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SUMMARY.

THE environment of the jarrah forest, with its dry summer climate, and poor gravelly soils, produces strong competition which must be particularly severe for a small plant with a limited root system. The importance of the lignotuber in the survival and development of jarrah regeneration has long been recognised and some recent observations indicate that successful regeneration depends on the presence of well developed lignotuberous advance growth at the time of logging.

Detailed counts on permanent milacre quadrats over periods of up to 24 years under various forest conditions, have led to the following conclusions:—

(1) Under the canopy of virgin forest, seedlings and advance growth up to 3 ft. high become established in varying quantities, greater numbers being found under a more open canopy and on old ash beds. These plants have been observed to persist in a dormant condition for over 20 years. The dynamic development as saplings is confined to openings in the forest, caused by the death of old trees.

(2) Following the logging of an area, the reduction in competition results in a regeneration period, during which the remaining vegetation has the opportunity to make accelerated growth. Some jarrah advance growth commences its dynamic development at this time. This period of free growth continues for a number of years until full utilisation of the site is resumed. With full utilisation there is no development of new saplings until some further reduction in competition occurs. This may be brought about by fire, silvicultural treatment or the next trade cut.

(3) The establishment of seedling regeneration is encouraged by controlled burning treatment. The removal of the heavy litter apparently produces a suitable seed bed and seedlings become established in thousands per acre following a burn in a seed year.

Preliminary results of some planting trials with jarrah established in 1958 indicate that, while initial responses to manurial treatments are obtained, the rate of development is reduced by the drought conditions experienced in the summer.

THE JARRAH FOREST ENVIRONMENT.

Jarrah (*Eucalyptus marginata* Sm.) is the principal timber species in Western Australia and is confined to a relatively small area of high rainfall in the extreme south-west of the State. The prime jarrah forest covers some 4,000,000 acres in the Darling Ranges south of Perth.

Although the annual rainfall is high, very hot dry summer conditions are experienced and this must have an important influence on plant growth. Dwellingup, in the centre of the prime jarrah belt, has an average rainfall of 51 in. Approximately 60 per cent. of this (or 30 in.) is received in June, July and August, whereas in December to March only 2.5 in. (or 5 per cent. of the annual total) are received. This dry summer, which results in drought conditions for a small plant on the forest floor is one of the principal factors governing the survival and development of jarrah regeneration.

In addition to drought conditions, young plants in openings in the forest have to withstand extremely high surface soil temperatures, due to insolation. Hatch (unpublished data) has recorded that on a normal summer day with a noon screen temperature of 90°F., the bare soil surface in an exposed site reached 150°F. By contrast, the surface temperature at the same time under a heavy canopy was only 77°F.

The jarrah forest soils are generally lateritic and are characterised by heavy gravels which occupy up to 90 per cent. of the total soil weight in the upper horizons. They are usually of light texture, mainly sands, loamy sands and silts, and chemical analyses show that they are of low fertility. These soils do not provide a favourable medium for seedling growth due to their poor moisture holding capacity and the impedence of root development in the compacted gravels.

THE LIGNOTUBER AND ADVANCE GROWTH.

In common with most eucalypts, the jarrah seedling produces a lignotuber. Considering the harsh conditions for regeneration in the jarrah forest the lignotuber is the key to jarrah regeneration. The eucalypt lignotuber described by Jacobs (1955), is a woody swelling at the base of the seedling stem which appears in the first year, and slowly increases in size. It bears numerous dormant buds from which new shoots can be produced when the need arises. As the tuber grows in diameter it extends down the stem so that the greater part becomes buried below ground level. Once established it is not normally destroyed by fire, drought, or animals and if the aerial portion is damaged by any of these agencies new shoots develop from the dormant buds.

The jarrah seedling does not immediately develop an upright single stem, but slowly grows into a bushy shrub, less than 3 ft. high, with numerous leafy shoots arising from the lignotuber. (See Plate 1.) This static form is a characteristic stage in the development of the jarrah tree under forest conditions, and such plants are locally known as lignotuberous advance growth. (Harris, 1956). The advance growth persists for many years on the forest floor in this dormant form while developing a root system which can sustain the more vigorous growth of the sapling when conditions become favourable.

Dynamic Development.

The conditions required for dynamic upright growth into the sapling stage are brought about by the reduction in competition on the site resulting usually from the removal of mature trees, either by senescence and death in the virgin forest or by logging operations. The logging is carried out under departmental tree marking control following a system of selection by groups and single trees. The period between trade operations is normally 30 years or more.

Plate 1.

Lignotuberous advance growth more than 20 years old showing the lignotuber (2 in. diameter) and strong tap root exposed.

STUDIES OF THE BEHAVIOUR OF ADVANCE GROWTH.

Some information on the behaviour of advance growth under various forest conditions has been obtained from regeneration plots established between 1935 and 1937. Detailed counts of all regeneration on milacre quadrats were made in both virgin and cut-over forest. A number of the virgin bush plots have been cut over in recent years, so that a record of the regeneration under three forest conditions, (a) virgin, (b) recently cut over and (c) cut over prior to tree marking control, are available. Reassessment of the plots was carried out in 1959.

Regeneration in the Virgin Forest.

In the virgin forest, dormant advance growth occurs in varying quantities depending on the density of the canopy, greater numbers occurring under the

Plate 2.

An opening in the virgin forest with a good stocking of lignotuberous advance growth.

more open canopy. High concentrations are found on old ash beds caused by the burning of logs and heaps of debris. (See Plates 2 and 3.)

Advance growth may persist in the dormant form for many years and plants in this stage well over 24 years old have been observed. Dynamic development from the advance growth stage to the sapling stage is rare under the undisturbed canopy and is generally confined to openings in the forest caused by the death of old trees. During the long period of decline preceding the death of the old tree, advance growth becomes established in large numbers under the deteriorating crown and gradually takes over the site. The virgin forest is characterised by small groups of even-aged trees which have become established in this way. (See Plate 4.)

Table 1 sets out results of an assessment of regeneration in 1938 and 1959 on 200 permanent quadrats in virgin bush. These figures show that in the 21

Plate 3.

A dense patch of advance growth (tagged) in an opening in the virgin forest.

years between assessments, the number of advance growth has increased considerably but there has been very little dynamic development of regrowth.

Table 1.

Number of stems per acre.

	Seedlings less than 2 y.o.	Seedling advance growth less than 6 in.	Advance growth 6 in.-36 in	Large advance growth 36 in.-60 in.	Regrowth 5 ft.-15 ft.	Saplings over 15 ft.
1938 (Virgin Forest)	—	1,720	725	10	—	—
1959 (Virgin Forest)	—	1,695	1,450	10	10	—

Effect of Logging.

Following logging the forest usually produces adequate regeneration. (See Plate 5.) Trade cutting on an area is followed by a period of active development of the remaining vegetation, probably due to the great reduction in competition for water resulting from the removal of the large trees. Some of the advance growth present commences dynamic development at this time. A single shoot assumes dominance and quickly develops into a small sapling with a growth rate of 2 to 3 feet per year. Top disposal burning after logging may assist the advance growth to get away. New shoots follow the burn and under the more open conditions, one may assume dominance.

Plate 4.

A group of saplings which has become established in a gap in the virgin forest. The understorey species is *Banksia grandis*.

In Table 2 the results are shown of an assessment in an area where dense regeneration developed following logging and a mild slash burn. This area carried adequate advance growth in 1938 and was cut over in 1953, six years prior to the second assessment. The figures are based on counts on 100 quadrats.

TABLE 2.

Number of stems per acre.

	Seedlings less than 2 y.o.	Seedling advance growth less than 6 in.	Advance growth 6 in.-36 in.	Large advance growth 36 in.-60 in.	Regrowth 5 ft.-15 ft.	Saplings over 15 ft.
1938 (Virgin Forest) Logging-1953	—	490	1,900	—	—	—
1959 (6 years after logging)	20	100	1,330	330	290	20

There are areas in cut-over jarrah forest where the understorey species, *Banksia grandis* and *Casuarina fraseriana,* have developed densely after logging. This can seriously affect the regeneration of jarrah on the site if advance growth is not present and ready to get away at the time of the cut. Results of assessments in an area which was not adequately stocked with advance growth prior to logging, are shown in Table 3. This area was heavily logged in 1955 and the slash burn was extremely hot. In 1959, four years after logging, there had been no dynamic development of regrowth.

TABLE 3.

Number of stems per acre.

	Seedlings less than 2 y.o.	Seedling advance growth less than 6 in.	Advance growth 6 in.-36 in.	Large advance growth 36 in.-60 in.	Regrowth 5 ft.-15 ft.	Saplings over 15 ft
1938 (Virgin forest) Logging-1955	—	170	110	10	—	—
1959 (4 yrs. after logging)	—	20	100	—	—	—

Regeneration in Cut-over Forest.

The balance between the demands of the forest and the capacity of the site, is upset by logging, but is restored in time by the accelerated development of the regeneration, the other understorey species, the remaining trees, and coppice. When full utilisation of the site is resumed there is no further development of regeneration from the advance growth stage, except in response to some new reduction in competition. In much of the cut-over forest later development has been brought about by the regeneration treatment of the early 1930's which involved the ring-barking of marri *(E. calophylla)* and useless jarrah and the falling of malformed saplings. The temporary reduction in competing vegetation caused by even a moderate fire may also give the advance growth a chance to get away.

Results of assessments carried out in an area which had been logged in 1916 and which received regeneration treatment in 1932, are shown in Table 4. These figures indicate that during the 24 year period, 1935 to 1959, development of new regrowth and saplings has been confined to coppice shoots resulting from the 1932 treatment, to large advance growth over 36 in., and to occasional advance growth which had been released by the ringbarking of nearby trees. The large increase in numbers of seedling advance growth is due to burning carried out over portion of the area in 1954, a seed year. The figures in Table 4 are based on assessment of 1,400 quadrats.

TABLE 4.

Number of stems per acre.

	Seedlings less than 2 y.o.	Seedling advance growth less than 6 in.	advance growth 6 in.-36 in.	Large advance growth 36 in.-60 in.	Regrowth 5 ft.-15 ft.	Saplings over 15 ft
1935 (19 yrs. since logging; 3 yrs. since treatment)	5	194	368 50*	14 21*	23 61*	39
1959	100	2,000	672	54	87	122

* coppice shoots resulting from regeneration treatment in 1932.

ESTABLISHMENT OF SEEDLING REGENERATION.

The establishment of seedling regeneration is not usually a problem in the jarrah forest. Observations indicate that burning the litter on the forest floor provides the most suitable seed bed for jarrah, and seedlings become established in thousands per acre following a burn in a seed year. Plots established in dense seedling regeneration following a severe fire in 1941 showed a great reduction in the numbers of seedlings in the first 5 years. The stocking per acre fell from over 18,000 to 1,500 in this time. This figure decreased further to approximately 500 per acre at age 17 years. Plants on ashbeds were larger than those off the ashbeds but none of them had developed beyond the advance growth stage.

The time taken for the advance growth to reach the stage where it can commence dynamic growth depends on the opportunities it has for development. It must produce a root system capable of sustaining vigorous growth in face of the competition on the site. Under conditions of minimum competition in cultivated plots and in gardens watered through the summer, jarrah does not stagnate in the lignotuberous stage, but develops an upright form immediately. In the forest, the advance growth takes at least 15 years to obtain a sufficient grip on the soil to enable it to take advantage of the opening up of the stand and make dynamic growth. Harris (1956) has pointed out that the size of the lignotuber is an indication of the stage of development of the advance growth, and suggests that under forest conditions, advance growth will not

Plate 5.

A dense stand of dynamic saplings six years after the trade cut. These saplings have developed vigorously from the advance growth stage since logging.

commence dynamic development until the tuber has reached a size of 4 in. diameter.

There is considerable evidence that seedlings established on ashbeds develop more quickly than those off the ashbed and observations suggest that of the seedlings which germinate after logging, only those on ashbeds have a chance of developing into saplings before the next felling.

ARTIFICIAL ESTABLISHMENT OF JARRAH.

A series of planting trials was established in 1958 to gain further information about the development of jarrah seedlings, and to test the possibilities of artificial establishment. One-year-old seedlings raised in pots, were planted in openings in recently cut-over forest. Cultivation and fertiliser treatments were tried with pronounced effects on the plants. With cultivation only, survival was 81 per cent. and plants were sturdy and well developed at the end

of the first summer. In the control, only 46 per cent. survived the summer and seedlings had virtually stagnated since planting. Cultivation plus a fertiliser treatment with an enriched compost, produced vigorous leaf development in the spring, but the plants could not survive the hot dry summer as well as those with cultivation only. Survival at the end of summer was 50 per cent.

It appears from these early observations that initial cultivation perhaps followed by a later application of fertiliser once a stronger root system is established, will give the best results.

CONCLUSIONS.

Successful regeneration in the jarrah forest depends on the presence of advance growth with a well developed root system ready to take advantage of the reduction in competition which results from logging. Seedlings which germinate after logging are not likely to play a part in the regeneration of the forest until a further opening up of the stand takes place.

Regeneration problems do occur in areas where the advance growth is either not present, or not sufficiently developed to respond to the reduction in competition. Heavy cutting in such areas will result in either a dense development of weed species or a severely understocked forest, unable to produce adequate regeneration for a long time.

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