KARRI SILVICS

RESEARCH NOTE No.1

B.S. White

FORESTS DEPARTMENT OF W.A.

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*   SILVICS OF KARRI   *
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SILVICS OF KARRI

by B. J. WHITE

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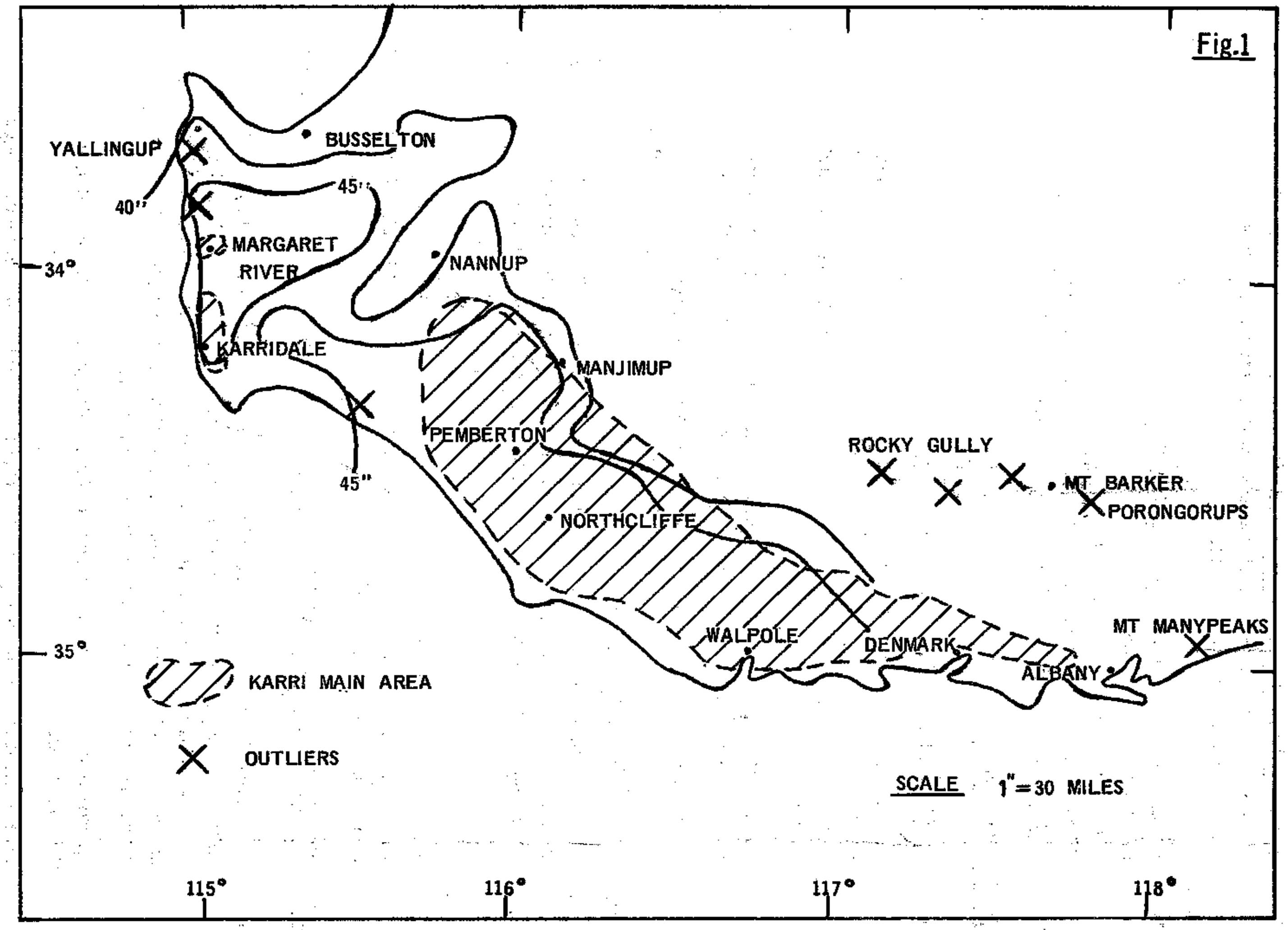
Fig.1


YALLINGUP
BUSSELTON
40"
45"
MARGARET RIVER
NANNUP
KARRIDALE
MANJIMUP
PEMBERTON
45"
NORTHCLIFFE
ROCKY GULLY
MT BARKER
PORONGORUPS
WALPOLE
DENMARK
ALBANY
MT MANYPEAKS
34°
35°
115°
116°
117°
118°
KARRI MAIN AREA
OUTLIERS
SCALE 1" = 30 MILES

1.0. NOMENCLATURE AND TAXONOMY

1.1. Name - Eucalyptus diversicolor F. Muell. - common name "Karri". 'Diversicolor' refers to the difference in colour between the upper and lower surfaces of the leaves.

1.2. Classified as - A. Section (MACRANTHERAE)
(a) Subsection cordiformes.
Series "Transversae" - No. 57 on Blakely's scale.
Comes close to the Eastern Blue gum group, E. saligna, E. grandis, E. botryoides, E. robusta, and Red Tingle E. jacksoni - (1).

2.0. DISTRIBUTION

2.1. PRESENT GEOGRAPHICAL OCCURRENCE - see map Fig. 1.

Endemic to South West of Western Australia, Latitude 34^{o}-35^{o}S. Main occurrence bounded by 45" isohyet; is associated with the River Systems of the Donnelly, Lower Warren, Gardner, Shannon and Lower Frankland Rivers.

Outliers are to be found at Karridale, Margaret River, Yallingup, Black Point, Mount Barker, Porongorups, Mt. Many Peaks, Rocky Gully.

Area of present occurrence is approximately 350,000 acres.

2.2. PAST GEOGRAPHICAL OCCURRENCE

Work on pollen counts in cores from Peat Swamps by D. M. Churchill (2) suggests that in earlier times of greater annual rainfall, distribution was wider than it is at present. Annual rainfall is perhaps the main factor governing occurrence.

2.3. OCCURRENCE AS AN EXOTIC

Karri is grown in plantation form in South Africa. On the best sites it is reputed to have reached 200' in 40 years.

3.0. FOREST TYPES AND ASSOCIATIONS

3.1. Two major forest types are recognized : pure Karri and a Marri-Karri mixture. Pure Karri occupies the more favourable sites. Mixed stands occur on soils transitional between the typical red brown-yellow brown loamy sands of the pure Karri and the typical lateritic Jarrah soils. Jarrah may accompany the mixture on the periphery.

Approximately half the occurrence of Karri is in pure stands, and half in MK mixtures.

Pure Karri stands tend to be over mature, even aged in appearance, though large groups of younger age classes can be recognized. The structure of the mixed stands is typically two tiered, with tall Karri emergents above a general level of Marri. Stem numbers above 90" GBH tend to be about equally divided between Marri and Karri; but Marri is heavily favoured in the smaller size classes.

3.2. ASSOCIATED SPECIES

Overstorey - Mixed Stands - Marri and Jarrah as in 3.1. Red Tingle (E. jacksoni) and Yellow Tingle (E. guilfoylei) in vicinity of Walpole only.

Understorey - Casuarina decussata - Karri Oak - general. Banksia grandis - Bull banksia - in mixed stands.
Agonis juniperina) on stream benches
Agonis flexuosa) and damp situations.

Scrub - Trymalium spathulatum - Hazel - better sites in Pure Karri.
Bossiaea aquifolium - water bush - fireweed in Western half of main occurrence.
Acacia pentadenia - Karri wattle - fireweed in Eastern half of main occurrence.
Acacia urophylla - fireweed - associated with heavier soils.
Pimelia clavata - banjine - scattered, general.
Bossiaea linophylla)
Acacia strigosa (Brumby Bush))
Hovea elliptica) MK mixtures
Acacia pulchella)
Crowea dentata)
Acacia decipiens)
Oxylobium lanceolatum) Damper situations
Lepidosperma tetraquetrum)

4.0. BOTANICAL CHARACTERISTICS (References 3 and 4)

4.1. LEAVES

Juvenile : alternate stalked, ovate to broadly lanceolate 2-3.5" x 1-2". Green above, paler below.
Adult : alternate,petiolate, lanceolate, acute, 4-5.5" x 1.3-1.5"; dark green above paler below. Faint or occasionally moderately conspicuous, fine, regular venation at 35^{o}-40^{o} to midrib; intramarginal vein distinct.

Leaves of young Karri seedlings have a wavy edge. The colour distinction between upper and lower edges is obvious on windy days.

4.2. CROWN

The crown is conical in the sapling and pole stage. In the lower crown from the pole stage onwards the branches tend to curve upwards at the extremities. Leaves are borne on branch extremities in compact "umbrellas", and tend to give an overall umbrella effect. Over-mature crowns in horizontal view may appear stepped or tiered.

4.3. BARK

Gum - type, smooth, shed over the whole of the trunk in irregular plates. Newly exposed bark is pink-brown in colour, which fades to bluish grey with time. In autumn, when most bark is shed, stems have a two-tone effect.

4.4. INFLORESCENCE

Axilliary umbels of 3-6 flowers, the individual stalks short. Buds club shaped to cylindroid 0.6-0.7 x 0.25-0.3 inches. Operculum hemispheric to ovoid conic.

4.5. FRUIT

Pear shaped; ovoid or globose 0.4-0.5 x 0.4-0.5 inches. Smooth, on stalks 0.3-0.4 inches long. Disc intermediate or wide, obliquely sunken; valves small, deeply enclosed, or occasionally rim level.

4.6. WOOD

Red, hard, heavy (56 lbs./cu. ft.), strong, stiff and tough, moderately durable. Grain often interlocked. Splits more easily on back than quarter.

4.7. LONGEVITY

Most of the virgin forest is aged between 150 and 200 years. Physical maturity is considered to be approximately 250 years. Degrade is frequently rapid after 400 years, although an occasional sound tree is considered to exceed 700 years.

Growth rings can be counted on selected stumps and butts with an accuracy of ± 5%. In average forest a tree of 150" GBH can be said to be roughly 150 years old. Dominants can be considered to grow at 1" girth per annum - unthinned.

4.8. SIZE ATTAINED

Karri is one of the very tall trees of the world, second in height in Australia to <u>E. regnans.</u> Typically it reaches 170'-240', rarely 270'. The tallest measured Karri is 286 feet (Mattaband Block, Shannon River). Girths of 20'GBH are common, and 40'2" GBH has been measured.

5.0. HABITAT

5.1. GEOLOGY

The main Karri occurrence is underlain by granite gneiss with scattered basic intrusions.

5.2. SOILS

The characteristic Karri soil is a red brown to yellow brown podsolic loamy sand, derived direct from the underlying granite gneiss. This occurs where the lateritic cap has been truncated by stream flow, or where soil has formed on large residual granite - gneiss outcrops, usually found in previously drowned coastline near the South Coast.

Soils contain a high silt fraction on the surface, giving it a "puffy" consistency when dry. Structure is favourable to root growth and moisture penetration, though some recent ash beds tend to resist wetting.

Karri soils resist water erosion better than other soil in the vicinity.

Rounded and angular lateritic gravel is common in many Karri soils. High quality pure Karri can be found associated with gravels, but usually they are associated with mixed stands (MK MJK).

In the Western (Karridale) and Eastern (Manypeaks) outliers Karri grows on red sandy soils derived from limestone (terra - rossas).

Depth and good drainage is essential for good Karri growth.

5.3. SOIL FERTILITY

Karri soils are deficient in phosphate, and often minor elements - e.g. zinc and copper. Their appearance belies their fertility. Young planted Karri respond to a mixture of N and P fertilizer.

5.4. SOIL REACTION

Mildly acidic.

5.5. CLIMATE - (References 5 and 6)

5.51 General :

Climate is generally mild with an assured rainfall and well marked wet winter and dry summer. Summers warm, but it is unusual for temperatures in shade to exceed 95°F. Mean summer rainfall is about 1 inch per month.

5.52 Rainfall :

Mean monthly rainfall for Pemberton.

Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
99	69	162	336	672	850	889	743	493	405	250	163

Annual 5131 points.
Range 45-60 inches - except for outliers, the 45 inch isohyet encloses the Karri occurrence.
No. of wet days 150-170.
Karri areas have a significantly higher summer rainfall than elsewhere in the South West.

5.53. Temperature :

Generally mild, extremes rare.

Pemberton

JANUARY		JULY	
Temperature		Temperature	
Mean Max.	Mean Min.	Mean Max.	Mean Min.
78.4 highest 106.0	54.8 lowest 40.0	57.9 highest 70.0	45.7 lowest (on record) 32.0

5.54. Frosts :

Average frequency (36°F or less).

Pemberton

Apl.	May	June	July	Aug.	Sept.	Oct.	Nov.	Year
0	0	1	1	2	1	0	0	5

5.55. Growing Season :

From Prescott's Formula : P/E 0.7 = 0.54

	Average Break of Season	Average Length of Season
Manjimup	Late March	8.0 months
Pemberton	Mid March	9.1 months
Nornalup	Mid February	10.2 months

5.6. PHYSIOGRAPHY AND LAND FORMS

Altitude varies from 0-1000'.

The main Karri belt is dissected by the Donnelly, lower Warren, Gardner, Deep, Shannon and lower Frankland Rivers and their tributaries.

Topography is rounded and undulating rather than steep. Karri occurs in all topographic situations - ridge tops, upper, mid, and lower slopes of all aspects. It does not flourish in permanently damp situations where Agonis jumperina and Agonis flexuosa predominate. However, Karri tends to occur where soils have been derived from granite gneiss exposed by truncation of the lateritic cap by stream flow in the main area, and on tops of residual outcrops in previously drowned coastline towards the south coast. In the main belt Karri is therefore associated with the major streams, and as islands among flats towards the coast.

In general best Karri development is found on the more sheltered South and South East aspects.

On the higher ground, ridge tops etc., where lateritic cap is the soil parent material, the common forest type is a Jarrah-Marri mixture. Where the lateritic cap has been removed by erosion, Karri will occur on ridge tops.

Appreciable areas of coarse sandy soil derived from quartzite occur, and in most cases support Jarrah or treeless flat. Such soils are not favoured by Karri, the division between forest types being very distinct and sudden. Where these soils are underlain by a yellow clay subsoil they can support high forest usually rich in Marri. Treeless areas can occur in any topographical situation.

6.0. PHENOLOGY (recurring natural Phenomena, ref. 7 and 8)

6.1. LEAF GROWTH

Incipient flush usually appears on the terminal branchlets early in November. By January the shoots attain approximately half their ultimate length. Leaf and shoot development is rapid, and over the following two months, during mid-summer, the parts thicken and harden. Throughout this growth a large number of leaf buds and immature leaves fall, apparently nipped off by insects.

No other season of flush growth has been observed in Karri.

6.2. LONGEVITY OF LEAVES

Most leaves live for one year only. Observation has shown that over a range of trees :

Fig.2 MONTHLY GROWTH OF KARRI POLES – CHANNYBEARUP – UNBURNT CONTROL
(from fire damage studies – G.B. Peet.)

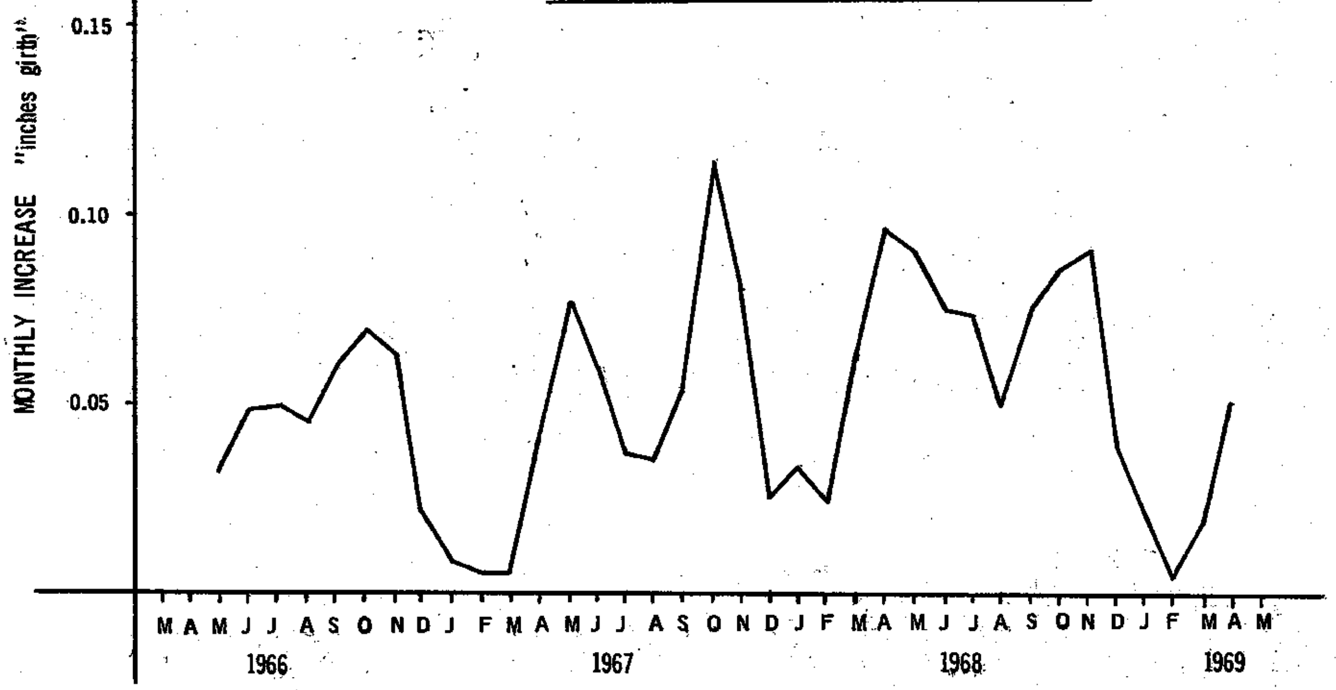
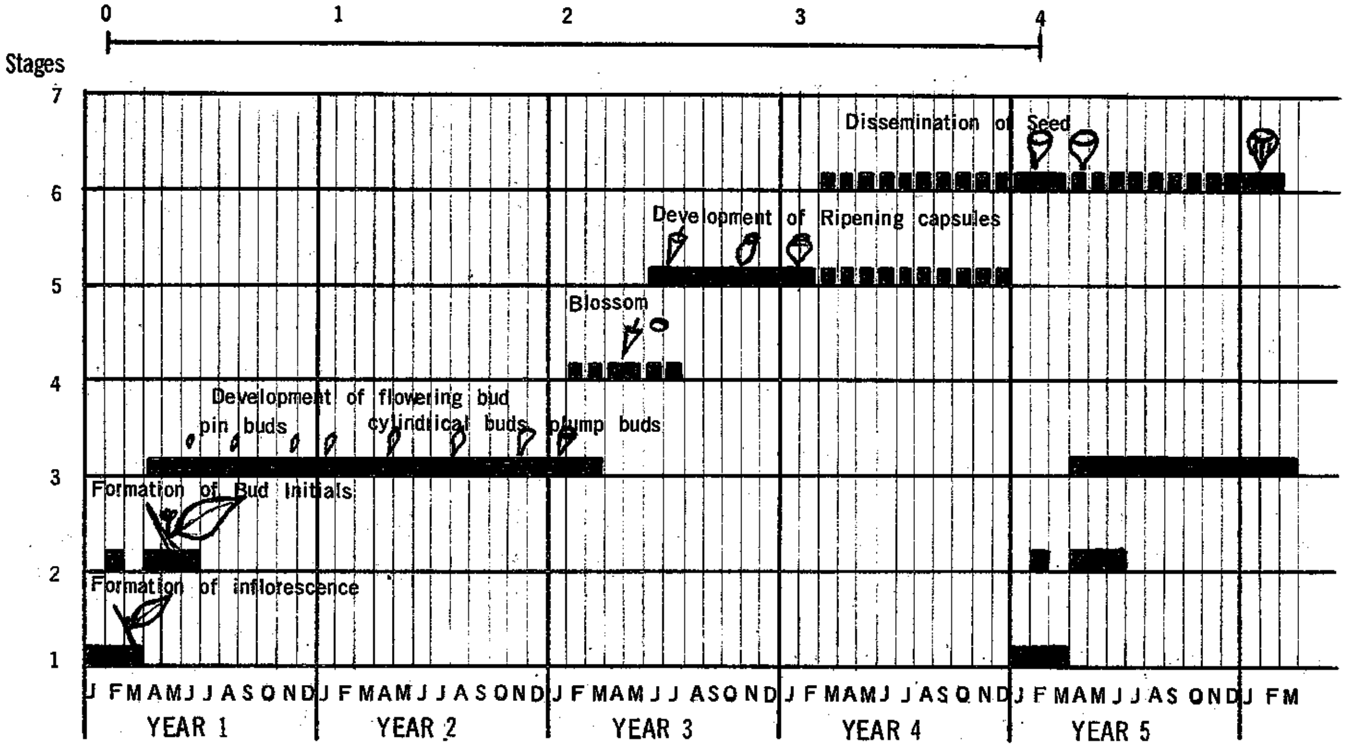


Fig.3 FOUR YEAR SEED CYCLE



	± 70% of leaves lived 1 year
up to	40% of leaves lived 2 years
	± 7% of leaves lived 3 years
	± 5% of leaves lived 5 years

Vigorous shoots shed leaves most rapidly. Stagnant branchlets which omitted or ceased to flush retained the oldest leaves.

6.3. GIRTH GROWTH

Annually Karri has two peaks of rapid girth growth, autumn and spring, and two troughs of restricted growth, mid-summer and mid-winter.

Graph of monthly girth growth of pole sized Karri is shown in Fig. 2.

6.4. FLORAL CYCLE

A simple version of the Karri seed cycle is given diagrammatically in Fig. 3.

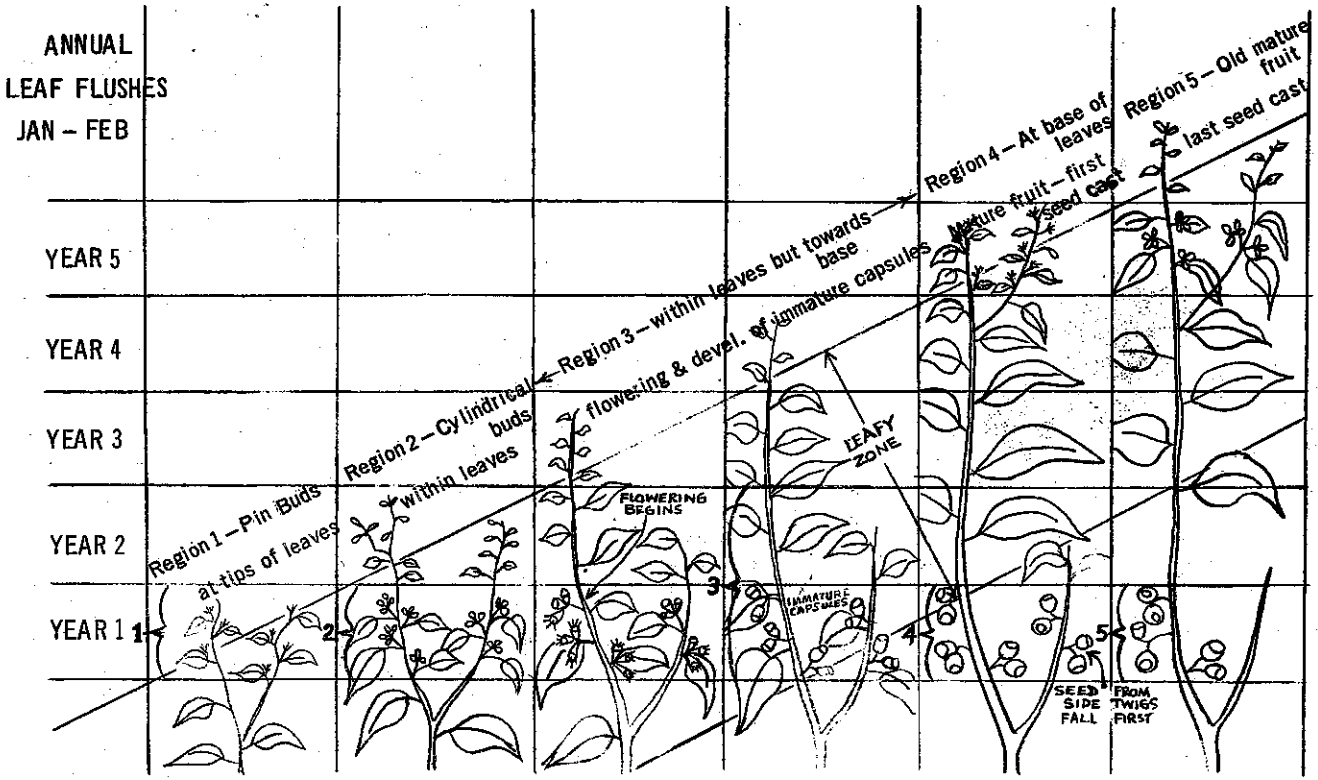
The inflorescence, produced in summer, takes 2¼ years to blossom in autumn, and four years to reach seed maturity. Half the seed falls naturally in summer No. 4 : the balance remains in unopened capsules on the tree and falls in summer No. 5.

6.41. Stages of Floral Development

Six stages of floral development are indicated on the diagram, and defined.

Stage 1-2	Formation of inflorescence - in terminal axils of leaves of current leaf flush, January.
Stage 2-3	Formation of bud initials - recognizable as such in March.
Stage 3-4	Development of flower buds - pin buds - ¼-¾" length. During first winter, growth slow. cylindrical buds - ¾" in 12-15 months. Bud caps green, conical, pointed. plump buds - after second winter plump buds become yellow green to pale brown, operculum dome shaped.
Stage 4-5	Blossom - One week prior to flowering a white line appears between operculum and hypanthium. Operculum falls off, exposing stamens which unfold and expose anthers, taking 4-5 days. Stigma sticky, ready for fertilization at this stage. Flowering of individual bud takes one week. A tree may flower for 6 months, with a 2-3 month peak.
Stage 5-6	Development of ripening capsules - Hypanthium continues to develop through one full winter before

Fig.4 REGION OF FLORAL DEVELOPMENT



maturation. Immature capsule is ovoid truncate; has a constriction below rim. Seed crop is ready after one full winter after flowering.

Stage 6-7 — Dissemination of seed - One full winter after flowering seed is ripe. In mid summer the valves open, releasing seed. In first summer seed from ± half the capsules are cast. Balance remain unopened and seed is cast the next summer. Fruiting side branches with no leaf flush cast seed in the first summer. Actively flushing branchlets retain unopened capsules for a further twelve months.

6.42. Regions of Floral Development :

Floral parts remain stationary upon the growing branchlet. Each (Nov-Jan) leaf flush the developing parts maintain a characteristic position relative to the growing tip, and leaf zone.

Five regions are recognized, and are indicated on diagram. Each region corresponds to one year's flush growth, except region three which corresponds to two annual leaf flushes - see Fig. 4.

Stages of development of the floral cycle can be gauged by their relative position within the branchlet. Capsule maturity is not reached until zone four. Seed cast is completed in zone five.

6.43. Variation Within and Between Floral Cycles :

Whereas the floral cycle above appears straight forward, in fact it can be complex and unpredictable. Sometimes the cycle can be shortened to three years, sometimes lengthened to five. Often one set of bud initials is followed by a second crop the following year. The two crops have been known to proceed in unison in the manner shown. Both crops can however, merge in the flowering stage, which can then occur over an extended period either early or late. Examples of complex seed cycles are shown in Fig. 5.

Genetic variation exists between trees. Some always flower early, others late. The flowering process is also under environmental control. Bumper seed years are associated with periods of above average rainfall, during the cycle. Insects and drought have been suspected of reducing promising crops to remnants. One bumper crop is seldom followed by another. It would appear that food reserves have to be built up following a heavy seeding. Since 1950 only two bumper crops in two decades have occurred.

Where cycles are complex and flowering occurs over an extended period the proportion of capsules which can be expected to be mature in any summer can be gauged by the fact that, from flowering time, developing capsules must overwinter before maturity. Any spring or summer

Fig.5

VARIATIONS IN KARRI FLORAL CYCLES

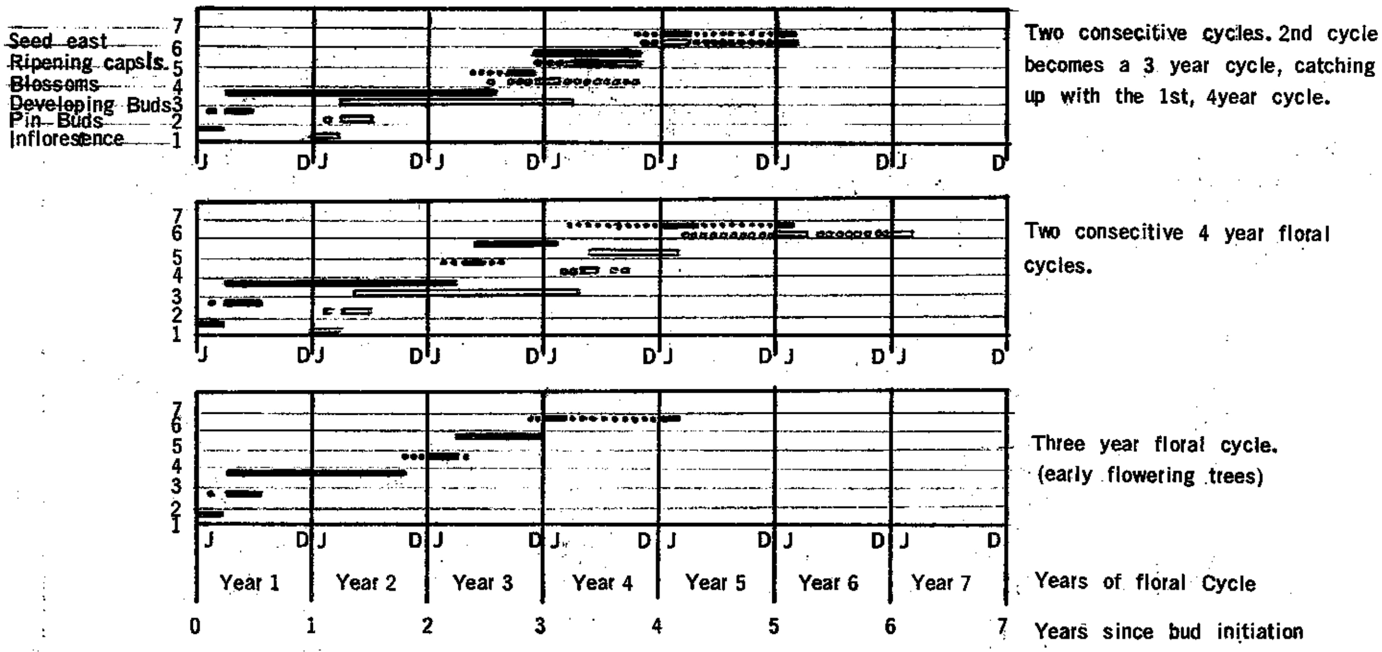
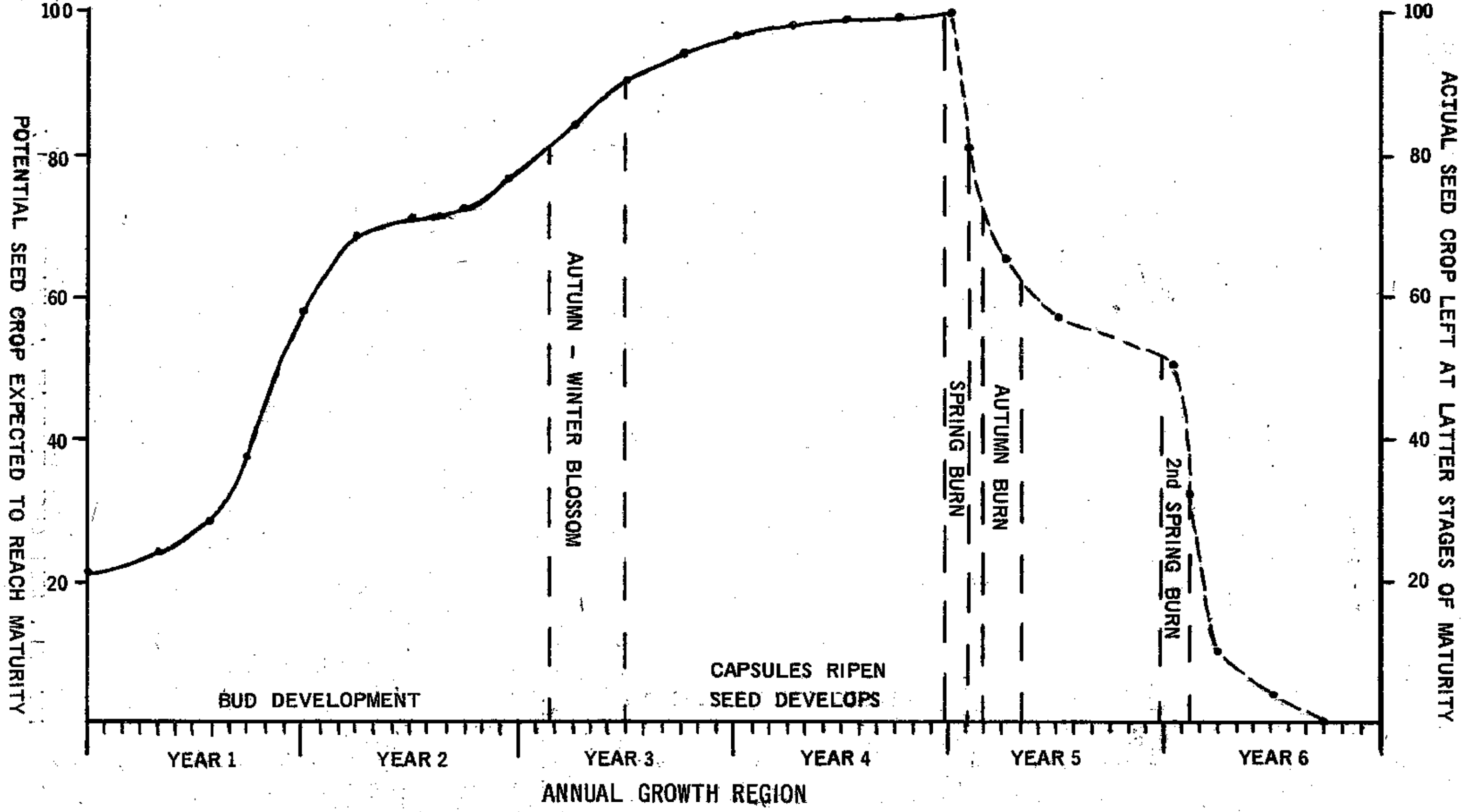


Fig.6
GRAPH USED TO ILLUSTRATE THE PERCENTAGE OF A SEED CROP EXPECTED TO REACH MATURITY



Curve illustrating the percentage of potential seed crop expected to reach maturity

Curve illustrating the of percentage of ripe crop left in subsequent seasons flowering before April will be mature by the following Christmas. Flowering subsequent to April will not be mature till the following Christmas 12 months.

6.44. Prediction of Seed Supply

Throughout all floral cycles there is a continual loss of floral parts by various agencies. Major losses occur during the young bud period, and at flowering time. Stages of flowering can be determined by observing fresh floral parts on the ground beneath trees. By using seed trays it has been possible to evaluate this loss. As Eucalypts shed the operculum at flowering time, it is possible, by estimating the number of operculum shed, to estimate the number of potential capsules held in trees. If any further loss of immature capsules is subtracted, the balance should represent the number of mature capsules available for seeding. This is called the "Floral Balance".

Study of repeated floral cycles by seed trays since 1950 have indicated that the rate of loss is similar, irrespective of the density of the crop. By combining all cycles, a graph has been compiled which shows the proportion of the crop at any stage during the cycle which may be expected to reach maturity. (See Fig. 6)

Should it be possible to measure the density of floral parts at any stage, it is then possible to make an intelligent prediction of the number of capsules expected to reach maturity at a later date. Hence within broad limits seed supply can be predicted.

6.45. Measurement of Floral Parts

Of the various ways tried to measure floral density (floral parts per unit branch diameter, floral parts per unit crown area, vol. etc.) the most satisfactory and easiest measured was found to be floral components per twig. A twig was defined as "one length of a season's growth". Twigs being the result of the annual leaf flush correspond to the zones mentioned in paragraph 6.42.

By taking at least 10 branch samples from an area and by counting the floral parts on every 10th twig, a reasonable estimate of crop density can be obtained. By using the graph (paragraph 6.44) and this measure it is possible to predict future seed availability if the crop is in the developing period of the cycle. If the floral components observed are mature capsules, then this measure can be used directly as an estimate of seed availability.

6.46. Seed per Capsule

Components per twig will only predict or measure mature capsule density. A further measure - viz. seed per capsule, is required to estimate seed supply.

In Karri, seed per capsule is commonly low, but can vary from 0.4 to 4.0. For the purpose of prediction a figure of one seed per capsule is used, which is about the average figure found. When measuring a mature seed crop, seed per capsule is counted.

6.47. Seed Fall per Acre

So far the measure of density of seed crop, or potential seed crop, refers only to what can be found in the trees. A further step is required to estimate what this measure means in terms of seed fall per acre.

Assuming that seed crop density within crown is fixed, actual seed fall per acre will vary with :

(a) Number of seed trees per acre.
(b) Crown area, crown depth, and therefore crown volume.
(c) Tree size.
(d) Tree maturity.
(e) Crown condition - health, dominance, fire damage etc.
(f) Pattern of natural seed throw.

The above factors are inter-related and vary widely from stand to stand. With so many variables accuracy cannot be expected; however, an attempt has been made (ref. 10) to relate crop density within crowns to seed fall per acre. The following formula is used :

Estimated seed per acre = CA x 6 x S.
Where CA = Crown area per acre = Crown coverage % (by densiometer) x 435.6 (sq. ft.).
6 = Constant - representing the observed relationship between unit seed per twig per square foot of Crown area and the number per square foot caught in seed trays on the ground.
S = Seeds per twig = Capsules/twig x seed/capsule.

Variation in results using the above formula was reduced by applying the following correction :

$$P = \frac{CA}{(BA \text{ per } Ac)^2}$$

Where CA = Crown area per acre
BA per Ac = Basal area per acre, measured by the product of number trees per acre and Basal area of the mean tree.

If P is greater than 10 no correction to the estimate is made.

If P is less than 10 the estimate is adjusted as follows :

DATE: 2 – 12 – 1969

Fig. 7

KARRI SEED CROP ESTIMATE

DISTRICT: SHANNON **LOCATION:** DEESIDE COAST ROAD (JUST NORTH OF NELSON RD.) **S.M.P. No** 1329 **MAP REF:** JG 82

Telescope count mean of 10 twigs	Trees per acre ½ ac. pl.		Girth at Breast Height			Densiometer Readings	
	1	1	17' 10"	13' 4"	10' 3"	15	17
	1	1	22' 7"	14' 10"	13' 5"	23	16
	0	0	22' 2"	13' 8"	10' 11"	23	11
Mean for Main Karri region used	0	1	13' 4"	15' 0"		15	13
	2	0	15' 4"	19' 3"		21	8
	0	0	15' 5"	13' 7"		6	11
	1	1	26' 3"	15' 2"		7	13
	0	3	15' 1"	19' 3"		4	10
	1	1	16' 1"	15' 4"		14	13
	1	1	13' 9"	16' 10"		9	13
	.8 1.6 per acre				16' 0"		13.1

4.6

MEAN FOR MAIN KARRI REGION EXCEPT:-

(1) If seed in the area appears less; then do telescope counts.

(2) In Margaret River, Walpole and Denmark use mean for these districts only

ESTIMATE:

Mean densio. readings 13.1 x 435.6 = 5706sq

C.A. x 6 = 34236 x seed / twig = 157486seed per acre

CORRECTIONS:

Mean B.A. per tree 1.6 $\frac{20.4 \text{ x mean trees per acre}}{32.6 \text{ mean B.A. per acre}}$

$$\text{Product} = \frac{\text{C.A. per acre}}{(\text{B.A. per acre})^2} = \frac{5706}{1062.8} = 5.4$$

If less than 10, consult Figure 4. Percent overestimate 46% Reduce estimate by this percentage

85,042

COMMENTS: There appears to be a fair amount of seed in this area. It is also a good stand.

Value of P	Reduce Estimate by
9	10%
8	20%
7	30%
6	40%
5	50%
4	60%
3	70%

The estimating formula works best when seed trees are ideal large healthy specimens. The correction appears to prevent over-estimates when crowns are decadent due to fire damage and gross over-maturity, or when a greater number of smaller younger trees are left as seed trees. In the latter case capsule density is less and generally the smaller trees are not sampled for capsule and seed density.

Precision of estimates are approximately ± 60%.

A standard form used for estimating, with an example shown is given in Fig. 7.

6.48. Dominance and Seed Supply

80% of available seed supply is found in the larger Dominants and Co-dominants. Suppressed and smaller trees contribute little to total seed supply, especially in the poorer seed years.

6.49. Pattern of Natural Seed Throw

Seed is widely and haphazardly dispersed after burning. The haphazard nature is more obvious than any regular pattern involving distance from seed tree.

The valves of capsules open when moisture content falls below about 25%, whereupon wind is the dominant factor influencing dispersion. Karri seed is light, but not winged.

Some patterns are discernible however, in open gaps :

(1) The number of seeds in the gap at half tree height was equal to the number of seeds under the nearest seed tree.

(2) The number of seeds in the gap at three quarters tree height was equal to three quarters the number of seed under the nearest seed tree.

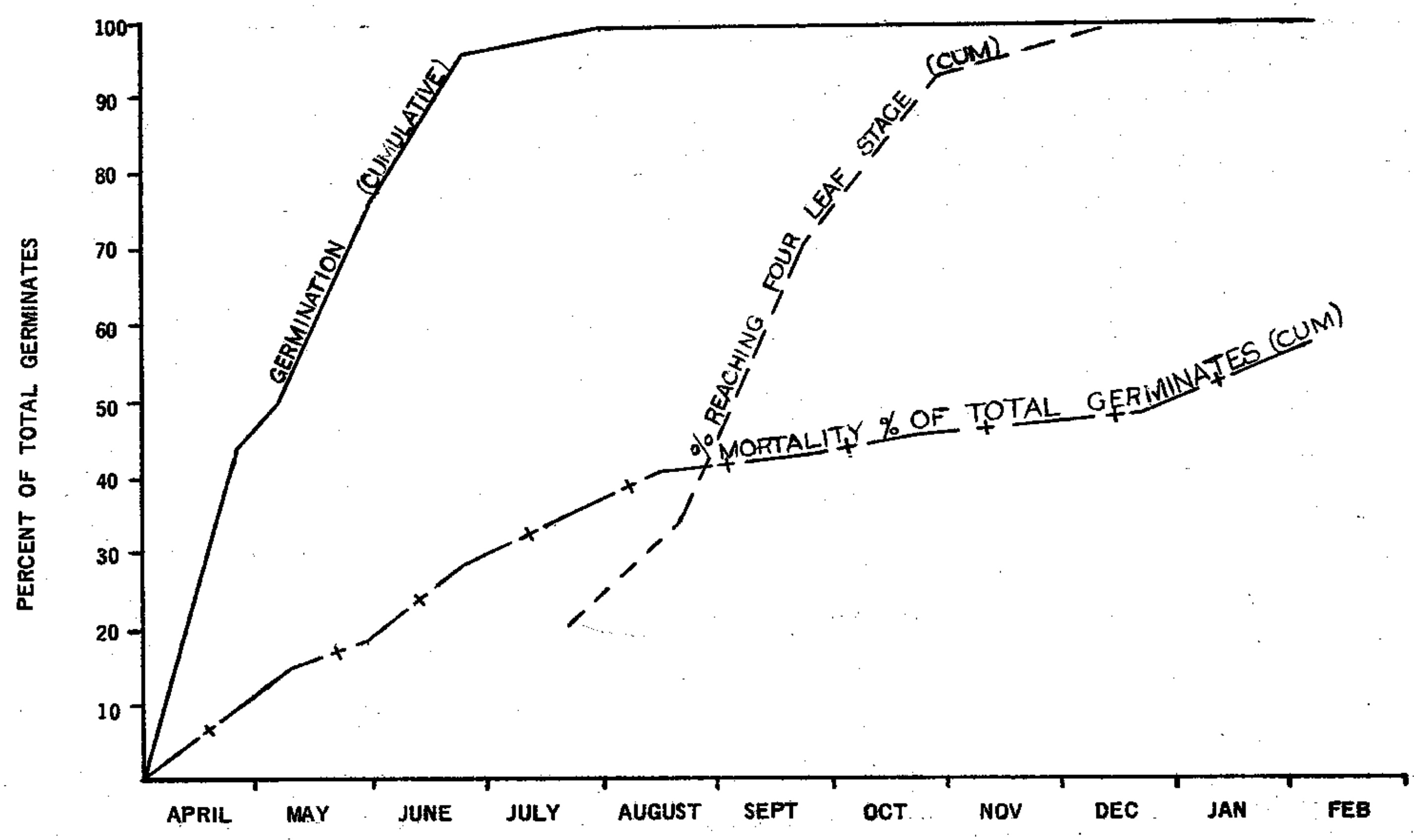
(3) The number of seeds in the gap at tree height was equal to half the number of seed under the nearest seed tree.

In general therefore, seed trees should not be spaced more than twice tree height apart, otherwise unseeded areas might be too common. Allowing one chain crown width, on trees 200' tall, the maximum

Fig.8

GERMINATION. MORTALITY AND GROWTH OF YOUNG KARRI.

March Rd – 1969 – 70 (P.Christensen ref.)



distance is therefore 5 chains. 200' (H) x 2 - 66' (W) = 334'.

The usual prescription stipulates 1-2 seed trees per acre, which corresponds to a triangular spacing of 3 chains x 3 chains.

7. 0. REPRODUCTION

7.1. NATURAL REPRODUCTION

Karri is considered to be an intolerant species and does not form lignotuberous growth beneath canopy as do Jarrah and Marri. Natural reproduction is by seed, which germinates and grows directly into tree form. It will coppice after fire. Burnt saplings will sprout from ground level or higher up the stem, depending upon fire intensity and extent of cambial damage.

In the virgin state the occurrence of sapling size classes are not a feature, and occur only in natural gaps. Within the general over-mature pattern, groups of younger trees are evident, which have apparently developed in large natural gaps.

The even aged nature of many pure Karri stands can perhaps be related to catastrophic fires in the past. Karri can be killed or severely debilitated by fires of high intensity, particularly if repeated within a short space of time. Where such fires have occurred in times of seed supply, an even aged regrowth crop emerges.

Surviving members of the old stand tend to lose crown and vigour with time and competition with vigorous younger growth.

FACTORS AFFECTING NATURAL REPRODUCTION

Natural regeneration from seed is used for restocking areas cut over, irrespective of what silvicultural system is used. Requirements for successful regeneration are listed below.

7.11. Seed Supply

Must be present in adequate quantity at time of regeneration.

On average sites, 120,000 seeds/acre are required for Spring regeneration burning; 80,000 seeds/acre for Autumn regeneration burning.

7.12. Seed Bed

For successful germination and growth Karri requires mineral soil free of overhead canopy and free of ground competition in the form of scrub. An ash bed provides the optimum conditions.

7.13. Germination

Follows natural summer seed fall, and takes place after the first significant autumn rains : 150 points over three days, usually about mid April. Germination is largely complete by early July. There is no experimental evidence of delayed germination the following spring.

7.14. Survival and Establishment :

Whilst conditions are optimum, regeneration is dense (it can average 50,000/acre). Most deaths occur early when germinates are small, with the smaller germinates being the most likely to die.

Growth during the winter months is slow, but accelerates with the onset of spring. By October 80% of survivors had reached the four leaf stage.

Deaths can be attributed to insects, fungi (damping off), frost and drought.

A graph (Fig. No. 8) illustrates the progression of deaths and early growth.

7.15. Tree Per Cent :

The average number of seedlings which become established in forest from each hundred seed shed into it is known as Tree Per Cent. For cut-over Karri this figure varies from 0.6 - 2.8%. Tree Per Cent is best in fresh ashbeds or clear disturbed surface soil.

7.16. Fire and Seed Bed :

Fire can be used to create ash bed and remove competition. A regeneration burn is one that consumes logging slash and promotes seed fall from seed trees retained for the purpose.

Regeneration burning is the standard site preparation for natural regeneration.

7.17. Fire and Seed Fall :

Fire stimulates seed fall. Where intensity is sufficient to scorch crowns, all seed is shed within weeks. Seed fall even after intense fire does not begin falling for several days, by which time the ground is cool; - hence little or no seed is consumed by the fire itself. Karri seed being soft coated would not be expected to survive fire.

When seed is mature even a fire of mild intensity will stimulate seed fall. However fires of low intensity, particularly if capsules are young mature, may have no stimulating effect on seed fall.

In a normal four year cycle, seed is mature by summer 4. Half of this crop falls naturally during summer 4, and half is carried over till summer 5, during which all is shed. Three opportunities exist therefore to carry out regeneration burning.

(1) Spring, Summer 4)
(2) Autumn, Summer 4) see Fig. 6.
(3) Spring, Summer 5)

Where a seed cycle becomes complex with successive crops running together, the opportunities for regeneration burning are increased.

7.18. Regeneration and Gap Size :

Karri regeneration develops best on ash bed free of ground competition and crown cover. The inhibitory effect of canopy can be attributed to both light restriction and competition for moisture. The roots of a tree occupy at least the equivalent ground space of the projected crown area. Within this space regeneration has to compete with an established root system, and hence, in time of moisture stress, succumbs. If the crown area is that of young growing stock, as in a selection system, regeneration is neither wanted or sought. Occasionally Karri saplings can be found beneath canopy. This can usually be associated with defoliation at the time of burning and seed cast, such that reduced biological activity of roots permits establishment.

Regeneration will not develop vigorously unless a gap exists of sufficient size to permit freedom from side and overhead shade. The minimum size gap is considered to be one of 2 chains between the edges of surrounding crowns.

71.9. Regeneration and Scrub Competition :

When Karri seed falls into established green scrub germination takes place but competition for light and moisture inhibits growth and most die. A few may survive, but remain in an etiolated suppressed condition for many years before finally overtopping the scrub and achieving release. Ten years' growth or one tenth of rotation can be lost.

When Karri seed falls on clean, scrub free ash bed or disturbed mineral soil, both Karri and scrub germinate together. Karri grows faster, and will dominate scrub from the start to form a stand.

Timing of regeneration burns is important. For instance, a burn of low intensity when capsules are green may not promote seed fall, but will germinate scrub. Karri seed will fall naturally at a later date into established scrub and will be suppressed.

The scrubs in question are Acacia or Bossiaea fire weeds. They have a hard seed coat which needs a fire to crack it before germination.

7.2. ARTIFICIAL REPRODUCTION

When natural regeneration fails, Karri can be established artificially. A variety of ways are available, viz. :

7.21. Direct Seeding :

Karri can be established by broadcast seeding onto ash bed, preferably early in winter. However, results have been variable. Artificial seeding results in later germination and less vigorous early growth than natural seeding.

At least one pound of seed and chaff per acre is required on good sites, more on marginal sites. Tree per cent has ranged from 0.02% - 1.16%.

High cost of seed detracts from broadcast seeding as an operational technique.

Spot seeding trials have shown that only 25% of spots can be expected to establish seedlings, irrespective of the number of seeds per spot sown. No difference was found from 8 seeds per spot to 128 seeds per spot. Wider spot spacing than 6 x 6 achieves an unacceptable distribution of stems, with less than 300 per acre (12' x 12'). One pound of seed covers 5 acres.

High seed cost and variable results detract from its use operationally.

7.22. Planting :

Karri has proved amenable to artificial planting. Three methods can be used :

7.221. Wildings :

Wildings are naturally grown seedlings. They often occur in overstocked patches which can then provide a source of planting stock for failed areas.

Indications are (ref. 12) that best survival and growth is obtained by using one year old wildings of about 2' height. Wildings can be pulled direct from the ground without significant detrimental results. Wildings planted earlier in winter survive better than late plantings. If later plantings are undertaken, smaller plants should be used.

Technique of planting is the same as for hand planting pine. Care must be taken to transport lifted stock in damp bags or plastic bags to reduce moisture loss.

Cutting back stems did not enhance success.

7.222. Open Rooted Nursery Stock :

Recent work indicates that Karri can be successfully raised in open beds and transplanted in similar fashion to pine.

7.223. Peat Pots :

The surest means of planting Karri is by using $2\frac{1}{2}$ x $2\frac{1}{2}$" jiffy pots.

Root systems are undisturbed, survival is higher and response to fertilizer is better.

Planting costs tend to be higher, because the greater weight of seedlings reduces the number that a planter can carry.

7.23. Fertilizer at Time of Planting :

In common with most eucalypts, Karri responds strongly to the application of NP fertilizer at time of planting (ref. 13). Standard treatment is 2 oz. of Nutrifert, a complete fertilizer, at planting time, applied on the surface or buried beside the plant.

7.24. Planting and Scrub Competition :

Seedlings, especially open rooted stock or wildings, are more likely to establish on freshly cleared sites (e.g. ashbeds) than where competition is present.

Where natural stocking is suspect, it may be necessary to wait for a year to assess actual stocking. By this time scrub is established, and artificial restocking must contend with it. Fertilizer and use of jiffy pots helps. Work is proceeding on use of weedicides prior to planting.

8. 0. INIMICALITIES

Karri has the usual natural enemies chief among which are :

8.1. INSECTS

8.11. Defoliators :

Young Karri regeneration is prone to attack by a wide variety of defoliators, none of which, however, have caused more than a temporary setback.

Defoliators identified include :

Sap suckers - aleuroid white fly, related to aphids and scale insects,
Jassids,
Eriophyid mites, and
Eucalyptus tortoise beetle - Paropsis sp.

8.12. Buds and Fruit Eaters :

The larval stage of a beetle, family Bruchidae, eats the seed within capsules. Evidence of their activity is a neat round hole in the mature capsule.

A curculionid beetle and others from the family Bruchidae, are responsible for injury to Karri buds. After eggs have been laid therein the insects then nip off the bud which falls to the ground.

8.13. Gall Forming Insects :

An insect, Apiomorpha sp. related to scale insects and mealy bugs causes galls to form on young Karri branchlets. The female causes the formation of large woody galls, the male, tubes clustered on leaves.

The gregarious gall weevil (Strongylorhinus ochraceus) causes the formation of large multiholed galls on young Karri.

8.14. Seed Eaters :

Ants (Pheiodole sp.) have been observed removing seed cast naturally.

8.15. Wood Eaters :

Pin hole borers cause serious degrade in stems which have suffered cambial damage.

Severe damage in poles is caused by a Cerambycid (longicorn, bardie grub) borer, and a cossid moth. The cerambycid beetle lays its eggs in apparently healthy bark. Entry of the cossid moth is usually through old rotten branch scars.

Cerambycid borer damage tends to be concentrated on the lower 20' of bole, the cossid moth damage above 20'. Attack is most prevalent in dominants and co-dominants; and has been found in ages 7-40 years. Older trees show more attack.

Termites :

Calotermes sp., will attack Karri of all ages.

8.2. FUNGAL ATTACK

8.21. Germinates :

Can be killed by "damping off" fungi. Some areas appear more prone to attack than others. Low stocking in some places can be due to this in spite of good seed supply.

8.22. Root Rotting Fungi :

Phytophthora cinnamomi will attack Karri roots in pot trials. Root regeneration however is rapid. Areas have been observed where Phytophthora is present in the Karri understorey, but so far no deaths have been attributed directly to it.

Armillarea mellea has been identified as a pathogen, killing Karri in Warren Block. This is most likely a natural occurrence.

8.23. Wood Rotting Fungi - (ref. 14)

Secondary

Trametes lilacino - gilva; - producing a brown coloured cubical rot.
Polyporus mylittae - black fellows bread.
Lentinus dactyliodes - sleepers in dry inland.

Primary and Secondary

Polyporus australiensis - Karri cubical rot.

8.3. FIRE

Karri is a fire resistant tree. However, it can be killed by repeated high intensity fire. It is less fire resistant than Jarrah.

A wildfire usually causes cambial damage up to about a stem diameter of 3".

Slash burning, which is usually of a prolonged nature, can cause cambial damage on a Karri some chains away, and high up the stem. This is noticeable in many regenerated selection stands.

Depending on intensity, crowns defoliated by fire can recover from sprouts in the crown and further back the stem. Particularly in an opened up stand, the lower sprouts become permanent at the expense of those in the crown.

Karri's fire resistance allows the use of control burning to afford protection. Trials have indicated that Karri under 30' total height cannot be control burnt without considerable damage. Full protection to this stage is indicated.

8.4. WIND

Karri does not suffer excessively from wind throw, even in an opened up condition. As seed trees are always dominants they are likely to be naturally wind firm.

8.5. FROST

Karri areas are not prone to heavy frosts.

8.6. BROWSING

Browsing by native or introduced animals has not caused concern to date.

9.0. SILVICULTURAL SYSTEMS IN PURE KARRI

Both selection and clear falling systems have been used. First cutting at Pemberton was by clear falling. By 1940 a selection system had evolved,which, with some variation, existed until 1968. In the past few years a change back to clear falling with seed trees has taken place.

Reasons for the change can be summarised under these headings.

9.1. USE OF FIRE

Fire is used to regenerate cut-over Karri, and, in the virgin state, to afford fire protection by control burning.

A regeneration burn, whether in selectively cut or clean stands, involves consuming considerable quantities of slash, and fire intensity is therefore likely to be high. In selection stands, experience has shown that it is difficult to restrict intensity such that damage to growing stock is kept within acceptable limits; - yet for regeneration a clean, and therefore hot burn, is desirable. In seeking the balance too many stands were burnt either too hot, with good regeneration but poor growing stock, or too cool, with good growing stock but poor regeneration.

In clear falling with seed trees, the situation to be avoided is that where intensity is too low, resulting in a poor seed bed. Provided seed supply is adequate, a high intensity burn is not undesirable in that no growing stock is involved and regeneration is favoured. Decimation of seed trees is not catastrophic provided they are utilized within two years. The main reason for not decimating seed trees is in case of failure, in which case they may be retained for a later seed cycle. Regeneration burning is therefore not as critical as in the selection system.

The problem of regeneration burning in selection stands will be multiplied in later cutting cycles, with younger age classes involved.

Control burning in mixed aged stands must be governed by the youngest age class present. In general therefore, only the lower fire danger ratings can be used. Control burning is much easier in even-aged stands with more uniform litter and scrub. Depending upon age, a much greater range of fire dangers can be utilized.

9.2. COMPACT CUTTING COUPS

To obtain the same annual cut, clear falling means smaller, more compact cutting coups, from which there are practical, economic, sanitation and management benefits to be gained : e.g. less roading, more efficient supervision, less chance of Phytophthora spread, simplified fire protection.

9.3. SILVICULTURAL CHARACTERISTICS OF KARRI

Karri does not develop advance growth beneath canopy, as do Jarrah and Marri. Regeneration is from seed only, and optimum conditions for establishment exist on clean ash beds with a complete absence of canopy. There is a minimum sized gap which can be said will produce vigorous unimpeded Karri regeneration : - a gap of 2 chains diameter has been suggested. Restocking of gaps is therefore, not automatic.

Karri is a very tall tree, of large girth. Heavy equipment is needed for its removal. Logging of large stems from mixed aged stands presents problems.

Karri has the ability to establish dominance quickly and permanently in overcrowded regrowth stands. If left unthinned dominants can continue growing at 1" girth per annum. An MAI of 2 lds./ac./annum at age 92 has been measured. Unthinned stands do not therefore lock and become unproductive.

Karri lends itself to even aged management. There would therefore need to be compelling reasons to do otherwise.

9.4. HISTORICAL

The traditional sawn Karri demand has been for a large section, long length product of high quality, which the virgin forest is well suited to supply. Where the demand has been solely for this class of product, smaller trees were not utilizable, and hence in earlier clear cutting many such stems, often of superior form and vigour, were wasted. Attempts to retain these stems as growing stock marked the beginning of the selection system, which gradually developed such that progressively larger trees were retained, representing a higher proportion of the standing crop. However, over the years a market for smaller scantling sizes has developed alongside the continuing traditional demand. The minimum utilizable log size is now considered to be 15" top diameter, 12' long. Treated Karri transmission poles are now saleable, and pulpwood is likely to be saleable in the forseeable future. The reasons for the retention of smaller sizes in the forest have therefore become less compelling.

9.5. PRESCRIPTION FOR CLEAR FALLING WITH SEED TREES

A typical prescription for clear cutting with seed trees is :

(1) (a) Select 1 - 2 Karri seed trees per acre for temporary retention : - trees must be spaced as evenly as possible. (1 - 2 seed trees per acre corresponds to a triangular spacing of approximately 3 chains x 3 chains).

(b) Specification for Seed Trees :

A seed tree must be a dominant or co-dominant with a healthy spreading crown. Preferably, it should be a tree of good form, free of such defects as double leader, heavy branching low down on bole, pronounced spiral grain, bumps and swellings, apparent lack of vigour in bole and excessive taper. Where a choice exists, cull type trees with hollow butts, dry sides, termites should be avoided (such trees may not survive the regeneration burn). Where no choice exists a cull type tree is better than no seed tree.

(c) Indicate seed trees by painted crosses (3, spaced evenly around bole).

(2) Tree mark for removal all marketable trees, except those selected for retention as seed trees, and any tree which will in falling damage a seed tree.

(3) Instructions to fallers and tractor drivers :

Damage to seed trees must be avoided in falling and snigging.

(4) Fall cull trees.

(5) Scrub roll, if necessary.

(6) Burn for regeneration when seed is adequate and mature in crowns.

(7) In the 1st. summer following the establishment of a satisfactory level of regeneration, remove seed trees and any other marketable trees remaining.

(a) Trees to be marked to minimise damage to regeneration.

(b) Instructions to Tractor Drivers :

(i) Use old snig tracks and landings only. Do not make new ones.

(ii) Logs to be extracted with the minimum of sideway slewing. Logs to be pulled back past stump.

(iii) Logging arches to be used.

Depending upon the condition of the stand the number of seed trees to be retained can be varied. Cull trees may be left standing to reinforce seed supplies if necessary.

10. 0. SILVICULTURE OF MIXED MK STANDS

A stand in which Marri stems outnumber Karri is termed a Marri-Karri stand. In such stands stems numbers in the larger girth classes (90" GBH) are usually about equal, but Marri outnumbers Karri by a big margin in the smaller size classes. Karri usually occur as emergents above a lower level of Marri canopy.

Should Karri only be logged selectively in such stands, retaining some as growing stock - seed source, gaps of insufficient size are formed to promote Karri regeneration. Smaller gap size, presence of Marri advance growth and overhead canopy, and a greater Marri seed source, combine to favour the regeneration of Marri. Without further attention selective logging of Karri is likely to manipulate the stand towards pure Marri.

Experiments have shown that if all Marri is removed, leaving a Karri seed source only, and if a regeneration burn is carried out in a Karri seed year, the balance can be swung in favour of Karri in the regeneration stand.

The possibility that chipping may utilize Marri in quantity opens up the possibility of economically treating mixed stands in this way. Otherwise Marri will have to be removed at cost.

Pending the commencement of Marri utilization for chipping, MK stands are avoided in logging.

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