughed and mounded treatments: the non-mounded treatment failed totally.

Application of N alone at planting time had a detrimental effect on all the pine species (Table 4). The combination of P + N conferred no additional benefit in terms of growth compared with addition of P only, and reduced the initial survival after planting (Table 2).

TABLE 3: Effect of site preparation on height growth of *P. pinaster*, *P. radiata* and *P. elliottii* (combined data), by age 9 for different sites.

	Mean Height (m)			
	Site			
Treatment	1	2	3	4 (*a*)
Ploughed and mounded	4.7	7.0^{A}	N/A	10.3
Ploughed only (control)	0 (*b*)	5.6^{B}	N/A	7.9

Analysis of variance was done for each site individually. Different superscripts indicate significant differences at $p \leq 0.05$.

(*a*) For Site 4 a statistical analysis was not viable due to the low number of replications of treatments.

(*b*) Ploughing only treatment failed totally at Site 1.

TABLE 4: Effect of initial fertilizer on height growth of *P. pinaster*, *P. radiata* and *P. elliottii* (combined data) by age 9.

	Mean Height (m)			
	Site			
Treatment	1 (*a*)	2	3	4 (*b*)
Nil P	N/A	3.3^{A}	3.2^{A}	N/A
60 g P/tree	6.4^{A}	5.9^{B}	6.6^{B}	N/A
120 g P/tree	N/A	7.4^{BC}	7.6^{B}	9.5
240 g P/tree	N/A	8.8^{C}	7.5^{B}	8.7
30 g N/tree	2.1^{B}	N/A	N/A	N/A
60 g P + 30 g N/tree	5.7^{A}	N/A	N/A	N/A

Analysis of variance was done for each site individually. Different superscripts indicate significant differences at $p \leq 0.05$.

(*a*) Height data in Site 1 refer only to the ploughed and mounded section because the ploughed only treatment failed totally.

(*b*) For Site 4 no statistical analysis was done due to the low number of replications of treatments.

N/A - Not applicable.

Soil sampling revealed high levels of soluble salts in Block 2 of Site 1, about 10 times the average 0.006 ppm of all blocks in Sites 1, 2 and 3, indicating a high saline water table. It is likely that there was some combined effect of salinity and urea application, because survival of *P. pinaster* and *P. radiata* in Block 2 of Site 1 was only 35 per cent (Table 2).

On Site 3, on well drained sands and sandy gravels at age 9, initial P application resulted in superior growth compared with the control (Table 4). Analysis excluded Blocks 2 and 3, which were refertilized at age 4 years. Height differences with different levels of P application were not significant at $P \leq 0.05$ on Site 3 (Table 4) This may have been due to the effects of P fixation in Block 1 (lateritic gravel) (Havel 1975c).

However, on moist sands (Site 2) increasing levels of P gave responses in height growth. Without P, growth was very poor (Table 4).

Although no statistical analysis was carried out for results of Site 4 (moist sandy loams) the indications were that height growth of *P. pinaster* and *P. elliottii* with moderate initial P (120 g/tree) was optimum, because application of 240 g/tree produced less height growth.

Height growth in different species

Height growth by age 9 of each species on each site (with fertilizer and site preparation treatments combined) is given in Table 5. Overall *P. pinaster* performed best over the range of sites, with least variation in height growth.

Pinus radiata exhibited better early height growth than the other two species. Between the ages of 2 and 5 years, however, the heights were similar.

Comparing *P. pinaster* and *P. radiata* on Site 2, the former was superior after age 5 (Fig. 1), with height growth being significantly better ($P \leq 0.05$) than that of *P. radiata*. These results refer to a single initial fertilization, and indicate that the better growth response of *P. pinaster* is due to this species being less demanding nutritionally, and better adapted to poor sites. On both Sites 2 and 3 height growth of *P. pinaster* was better than *P. radiata* by age 9 years (Table 5).

TABLE 5: Height growth of different species (*P. pinaster, P. radiata* and *P. elliottii* growing on different sites, by age 9 all fertilizer and site preparation treatments combined).

	Mean Height (m)			
	Site			
Species	1	2	3	4 (*a*)
P. pinaster	5.8^{A}	7.0^{A}	6.5^{A}	9.4
P. radiata	3.7^{BC}	5.7^{A}	6.0^{A}	N/A
P. elliottii	4.8^{AC}	N/A	N/A	8.9

Analysis of variance was done for each site individually. Different superscripts indicate significant differences at $p \leq 0.05$.

(*a*) For Site 4 no statistical analysis was done due to the low number of replications of treatments.

N/A - Not applicable.

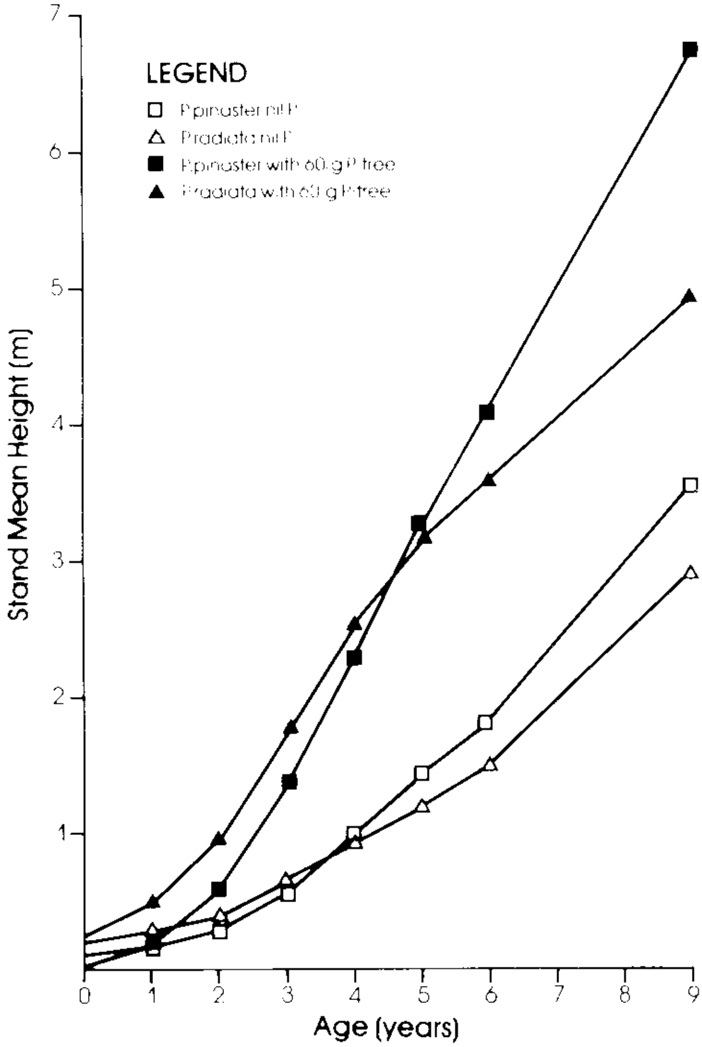

Figure 1

Effect of initial fertilizer on height growth of *P. pinaster* and *P. radiata* on site 2 (moist sands).

Although no statistical analysis of results was done for Site 4 (Table 5), indications were that there was little difference in height growth between *P. pinaster* and *P. elliottii*. However, height growth on this moist sandy loam site was markedly superior to growth on the other sites.

<u>Height growth in different species following refertilization at age 4 (Blocks 2 and 3, Site 3)</u>

Pinus radiata responded well to refertilization with 0.75 t Super Cu Zn.ha^{-1} + 0.250 t urea.ha^{-1} at age 4, compared with the unfertilized and initial fertilizer only treatments (Fig. 2). By age 9, height growth following an initial fertilizer application of 120 g P/tree had slowed, and the mean height of *P. pinaster* and *P. radiata* was similar. With no fertilizer applied, *P. pinaster* was able to grow at twice the rate of *P. radiata*.

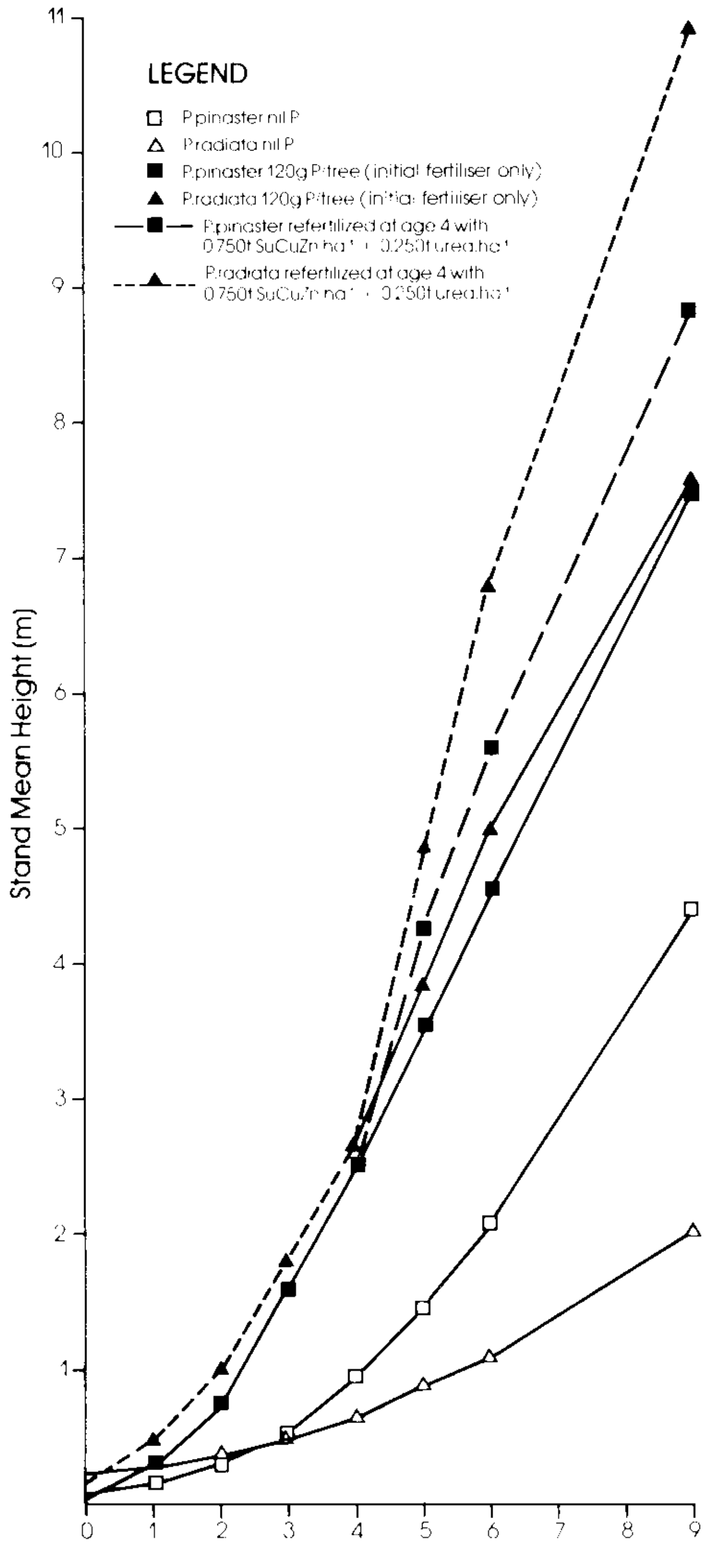

Figure 2

Effect of refertilization at age 4 on height growth of *P.pinaster* and *P.radiata* on site 3 (well drained sands and sandy gravels).

DISCUSSION

On the very wet sites (Site 1) it was obviously essential to mound to obtain satisfactory survival. Fertilizing with N alone had a detrimental effect on growth (especially where there was extreme waterlogging) while N + P was less satisfactory than P only.

In the more intermediate sites (Site 2), both mounding and fertilizer had some effect on growth. Mounding was not essential for survival on these sites although there was benefit from it in improved growth. The major effect was between applying and not applying fertilizer. However, benefits with higher levels of phosphate were more apparent on Site 2 than on Site 3.

On these well drained lateritic gravels of Site 3 satisfactory growth was only achieved with additional fertilizer (refertilization at about age 4).

On the best sites (Site 4), even with the low rate of 120 g P/tree, very good growth (9.5 m at age 9) was obtained.

Butcher (1979) indicated that, due to its low fertilizer requirement, *P. pinaster* was the most appropriate species for the sands of poor nutrient status on the coastal plain. The results of the present study show that in the Darling Ranges, on poor sites with minimal fertilizer application, *P. pinaster* performed better than the other two species tested, which supports Butcher's findings.

In the Donnybrook Sunkland, studies of *Phytophthora* spp. on similar soils of poor nutrition indicated that *P. radiata* was susceptible to the fungus (Chevis and Stukely 1982). The presence of the fungus in the Mt. Cooke area (stated to be dieback-affected) may contribute to the inferior growth of *P. radiata* relative to the non-susceptible *P. pinaster*. Depressed growth is possible without mortalities occurring in *P. radiata* (Butcher *et al.* 1984). Alternatively, lack of adequate nutrition may be the major factor for the poor performance of *P. radiata*. McGrath (1978) stressed that *P. radiata* requires additional fertilizer to perform adequately on yellow and grey sandy loams of the Donnybrook Sunkland.

The characteristic instability of *P. pinaster* on wet sites in other areas, resulting in butt sweep, was not evident in the study areas. Mounding may have resulted in this improved form on the wet site.

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