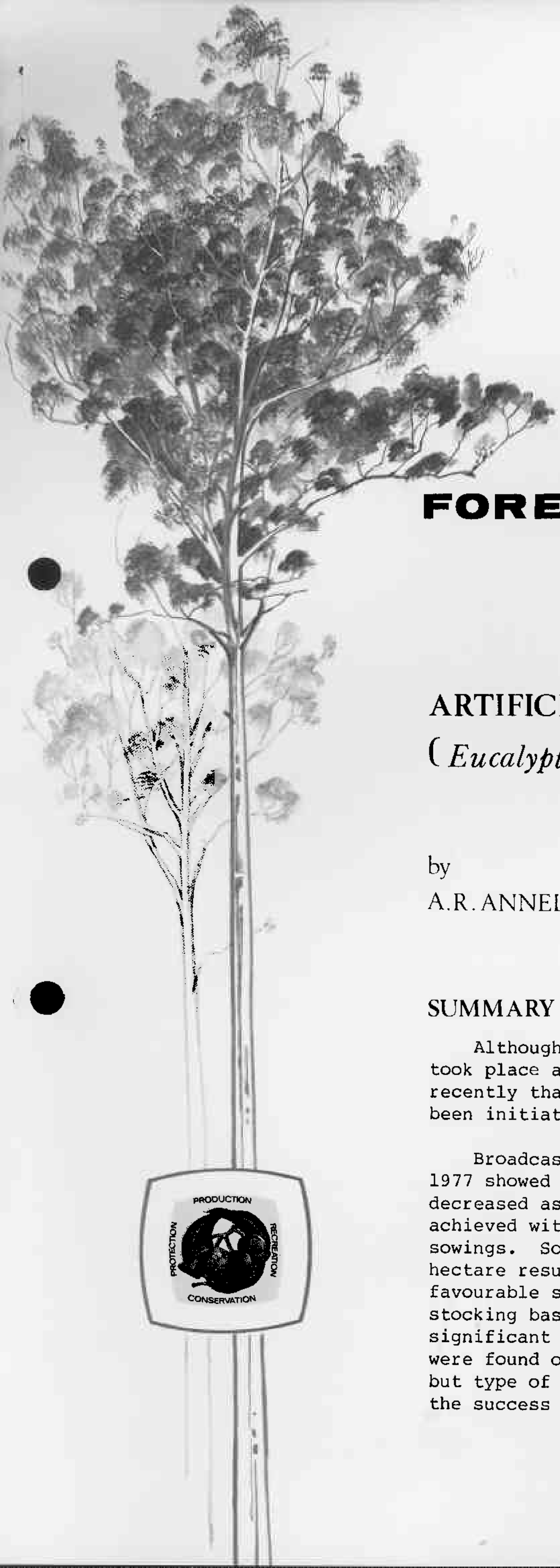

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ARTIFICIAL SEEDING OF KARRI (*Eucalyptus diversicolor* F.Muell)

by
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SUMMARY

Although research into artificial sowing of karri took place as early as the mid 1930's, it is only recently that large-scale broadcast sowing trials have been initiated.

Broadcast sowing trials carried out from 1974 to 1977 showed the following trends. Sowing success rate decreased as the season progressed: best results were achieved with April sowings and the poorest with June sowings. Sowing rates greater than 60 000 seeds per hectare resulted in increased seedling numbers on favourable sites but there was no improvement in stocking based on a stocked quadrat assessment. No significant differences in success of early establishment were found on the different soil types that were tested, but type of seedbed was an important factor affecting the success of sowing.

INTRODUCTION

Development of techniques for artificial regeneration of karri (*Eucalyptus diversicolor* F. Muell.) is an important consideration for future karri forest management in Western Australia. Successful artificial regeneration methods would ensure that regeneration need not be tied rigidly to the four-year floral cycle of karri. This would provide the forest manager with greater flexibility in selection of cutting coupes and in the seasonal deployment of the labour resource.

Regeneration by hand planting of seedlings has been utilized on an operational scale for some years but direct sowing of seed would be considerably cheaper if suitable methods were devised. Direct sowing of karri was studied in the 1930's (Loneragan, 1971; Christensen and Schuster, 1979) but was not consistently successful. Interest was renewed in 1973 as the advantages of artificial regeneration of karri became appreciated.

This paper reports the results of preliminary broadcast sowing trials in 1974 and 1975 and of later replicated experiments which studied the effects of soil type, time of sowing, and seed sowing rate on the success of establishment.

METHOD

Field trials

The first broadcast seeding trials established in 1974 and 1975 were on unreplicated blocks, and were used to test the feasibility of the technique, and to provide some information on suitable sowing rates.

The operations were performed using a Cyclone Agricultural hand spreader, which spread swathes 7.5 m in width. Hence, by traversing each plot on lines 7.5 m in width, marked at each end, a constant coverage of the plot could be obtained.

Areas to be sown were free of a natural seed source, and were burnt sufficiently to provide a satisfactory seed bed. In 1974 two areas were sown, 2.6 ha in Warren Block (10 km south of Pemberton) and 5.45 ha in Andrew Block (30 km west of Manjimup). In 1975, 10 ha were sown in Shannon Block (50 km south of Manjimup).

In 1976, 8 ha in Boorara Block (15 km south-east of Northcliffe) were sown using a split factorial design with three replications to test soil types and sowing dates. The three sowing dates were April, May, June.

Four different soil types were tested. Shallow podsols are shallow gravelly soils over yellow clays, type Dy3.62 (McArthur and Clifton, 1975). Deep podsols are deeper, less gravelly and generally of a darker colour and classified type Dy5.61. Red earths are the typical karri loams with a gradual transition from a sandy loam to a red clay, type Gn2.15, whilst gravelly red earths vary from these only that they have a component of gravel in upper layers, and are classified Gn2.14.

In 1977 a sowing trial in Poole Block (30 km south of Manjimup) consisted of a complete randomized block design testing three sowing rates. This trial covered 1.4 ha. A further 2.9 ha were used in this area to test the possibility of spot seeding karri.

Seed pelleting

After collection and extraction at a kiln, seed was sieved and cleaned by a winnowing device to rid it of all large debris that would hinder the pelleting operation. The seed was then placed in cold storage for two weeks to undergo stratification. This process decreases the period required for germination in the field (Jacobs, 1955), and also gives a more even germination of karri seed.

All the seed used in the trials was pelleted using techniques developed by the Victorian Forests Commission (1972). This involves coating the seed with a small amount of kaolin clay mixed with an insecticide, (DDT 50% powder 3.3 $g \cdot kg^{-1}$ seed) and a fungicide, (TMTD 80% active ingredient 0.6 $g \cdot kg^{-1}$ seed) and then coating with further layers of kaolin clay.

The pellets were sieved to a uniform size to allow for ease of spreading and mixed with a bulking agent to provide a manageable volume for spreading. The granular commercial fertiliser "Potato Manure E" was used for this purpose, and the application rate of pelleted seed and bulking material was approximately 5.5 $kg \cdot ha^{-1}$.

Assessment

The plots in Warren, Andrew and Shannon Blocks were assessed by running parallel lines 20 m apart across the direction of seed sowing. Along each line a 4 m^2 quadrat was assessed every 20 m.

The number of plots assessed varied with the size of the area sown and is shown in the tables. Later sowings were on smaller blocks, and were assessed on closer grids by the same method. The 4 m^2 plots are a metricated version of the milacre plot previously used for stocking assessment.

By counting the total number of seedlings per plot it is possible to obtain an estimate of numbers of seedlings per hectare. Seedling distribution is obtained from the percentage of plots actually stocked with one or more seedlings.

The 4 m^2 plot size for assessment was used because it is a convenient sized area to examine for seedlings and also conforms to current regeneration assessment techniques within the Western Australian Forests Department.

RESULTS

Stocking levels

Table 1 lists the sowing rates used in all trials and the success in establishment as assessed by the percentage of stocked quadrats at age one year. If 30% of the quadrats contain karri seedlings the distribution of seedlings is considered adequate. A minimum of 1200 stems per ha at age one year is required for acceptable karri stocking. On these criteria all except one of the trials, (Andrew Block, 1974) was satisfactory.

The data in Table 1 cover trials in three separate seasons and some of the variation in results may be a reflection of varying seasonal conditions, as well as varying site factors. Nevertheless, the results indicate that adequate regeneration can be obtained by sowing only 20 000 seeds per ha. Since some 200 000 seeds per ha were specified under the seed tree system of natural regeneration (White, 1971), this represents a considerable saving in seed requirements. This is an important consideration as karri seed supplies are always limited owing to collection difficulties.

It also appears that site factors affect the success of regeneration. Table 2 lists the results of an assessment of the 1974 and 1975 trials at age two years, with the quadrats subdivided according to seed bed types into which they fell by chance. Seed beds were classified as unfavourable (unburnt, compacted by logging machinery or occupied by a stump or log), disturbed (if the mineral soil had been loosened during logging operations)

TABLE 1

Quadrat stocking rates from direct seeding trials at age one year

Location	Year of sowing	Sowing rate (viable seeds per ha)	Percentage of quadrats (4 m^2) stocked with karri	Karri seedlings (No. per ha)	No. of plots assessed
Poole	1977	18 750	34.9	1667	63
Poole	1977	20 000	23.5	1428	63
Andrew	1974	35 800	26.7	940	157
Poole	1977	40 000	54.0	2976	63
Shannon	1975	55 300	60.0	3482	100
Warren	1974	59 300	40.0	1827	201
Shannon	1975	59 800	54.0	2865	100
Warren	1974	99 800	55.8	3754	240
Shannon	1975	126 700	54.2	2939	100

TABLE 2

Stocking percentage of 4 m^2 quadrats by seed bed type at age two years

Location	Viable seeds per ha	Percentage of quadrats stocked (all seed beds)	Stems per ha	Seed bed type: Unfavourable	Seed bed type: Disturbed	Seed bed type: Ashbed	No. of plots assessed
Andrew	35 800	47.2	2302	33.4	66.7	79.4	89
Shannon	55 300	63.3	4422	25.0	62.9	77.5	106
Warren	59 300	50.0	3260	8.0	62.5	82.6	72
Shannon	59 800	47.2	2739	27.3	68.8	53.0	55
Warren	99 800	57.7	3925	13.3	59.3	80.8	71
Shannon	126 700	62.6	4779	43.6	57.7	73.3	107

TABLE 3

The effect of sowing time on stocking rates

	Month of sowing					
	April		May		June	
Soil type	Percentage stocked plots	Stems per ha	Percentage stocked plots	Stems per ha	Percentage stocked plots	Stems per ha
Shallow podsols	73.4	3240	62.2	1867	17.8	220
Deep podsols	73.3	3020	62.2	1208	17.8	275
Red earths	75.6	2910	24.4	165	26.7	275
Gravelly red earths	86.7	2689	44.5	1262	35.5	658
TOTAL of all soil types	77.3*	2965*	48.3	1126	24.5	357

45 plots were assessed for each month on each soil type.

* indicates a significant difference at the 0.05 level between time of sowing (tested by analysis of variance).

or ashbed (where logging debris and slash had been burnt).

Overall, the regeneration situation had improved from the previous assessment, but there was a marked difference in the stocking percentage on the three seed bed types. Unfavourable seed beds were consistently the most poorly stocked and in most cases the ashbed sites were better stocked than the disturbed sites.

Sowing time and soil type

Table 3 shows the results obtained in the Boorara trial which tested the effects of sowing time and soil type on stocking rates.

Seed sown late in the season produced lower stocking rates than seed sown early. April sowing resulted in significantly better ($p = 0.05$) stocking rates than either May or June sowing. The success of seeding did not vary significantly between the three soil types tested.

Effects of seedbed and soil type

The stocking results for the Boorara trial have been assessed for the effect of seedbed on stocking and height. These results are shown in Table 4.

Table 4 shows the increased success of regeneration on ashbeds and disturbed sites compared with the unfavourable sites. In most cases both height growth and quadrat stocking were much greater on the ashbed than on the compacted sites.

No significant differences in the percentage of quadrats stocked with seedlings have been detected which relate to soil type.

TABLE 4

The influence of seed bed and soil type on karri stocking and height growth

Soil type	Seed bed*	Percentage of quadrats ($4\ m^2$) stocked with karri	Height (cm)
Red earth	UF	4.8	42
	D	22.3	37.9
	AB	50.0	107
Gravelly red earth	UF	17.8	28
	D	32.4	41
	AB	54.5	60.4
Deep podsols	UF	17.6	55
	D	22.5	42
	AB	72.7	191
Shallow podsols	UF	19.3	75
	D	33.8	72.5
	AB	56.6	116

*Seed beds: UF = Unfavourable, AB = Ashbed, D = Disturbed.

Spot seeding

The aims of the spot seeding trial were to reduce the quantity of seed used and to utilize the most favourable sites in the areas tested. In this trial, rates used varied from 2500 to 15 000 seeds per ha, sowing either two or six seeds per spot with 1000, 1750 or 2500 spots per ha. Results of all these were disappointing, because no treatment provided acceptable levels of karri stocking. Table 5 shows the results of assessment of the actual spots sown.

These data suggest that greater numbers of seeds per plot do not result in much greater stocking rates. This has been reported in earlier work (Loneragan, 1971). However, it is possible that a greater number of spots than those used here may provide satisfactory stocking and reduce seed usage.

DISCUSSION

Time of sowing appears to be critical to the success of broadcast seeding of karri. As the results show, it can mean either success or failure. Earlier work (Loneragan, 1971) indicated May sowings were more successful than those in either July or October. In the Boorara trials, April sowing was the most successful and this coincided with the onset of winter rainfall, before ground temperatures had decreased greatly.

Unfavourable sites, such as unburnt areas or consolidated snig tracks, are not successfully regenerated by broadcast seeding, except in the case of the most successful sowing month, April, where marginal stockings were found. A low percentage of such sites will be stocked but the value of such stocking to produce worthwhile stems is doubtful (Schuster, 1979). Even when established, the resultant seedlings displayed reduced growth compared with those on the other sites.

The results suggest that quantities of seed greater than 60 000 viable seeds per ha increase the number of plants but do not improve distribution. Distribution of plants is affected by availability of suitable seed beds and it is suggested that above a certain level of seed application this is the critical factor.

Spot seeding of favourable sites shows promise of further reducing the quantity of seed required to regenerate an area. Earlier work suggests that spot seeding may require only one fifth of the seed used by broadcasting (Loneragan, 1971) for similar results. However, current results suggest that this figure is optimistic. If a successful technique can be developed it could be of particular use in regenerating mixed karri stands. This would permit karri to be regenerated on the optimum sites of an area, such as ashbeds, while allowing marri (*E. calophylla* R. Br.

TABLE 5

Spot seeding trials, Poole Block 1977.
Data as at age one year

Spots per ha	Seeds per spot	Seeds per ha	Seedlings per ha	Spots per ha	Seedling per cent	Per cent spots stocked
1000	2	2000	125	116	6.25	11.6
1750	2	3500	158	150	4.39	8.3
2500	2	5000	191	175	3.38	7.0
1000	6	6000	141	133	2.36	13.3
1750	6	10 500	308	233	2.85	12.96
2500	6	15 500	350	316	2.33	12.67

ex Lindl.) advance growth to colonize the sites less favourable to karri, and hence ensure perpetuation of the species mixture.

Further research is required to define more accurately the lowest limits of seed application needed to ensure a satisfactory regeneration stocking. This aspect will be expanded in future research.

As an operational technique, broadcast seeding has had one 40 ha trial in Weld Block in 1976. Three hundred and fifty hectares in 1978, and some 200 ha in 1979 have also been seeded. Excellent results were achieved from the viewpoints of efficiency, ease of operation, and stocking levels.

The use of direct seeding on an operational scale offers many advantages to the forest manager. The regeneration operation need not be tied to the four-year seed cycle of karri, thus allowing greater flexibility in choice of cutting areas and also allowing regeneration burning to be programmed and carried out at times which best utilize available resources. A further advantage of direct seeding is its flexibility. Unlike planting which requires time to raise stock in the nursery, seeding can be planned and carried out in a matter of weeks. This allows cutting plans to be altered and regeneration carried out efficiently if the need arises.

The cost of a broadcast sowing operation in a given area is approximately 20% that of hand planting. Currently, however, high seed collection costs make broadcast seeding as expensive overall as hand planting. Improved efficiency in seed collection is expected to reduce the total cost of broadcast sowing to around 70% of the cost for hand planting (R.J. Underwood, personal communication).

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