THIRD WORLD CONSULTATION ON FOREST TREE BREEDING

Study Tour No. 6
South-West of Western Australia

FORESTS DEPARTMENT WESTERN AUSTRALIA

PRODUCTION PROTECTION RECREATION CONSERVATION

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THIRD WORLD CONSULTATION ON FOREST TREE BREEDING.

POST-CONSULTATION STUDY TOUR 6. MARCH 27 to APRIL 1, 1977.

SOUTH WEST OF WESTERN AUSTRALIA.

INDEX

Compiled by T. Butcher.

Section 1

General notes on Forestry in Western Australia.

Welcome to Western Australia.

Study tour 6 will show aspects of our softwood afforestation programme, and indigenous hardwood forests. The final day will examine the tree breeding programme for the *Pinus pinaster* species.

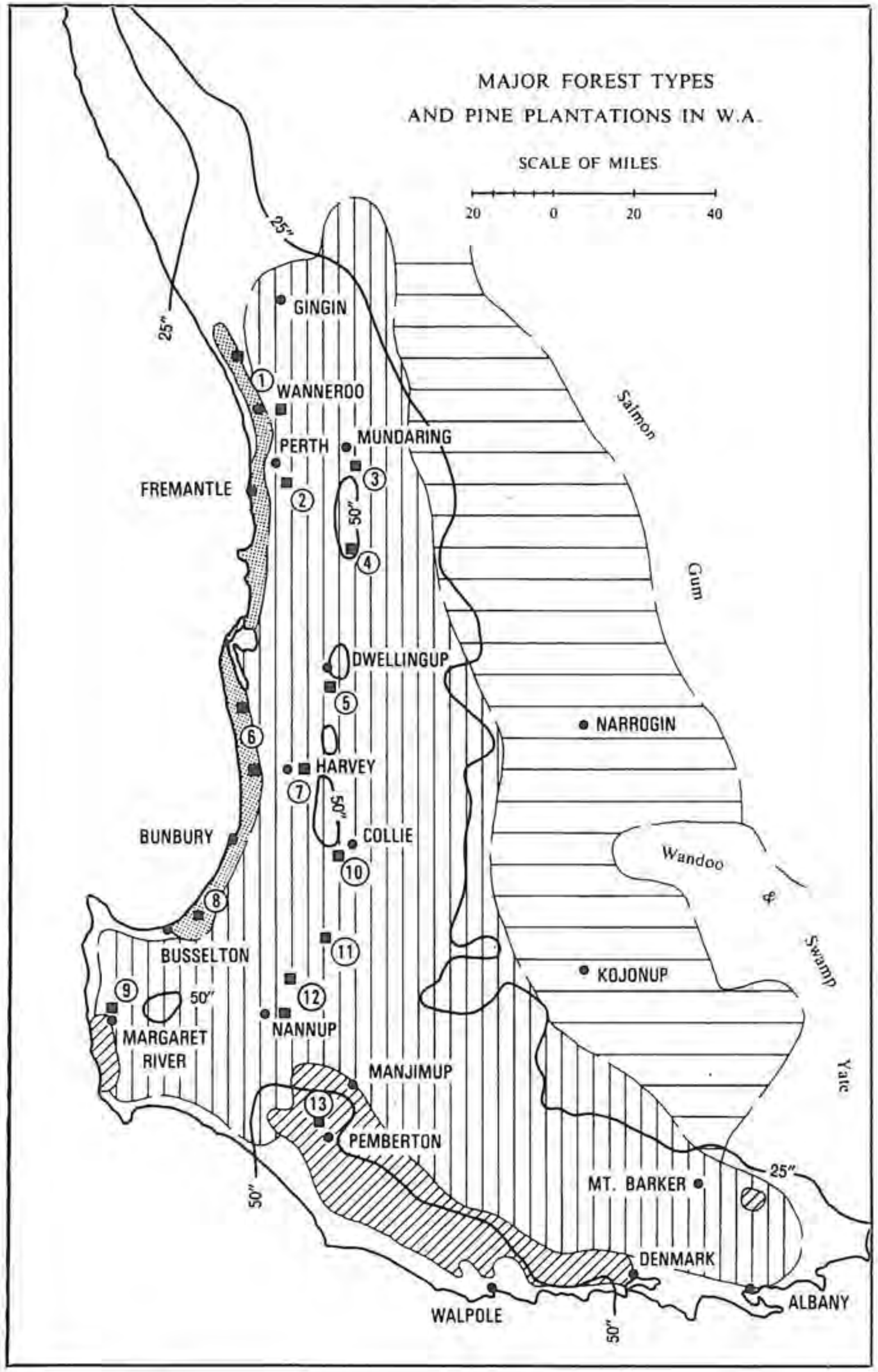
Climate in the southwest corner of the state is typically Mediterranean in character with cool, wet winters and hot, dry summers. Fortunately this tour is taking place in autumn when more equitable weather is to be expected. Perth temperatures in March are maximum 28°C and minimum 16°C. Perth rainfall is 890 mm with greater than 70 per cent of this falling in the four coolest months of the year.

Some important Western Australian statistics are a population (June 1976) of 1,144,857, with 805,489 resident in the Perth metropolitan area. Australian population is 13,548,472. Land area measures 2,525,400 sq. km, which makes it one third of the Australian continent. The dedicated State Forest area is exceedingly low, being less than 1 per cent of the State land area.

The Forests Act was passed in 1918 to provide for a permanent forest estate, and the control of cutting in native forests. This was recently revised, in 1976, and now emphasizes the multiple-use management of State Forests and Timber Reserves. Water supplies, and timber production are listed as the principal objectives of the revised Act. This is described in the Forest Focus number 17, which accompanies these notes.

The present yield of hardwood sawlogs is approximately 1 million cubic metres, but this cannot be sustained because of slow growth rates, and the impact of the dieback disease. It is considered that this must be reduced to the order of 0.5 million cubic metres per annum to ensure the continuity of hardwood log supplies. Conservative estimates indicate that the sawlog requirement will increase to 1.4 million cubic metres per annum by 2010 AD.

The departmental afforestation programme is planned to meet this deficit of sawlog timber. This will reduce this, and other excessive pressures on prime native forests by the creation of highly productive pine plantations. In fact, one hectare of pine has a productive capacity equivalent to 30 hectares of better quality jarrah forest. A softwood resource of 140,000 in 2,000 AD, is required to sustain the annual production of 0.9 million cubic metres sawlogs. Current resource is 20,000 ha *Pinus radiata*, and 23,000 ha *Pinus pinaster*.

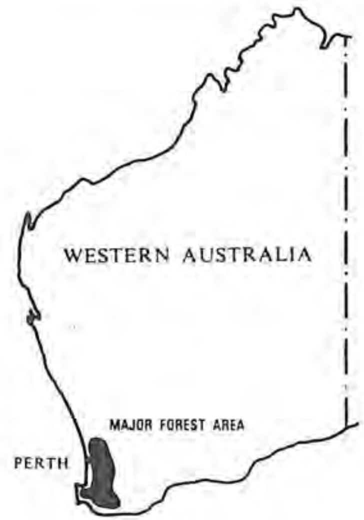


LEGEND

Jarrah Zone Shown	(vertical lines)
Karri	(diagonal hatching)
Wandoo	(horizontal lines)
Tuart	(stippled)
Isohyets	25"

PINE PLANTATIONS

1. WANNEROO (GNANGARA & YANCHEP)
2. METROPOLITAN
3. MUNDARING
4. GLENEAGLE
5. MURRAY
6. MYALUP-McLARTY
7. HARVEY HILLS
8. LUDLOW
9. MARGARET
10. COLLIE
11. GRIMWADE
12. FOLLY-LEWANA
13. PIMELEA



SECTION 2 Softwood afforestation in Western Australia.

Pine planting in W.A. was first tested in 1896. Even then it was realized that there would be a necessity to supplement the timber output from the indigenous hardwood forests in order to meet the demands of future populations. Local plantations of fast growing pines would be the solution to the natural deficiency of softwoods.

Several species, naturally occurring in similar climatic regions, were tried on our poor sandy soils. The first conclusion was that the desirable, and popular Pinus radiata, so successful in Eastern Australia, could only be grown on the limited areas of better soils, and that the bulk of the poor sandy coastal country was suitable only to P. pinaster.

Between the years 1900 and 1930, pine establishment techniques were perfected. Most work up to 1920 involved the direct sowing methods employed in Europe, and generally resulted in failure. After 1920, establishment efforts were mainly concerned with seedling stock raised in nurseries, and by 1927 suitable techniques of site preparation, stock raising and planting out had been developed to allow establishment to be continued with confidence.

Planting Pinus pinaster was not the solution to the whole problem, however. Four races of this pine were recognised and were included in the general programme, although no care was taken to keep the races separate. After 1927, with the increase in tempo of establishment, provenance tests were planned to determine if any particular source of seed was most suited to local plantation requirements. In fact, from this data, all seed of any species planted within the State has been recorded on a serial system whereby stock from any seed batch can be traced from the field, through the nursery and back to its place of origin and authority of collection.

From 1929 to 1939, provenance trials comparing stock from forest centres scattered over the natural range of the species were established annually and until 1948, careful measurements and uniform treatment were maintained for all trials. At this stage the results obtained from the project were considered to be conclusive and measurement was discontinued. As a result of this investigation, all seed used in the State plantation programme since 1940 has been of Portuguese origin.

Provenance of Pinus pinaster.

Provenance trials in Western Australia have established the afforestation values of four geographic races of maritime pine from the forests of Leiria in Portugal, French Landes, French Esterel and Corsica.

The Portuguese race is the most suitable, and is markedly superior from the viewpoint of total height, merchantable volume, and volume of the pruned section. Landes, Corsican and Esterel, in that order of importance follow the Portuguese race in these aspects.

Form assessments comparing the percentages of quality stems in the four populations favour the Corsican race with approximately double the number of acceptable crop stems per unit area of the Landes and Esterel. Portuguese stem quality is intermediate between Corsican and the better Landes percentages. Stem taper of the mean acceptable crop stem is similar for all races, with the exception of the Esterel in which it is significantly greater.

Differences in wood quality, appraised on the basis of fibre length, basic density and spiral grain, are small for these races. Fibre length differences between races are small. On the other hand, basic density values differ between and within a race indicating large amounts of variation for this feature within the species as a whole. Landes and Leiria populations recorded the highest densities, and have the best strength properties. Leiria race also has the least spiral grain angles, and Corsican trees show the greatest deviation.

Consideration of external characters of superior vigour and reasonable form together with internal characters of high basic density, good fibre length and small spiral grain justify the use of the Leirian race in Western Australia afforestation for sawn timber production.

Provenance tests were repeated in 1964 and 1967, and these will be viewed on the field trip. The 1964 trial was planned as a provenance demonstration unit, comparing the Leirian, Luccan, Landes, Corsican and Italian races, planted in large racial blocks with a Latin Square design. This trial is a replacement for the original provenance tests which had been destroyed by fire in January 1962. The 1967 trials explore the variation within the major racial groups. These are discussed in greater detail in the Appendix 9.1.

Parent tree selections have been made within the provenance groups, and used in the testing programme. Generally, the manipulations have been made within provenances only, but there has been some outcrossing of the provenance parents. Landes x Leiria, (to combine the character of frost resistance and vigour) and Corsican x Leiria (straightness and vigour), families have been created and are planted in field trials. Early height growth of the Landes x Leiria family is vigorous, and comparable to the average Leiria crosses, suggesting no loss in vigour by outcrossing. It would be interesting to determine the frost hardiness of this new family. This source could be of value to French forestry.

Progeny tests including the Corsican x Leirian families are only recent, and no measurements have yet been carried out.

SECTION 3 Pinus pinaster, tree improvement review.

A tree breeding programme for the Leirian race *Pinus pinaster* was implemented in 1957. Hopkins (1960) was able to illustrate considerable variation in stem form and individual tree vigour, and Nicholls (1963) has shown variation in the fibre length and basic density characters. Both authors worked on the same Western Australian Leirian population. The improvement of stem form was set, as the major objective of the programme, whilst at the same time, the current level of vigour was to be maintained. No goal was defined for wood properties.

All Leirian stands, 20 years and older were cruised and the best formed, dominant trees were selected. This age was considered as the minimum for selection. Sixty trees were located in this initial search, but only 16 were considered to have reached reasonable standards of perfection in form and vigour, and to be suitable for orchard use. Probably only 5 of these selections exhibited the desirable standard for both characters.

In the search, weight was given to favour the selection of trees in which the bole was straight, vertical, of circular cross section and with pronounced leader dominance. Only trees of dominant or co-dominant vigour were included in the final selection.

Unfortunately, the initial programme was severely limited in scope by the very small area, about 400 hectares, of plantation suitable for selection, and by the poor selection of plus trees. Nevertheless, the first seed orchard of 11 hectares was completed in 1963, and has provided this department's total seed requirement since 1971.

Concurrent with the development of the first orchard, grafts for each of the parents in the breeding population were established, in rows, in a clone bank. This is located within 6 km of H.Q. and has played a major role in the breeding programme. Simply, it provides a reserve of asexual and sexual material for each of the clones, it is a source of scions for grafting, and flowers for the isolated controlled crossings that have constituted the bulk of the programme. It also has been valuable as an easily accessible source of scion and pollen material for distribution to other interested organizations.

From the first cruise, the number of possible parents for a seed production population was considered inadequate. But it would be years before the search area could be extended sufficiently by maturation of further age classes to allow adequate selection from first generation stands. Rather than wait a decade to improve the situation internally, or to increase the current orchard area with further stems of inferior form, the decision was taken to search for plus trees in the native Leirian stands.

Approach to other forest authorities in Australia and New Zealand resulted in an agreement to share the considerable expense of sending an officer to Portugal, to search for plus trees and to despatch scion material, pollen and seeds to

Australia. Mr D.H. Perry of the Western Australian Forests Department was unanimously chosen for the task, which he completed in 1965. This project was extremely successful; 79 of the 85 plus phenotypes selected were successfully introduced, and are now established in clonal arboreta in this State. Propagules have since then been distributed to Victoria, South Australia, New Zealand and South Africa. It was estimated that the selection intensity involved was of the order of one plus phenotype per quarter million trees.

Immediate steps were taken to increase the genetic diversity of the first orchard seed population, by the interplanting in 1966 of Portugal clones within established graft rows. Although suppressed to a degree, they have made a valuable contribution to the pollen cloud and of the quality of seed produced in this orchard.

The use of untested Portuguese plus trees in local seed orchards posed problems concerning adaptability. It was assumed that stem straightness, a character shown to have high heritability, would be transmitted effectively under Western Australian conditions. The same assumption was not made with respect to the high degree of vigour selected in the Portuguese clones, because of a suspected vigour superiority in an adapted land-race. In the one instance where the performance of seed collected from first generation Portuguese stands in Western Australia, can be compared with that of the imported seed, the local source appears to provide an appreciable advantage in vigour.

In using the imported clones to introduce the necessary genes for straightness into local seed orchards, the problem of restricting a possible depression in population vigour arose. To counter this, double the number of ramets for each local clone were planted for each Portuguese clone. This was to ensure that at least half of the pollen cloud, and cone crop would have some regional adaptation. Transgressing a moment, progeny test families, involving the imported parents E182, and in particular E154 have shown similar outstanding vigour to vigorous local parents E29 and E40. This result is very significant. It underlines the value of importing pollen from the plus trees, through the immediate combination with local selections, and illustrates high g.c.a.s. for vigour, for both introduced male parents. Furthermore, of the 39 parents introduced as wild seed from the plus tree, 20 introductions have shown that they are equal, or superior to parent E182 in vigour (E154 is top). Moreover many of these high vigour parents from Portugal produce progeny with a high proportion of very straight trees.

* trial XS 7(1966) at Gnangara F7 pertaining to this data will be inspected during the field trip. Appendix 12.

The search in Portugal has introduced high quality, genetic material into the local programme. The primary objective, relating to vegetative material was extremely successful, and this is a tribute to the diligence of the technical staff at Wanneroo. Collection difficulties in Portugal allowed only pollen from two parents to be introduced. As mentioned in the previous paragraph, results of these crossings have given confidence to the quality of seed that will be available from the second seed orchard.

The second seed orchard is 11 hectares in area. Planting commenced in 1969, and was completed in 1972. This comprises 96 superior clones, of which 55 were selected in Portugal, 38 in Western Australia and 3 in South Australia. The first appreciable cone collection was made in 1975.

Detail on establishment, and management is listed in Appendix 8.

Progeny test

A register of all progeny tests is listed. Seventy six statistically designed tests, covering an area of 124 hectares are indexed. The first tests were planted in 1965, and they have continued annually. Tests aim at the evaluation of the 124 parents, local and imported, registered in the breeding population. Five mating designs have been used in the testing programme.

See Summary of Western Australian P.pinaster progeny tests.

The first of these, and perhaps the simplest, involved the collection of open pollinated seed from the plus tree. This technique was used to advantage for the rapid evaluation of parent trees selected in Portugal. Six tests, planted in 1965 and 1966 had this mating design. It is interesting to note that no local selection was tested by this means.

Polycross seed, collected from seed orchard for individual clones, is the major test design used for the Pinus radiata programme in Western Australia, and indeed, throughout Australia. However, apart from 3 tests planted in 1973 to investigate G.E.I. effects, it has not been used in the home P. pinaster programme, but it does form the basis of our co-operative projects. Polycross seed has been included with vegetative material, with introductions of the superior parents to South Africa and New Zealand.

The remaining 67 progeny tests are based on the controlled pollination of the elite parents. Most of the crossings were made at the clonal arboreta by the three man breeding team. Usually fertile cones developed from greater than 60 per cent of the isolations.

Initially, haphazard crossings were used, but this progressed to the use of the N.C. II system based on 3 to 5 tester pollens. All parents in the programme have been crossed with 3 or more tester pollens.

Tests in 1975 and 1976 are based on single pair matings of all parents in the breeding population. These tests of unrelated families were planted out as seedling seed orchards, area of 20 hectares, using a non-contiguous planting design.

Current testing continues at a low level, using partial diallel breeding units of 10 clones. A complete unit is constructed each year. AT this stage, two of four proposed units have been completed.

Summary of Western Australian Pinus pinaster progeny tests.

rial dent.	Year Planted	Location	Number of Par.	Fam.	Block	Tree Plot	Plot Design	Mating
YS 1	1965	Gnangara F7	7	7	7	9	Rec. LS	4
YS 2	1965	Gnangara F7	6	7	7	6	Rec. LS	4
YS 3	1966	Gnangara F7	12	13	20	10	Line RB	4
YS 4	1966	Gnangara F7	13	16	10	6	Rec. RB	4
YS 5	1966	Mundaring	11	13	20	5	Line RB	4
YS 6	1966	Yanchep A46	8	8	8	8	Rec. LS	4
YS 7	1966	Yanchep A46	12	12	10	3	Line RB	4
YS 8	1967	Gnangara F100	12	20	10	10	Line RB	4
YS 9	1967	Yanchep B37	9	20	10	10	Line RB	4
YS 10	1967	Mundaring	8	20	20	5	Line RB	4
YS 11A	1968	Gnangara G100	11	30	8	10	Line RB	4,5
YS 11B	1968	Gnangara G100	11	30	8	5	Line RB	4,5
YS 12	1968	Gnangara G100	13	21	10	10	Line RB	4
YS 13A	1968	Yanchep B60	11	30	8	10	Line RB	4,5
YS 13B	1968	Yanchep B60	11	30	8	5	Line RB	4,5
YS 14	1968	Manjimup	9	20	8	10	Line RB	4
YS 15	1968	Collie	9	10	5	20	Line RB	4
YS 16	1968	Mundaring	11	16	10	5	Line RB	4
YS 17	1968	Hamel	12	24	7	3	Line RB	4
YS 18	1969	Gnangara G100	17	32	12	5	Line RB	4,5
YS 19	1969	Yanchep B60	17	32	12	5	Line RB	4,5
YS 20	1969	Gnangara G100	19	32	8	5	Line RB	4,5
YS 21	1969	Yanchep B60	19	32	8	5	Line RB	4,5
YS 22	1969	Gnangara G100	19	27	10	16	Rec. RB	7,4
YS 23	1969	Manjimup	12	32	12	5	Line RB	4,5
YS 24	1969	Manjimup	18	32	8	5	Line RB	4,5
YS 25	1969	Hamel	14	30	10	3	Line RB	4,5
YS 26	1969	Hamel	17	26	10	3	Line RB	4,5
YS 28	1970	Gnangara G100	16	34	8	10	Line RB	4,5
YS 29	1970	Yanchep B61	16	34	8	10	Line RB	4,5
YS 30	1970	Gnangara G100	21	34	6	10	Line RB	4,5
YS 31	1970	Yanchep B61	21	34	6	10	Line RB	4,5
YS 32A	1970	Gnangara G100	20	30	9	5	Line RB	4
YS 32B	1970	Yanchep G61	20	30	3	5	Line RB	7,4
YS 33	1970	Gnangara G101	12	16	6	16	Rec. RB	7,4
YS 34	1970	Hamel	21	34	10	3	Line RB	4
YS 35	1971	Gnangara G100	8	15	4x6	6	Single RB	5
YS 36	1971	Gnangara J1	8	15	3x6	6	Single RB	5
YS 37	1971	Gnangara G100	18	25	20	5	Line RB	4
YS 38	1971	Yanchep B61	15	17	20	5	Line RB	4
YS 39A	1972	Gnangara G100	10	15	5	5	Line RB	4
YS 39B	1972	Pinjar C2	10	15	5	5	Line RB	5
YS 40	1972	Gnangara J1	28	34	10	5	Line RB	4,5
YS 41	1972	Pinjar C2	23	34	10	5	Line RB	4,5
YS 42	1972	Gnangara G100	28	30	10	5	Line RB	4
YS 43	1972	Pinjar C2	28	30	10	5	Line RB	4
YS 44	1972	Gnangara JI	30	30	10	5	Line RB	4

Summary of Western Australian Pinus pinaster progeny tests continued

Trial Ident.	Year Planted	Location	Number of Par.	Fam.	Block	Tree Plot	Plot Design	Matin
YS 45	1973	Gnangara J1	40	48	10	5	Line RB	4,5
YS 46	1973	Yanchep C23	41	48	10	5	Line RB	4,5
YS 47	1973	Gnangara G100	42	48	10	5	Line RB	4,5
YS 48	1973	Gnangara J1	24	24	10	5	Line RB	4
YS 49	1974	Gnangara J1	18	80	10	5	Line RB	7
YS 50	1974	Jarrah A3	18	80	10	5	Line RB	7
YS 51	1974	Gnangara G100	14	30	10	5	Line RB	9
YS 52	1974	Yanchep C23	13	28	10	5	Line RB	9
YS 53	1974	Jarrah A3	13	28	10	5	Line RB	9
YS 54	1975	Gnangara J1	91	81	50	1	Latin	6,4
YS 55	1975	Gnangara J1	87	81	21	1	RB	6,4
YS 56	1975	Gnangara G100	20	63	6	5	Line RB	5
YS 57	1976	Gnangara J1	107	60	12	4	Rec. RB	6
YS 58	1976	Gnangara G100	94	54	12	4	Rec. RB	6
YS 59	1976	Gnangara J1	80	45	12	4	Rec. RB	6
YS 60	1976	Gnangara J1	79	45	12	4	Rec. RB	6
YS 61	1976	Jarrah A3	64	35	8	4	Line RB	6
XS 1	1965	Gnangara F7	5	5	5	48	Rec. LS	1
XS 2	1965	Gnangara F7	5	5	5	48	Rec. LS	1
XS 3	1965	Gnangara F7	5	5	5	48	Rec. LS	1
XS 4	1965	Gnangara F7	5	5	5	48	Rec. LS	1
XS 5	1965	Gnangara F7	5	5	5	48	Rec. LS	1
XS 6	1965	Gnangara F7	5	5	5	48	Rec. LS	1
XS 7	1966	Gnangara F7	40	40	12	40	Line RB	1
XS 8	1966	Mundaring	20	20	10	10	Line RB	1
XS 13	1973	Gnangara J1	20	20	10	5	Line RB	2
XS 14	1973	Yanchep C23	20	20	12	5	Line RB	2
XS 15	1973	Gnangara G100	20	20	10	5	Line RB	2

Mating design.

1. open pollinated by wind on ortet
2. open pollinated (polycross) from seed orchard
3. pollin mix (polycross), usually with about 10 selected pollens
4. haphazard, miscellaneous crosses
5. tester, usually 4 pollen parents
6. single pairs, without repetition of parents
7. other controlled pollinations, in most cases diallel, some selfs
8. clonal self-rooted cuttings

Standard features of the W.A. progeny testing programme are -

a) inclusion of the minimum of the same three standard crosses in trials,

b) planting of a routine unimproved seed source from Portugal, and recently an orchard seed source,

c) use of tubed planting stock, and a very thorough site preparation in the field quaranteeing a complete survival - very important in the use of single tree plots.

d) duplication of tests on the two main planting sites for this species - at Gnangara on shallow, to water table grey sands, and at Yanchep on deep yellow sands,

e) accurate field checking and methodical record taking.

All forms of statistical design have been employed in the progeny testing programme. In early trials, Latin Square designs were commonly used, but most of the recent trials are of randomized block design. Various plot shapes and sizes have been used. Early plots used either a square plot of 9 or 16 trees, and use was also made of rectangular plots. Line plots are the most common in the programme. First of all 10 tree line plots were used, but this was reduced to 5 trees per line after the 1968 study. Single tree plots were used in 1971, in a family-fertilizer-interaction study, and in 1975 using the single pair matings to form a seedling seed orchard. The single tree plot is only possible where total survival, and establishment can be guaranteed. Our trials generally have survival rates surpassing 99 per cent.

The principal objectives of the family planting programme have been met. These are -

1) estimation of general combining ability, and determination of the breeding value of parents,

2) demonstration of genetic gains,

3) estimation of genetic, environment and interaction variances and covariances,

4) provision of pedigree material of known select parentage for future breeding programmes.

Genotype - environment - interaction

The effects of G.E.I on breeding strategy has been recognised for Pinus radiata. It is equally important in P. pinaster. Reference has been made to the clonal material introductions from Portugal into W.A., and subsequently to other Australian States, New Zealand and South Africa. What evidence is there of G.E.I?

Butcher (1974) has reported that families, and parents are stable and highly adaptable to the W.A. environment. Families were based on local parents, and established at six planting

15 *Pinus pinaster* parents planted at Gnangara and Mundaring

Summary of data at age 7.5 years

Clone	Straightness				Height at 3.5 yr				Height at 7.5 yr				Diameter				Basal Area				Branching			
	Rank	Gnangara	Rank	Mundaring	Rank	Gnangara	Rank	Mundaring	Rank	Gnangara	Rank	Mundaring	Rank	Gnangara	Rank	Mundaring	Rank	Gnangara	Rank	Mundaring	Rank	Gnangara	Rank	Mundaring
E104	13	-5	15	-22	10	-3	9	=	8	=	1	+3	7	+1	1	+6	8	+1	1	+13	8	-1	2	+46
E107	3	+5	7	=	14	-7	15	-9	12	-4	7	=	14	-6	14	-4	13	-11	15	- 9	4	+9	10	- 7
E110	7	+3	8	=	11	-3	16	-14	11	-3	12	-3	11	-4	10	-2	12	- 6	10	- 4	12	-10	4	+19
E115	4	+5	13	-5	7	+1	7	+2	5	+1	4	+2	12	-4	5	+2	11	- 5	6	+ 2	9	- 1	3	+46
E117	11	-3	6	+2	3	+6	2	+6	6	+1	5	+1	6	+2	4	+3	7	+ 2	4	+ 6	3	+13	12	-21
E118	10	+1	4	+5	9	-2	12	-3	13	-4	13	-3	13	-5	11	-2	14	-11	11	- 4	11	- 9	5	+19
E146	12	-3	5	+5	4	+4	5	+3	4	+2	8	=	2	+6	12	-2	2	+12	12	- 4	15	-13	11	-14
E152	5	+5	1	+12	1	+10	1	+7	2	+8	2	+3	3	+5	13	-2	3	+10	13	- 4	7	=	16	-40
E154	1	+7	9	=	2	+9	6	+3	1	+10	6	+1	1	+13	3	+4	1	+27	2	+10	10	- 6	7	+ 6
E158	6	+5	10	=	6	+2	4	+4	7	+1	10	-1	4	+3	7	=	4	+ 6	8	- 1	1	+16	13	-27
E162	8	+3	3	+7	5	+4	3	+5	3	+6	3	+3	5	+3	2	+5	5	+ 6	3	+ 9	6	+ 2	15	-34
E168	2	+7	2	+10	13	-6	11	-1	10	-2	14	-3	15	-6	16	-6	15	-12	16	-11	2	+16	6	+13
E172	9	+3	14	-12	15	-7	13	-3	15	-8	15	-3	10	-1	8	=	10	- 3	7	+ 1	14	-11	8	- 1
E173	15	-27	12	-2	16	-7	10	=	16	-8	11	-2	16	-8	15	-4	16	-16	14	- 8	13	-10	14	-27
E181	14	-9	11	=	12	-4	8	+2	9	=	9	=	8	+1	6	+2	9	=	5	+ 4	5	+ 5	9	- 1
Routine	16	-37	16	-32	8	-1	14	-5	14	-4	16	-4	9	+1	9	=	6	+ 3	9	- 1	16	-24	1	+52
Actual Mean	84%		82%		2.05m		2.97m		5.34m		8.07m		7.73cms		11.71 cms		$49 cm^2$		$110 cm^2$		62%		30%	

Ranking of families according to the percentage deviation from the mean.

sites, four of which will be seen on tour. The ratio of location family variance to family variance in this report was 0.09. However a ratio of 0.30 was measured on another trial testing 15 local families over four locations.

As most of the parents in the breeding population have been selected in Portugal, it is important to determine their behaviour in Western Australia. Table lists 15 parents, seed collected from parent trees in Portugal, and an unimproved Leirian seed source planted at Gnangara, on infertile grey sands, and at Mundaring on a loamy sand. Ratios of 0.17 and 0.25 were calculated for heights, and diameter growth respectively.

There are many trials in the local programme to evaluate G.E.I effects. W.A. families have also been planted at 4 locations in Victoria, the A.C.T. and in South Africa. An important finding is the very similar performance of families in Western Australia, and South Africa. This is important considering the active interchange of material, and current status of the species in both places.

The result of many trials in W.A. has shown that only the single breeding population is necessary for the optimum development of Pinus pinaster on the two major plantation types, viz shallow to water table, strongly leached grey sands, and deep weakly leached yellow sands.

Results of the Pinus pinaster improvement programme

The major requirement of the programme is to improve stem form, while at least maintaining the current level of vigour in the provenance. Selection standards have given most weight to favour trees in which the bole is straight, vertical, and with pronounced leader dominance. Only trees of dominant or co-dominant vigour were included in the final selection.

The family lines will be compared to the routine Leirian seed source used for operations planting. This gives an evaluation of the breeding population. The classification of individual parents and families will not be discussed here, but is looked at in various appendices relating to tour inspections of the progeny plots.

1. Straightness of the tree bole

The most pronounced weakness of the species is the inherent instability of the bole. It is subject to serious lean, butt sweep and bowing. Nodal swelling, heavy and irregular branching are also common important faults.

Assessment in the progeny trials of stem quality is not made until pine age of 8 years. The young pines have been low pruned to a height of 2 m, at age 5, so the main bole section of the tree can be easily evaluated. The main commercial component of the tree is the 6 metre pruned butt log, and any defects are obvious at this stage.

Tree form is evaluated on a subjective index of defects severity. Zero defect is one point and excessive defect, that would mean wastage of part of the log is given five points. The tree form is characterized by butt sweep, stem sweep and general straightness, and each of these factors is individually assessed on this 1-5 points system. Two trained observers are responsible for this classification.

Data in summaries is presented in two forms. The first is referred to as 'plus crop' stems, and are trees classified as either 1 or 2, i.e. are stems with zero, or negligible defect. The other form is the 'acceptable crop' tree, and includes the class 1, 2, and 3 stems. There is some slight defect, but all stems would meet the standards of the commercial final crop tree.

	pedigree	routine	improvement
number of trees assessed	16 240	767	
per cent 'acceptable crop' straight	78	55	+ 42%
per cent 'plus crop' straight	10	4	+150%

The above listing includes all progeny trial trees assessed for the straightness character at this time. The main comparison is made with the mean family performance and the unimproved Leirian seed source used in routine plantation establishment. All trees were raised as tubed nursery stock, and carefully hand planted in designed trials. It could be argued that these designed trials, with precise planting, may not give the same result under operational conditions as by the machine planting of smaller open-rooted nursery stock. A trial of this nature is currently being assessed. Seed was collected from the Joondalup orchard parents, raised open rooted and machine planted by operations people in large blocks, alternating with routine seed sources. Early results of these are -

	orchard	routine	improvement
number of trees assessed	3 848	2 978	
per cent 'acceptable crop' straight	64	42	+ 52%
per cent 'plus crop' straight	14	4	+250%

2. Vigour

A gain in individual volume production was not a particular objective of the programme. However, as there was a proviso that the candidate plus trees be at least co-dominant or dominant in the stand, there has been limited selection for this character.

First evaluation of progeny height growth is made during the fourth year. Any earlier measurement is meaningless. In the Western Australian test environment, Mediterranean climate and dry sandy soils, the *P. pinaster* seedling makes negligible above ground growth in the first three years. During this time, tree roots have proliferated through the total soil profile in search of soil moisture. The first real height increment is made in the fourth year. This early measurement has a high correlation with later measurements. This is illustrated in the following table for height growth of trial YS.1 (1965), the first of the W.A. progeny testing programme.

Family	Mean height at		
	4.5 yrs	9 yrs	11.5 yrs
E27 x E2	2.7 m	6.5 m	9.1 m
E21 x E5	2.8	6.7	9.0
E40 x E2	2.8	6.6	9.0
E21 x E2	2.7	6.4	8.9
E28 x E5	2.8	6.4	8.8
E16 x E2	2.5	6.3	8.8
Routine	2.2	5.2	7.2
mean family	2.7	6.5	9.0

Correlation coefficient for height at 4.5 and 9, and 4.5 and 11.5 is 0.87 and 0.80 respectively. Note the uniformity of the family lines, and the large difference to the routine. This trial will be inspected at Gnangara.

Considering all progeny trials, there has been a general increase in height growth of 15 per cent, above the routine plantation seed source. The variation between pedigree lines is also quite large. This can be seen in the appendices 2, 4, 9 and 12.

Ideally the next height measurement is scheduled during the nineth year. In this way, the family five year increment can be related to the five year height intercept parameter for Pinus pinaster. The relationship between height intercept and predominant height alters little with age, and any differences are fully expressed by the age of 10 years. Height intercept has been accepted as a suitable means of predicting height growth of P. pinaster, up to the age of 35 years.

The early tests did not quite meet this schedule. Impatience led to the measurement of these during the eighth growing season. Heights, and diameter were measured, and from this tree volumes were computed using the Gnangara regression equation.

Increases in volume production have ranged from 20 to 90 per cent, above the unimproved seed source. Trials that will be inspected during the tour are YS15 at Collie, gain of 20%; YS13 at Yanchep, up to 34% and the duplication trial at Gnangara YS11, up 50%; and trial YS1 at Gnangara, up 90%. Family data, and additional trial information is given in the appendices.

3. Branching

Pinus pinaster has a uninodal branching habit. In parental selections, emphasis is given to balanced, uniform crowns, while trees with heavy, and irregular branching patterns are avoided. The reduction in branching size is a valuable commercial trait, and is particularly important in the silvicultural regimes adopted for Pinus pinaster.

Branching character in progeny trials is assessed as branch thickness, and as branch angle. Both are rated on a 1-5 points system as before. Summary for all trials assessed to date is -

	pedigree	routine	improvement
number of trees assessed	12 410	447	
per cent of 'acceptable crop' branch T	74	44	+ 68%
per cent of 'plus crop' branch T	8	4	+100%

As branch thickness is strongly related to stem diameter, then it is feasible that the subjective branching classification has been affected by this. This was investigated at one trial, relating the subjective assessment to a measured ratio of branch/stem sectional area at two whorl positions. Correlation coefficient for this was 0.7.

Similarly, for classification of branch angle, all branch angles at two whorl positions were measured in the same trial and related to the subjective classification. Here the correlation coefficient of 0.6 was also high.

The relationship to actual measurement is shown below:-

Visual	Branch Thickness		Branch Angle	
Assessment	branch/stem	sd.	angle	sd.
1	*	*	*	*
2	0.29	.08	62^{o}	8
3	0.41	.12	56^{o}	7
4	0.53	.13	50^{o}	6
5	0.63	.18	*	*

* insufficient observations

Seed procurement for the P. pinaster afforestation programme

The dominance of the Leirian strain was established in 1940. Since that date, all plantings of P. pinaster have been of this provenance. Seed has been purchased from Portugal.

The first operational planting of orchard stock P. pinaster was in 1971. The total programme in 1972 was planted with Joondalup orchard stock, and this has continued. In 1977 seedlings from the rogued orchard will be used for the first time.

Mullaloo orchard stock will also be contributing to the programme in 1977. Sufficient seed will be available after 1979 to meet the entire programme from this superior orchard source.

The department's P. pinaster programme is based on the establishment of 1,000 hectares of plantation per annum, at a stocking of 1,140 s.p. ha. To meet this, annual collection of 105 kgms clean seed, from approximately 18,000 cones, is required.

Implication to forest management practice.

Quality sawlog production is the prime objective of the departmental softwood programme. Cultural practices have been modified accordingly because of the more favourable economics and hygiene.

On the P. pinaster plantation sites, moisture availability is the chief factor limiting productivity. It is desirable to ensure that the density of stands does not exceed the potential of the site to supply moisture. In dense stands, moisture deficits result in the deflection of growth potential from final crop trees to trees that will ultimately be removed as small, low value chip logs.

The second, equally important land use objective from the P. pinaster plantation area is the production of potable water, from the unconfined ground water aquifer. In order to reconcile pine silviculture with catchment management, it is necessary to maintain pine stands at a relatively low density to ensure adequate replenishment of ground water. The two forms of land use are compatible, as both require an open stand development.

These objectives were recognized in 1970, when the so called 'prescription 70' regime was implemented. Basically, this was a thinning to waste at age 6 years, reducing the 2240 s.p. ha planted to a commercial crop of 740 s.p.ha, and this was further reduced to a final crop stocking of 100 s.p.ha stepwise, by age of 25 years.

When orchard seed was available, and progeny trials had demonstrated a pronounced improvement in stem form of the pedigree stock, it was possible to reduce the number of trees planted, and to make the thinning to waste no longer necessary. This was feasible as the basis for final crop selection had been improved. This is illustrated by -

Old, prescription 70 regime.

unimproved seed source imported from portugal.
plant at 2240 s.p.ha.

expected number of acceptable trees	-	1234
expected number of plus crop trees	-	90
required number of final crop trees	-	100

New regime, after 1971.

improved seed source from Joondalup orchard
plant at 1140 s.p.ha.

expected number of acceptable trees	-	890
expected number of plus crop trees	-	115
required number of final crop trees	-	100

It is possible, using the Mullaloo seed source that stocking could be further reduced at planting to the equivalent of 700-800 s.p.ha. This is desirable to limit pruning and thinning costs, and to restrict the amount of chip size material production to an over supplied market.

The other bonus of the improvement programme has been the very significant increase in growth of pedigree stock. This increase has varied according to the location of tests. It does appear that on the coastal plain, tree volume production has been increased between 33 and 66 per cent.

A new regime for orchard P. pinaster has been formulated. This takes account of the improved form, by wider spacing, and the improved growth rates, by the adoption of a shorter rotation length.

SECTION 4 Review of Pinus radiata tree improvement.

Departmental research has programmes for the improvement of both P. pinaster and P. radiata in this State. Until recently, the major activity has been within the Pinus pinaster programme, not because improvement in this direction offers the maximum gain but because P. pinaster seemed to have the greater operational problems. Staff have completed the initial development with P. pinaster, and more attention will now be directed to P. radiata.

Past activity in Western Australia

The traditional approach to orchard establishment has been to select the best tree in form and vigour from every 400-800 hectares of mature plantation. These are used for orchard establishment.

In 1962 - 1964, all P. radiata plantations over 20 years of age were cruised for plus trees. The limited area available only provided 20 trees considered suitable. To provide a better selection clones of the 10 best plus trees selected in the A.C.T., N.S.W., South Australia, Victoria and several from New Zealand were imported. Certain of these have been used together with the local selections to commence orchard establishment.

A 4.5 hectare seed orchard using 40 clones was established at Chandler's Farm, in the Gleneagle division, in 1964 and 1965. The proportion of Western Australian ortets, and ramets in this orchard is 20 per cent. It was established to provide some improved seed of P. radiata as soon as possible. The actual site was selected because of its immediate availability, and relatively easy access to the Wanneroo breeding centre.

Generally, the orchard site is considered satisfactory from the viewpoints of low pollen contamination, and high soil fertility. It is considered unsatisfactory from the viewpoints or potential for extension and access to management. Maintenance of the orchard has been difficult, and unsatisfactory due to its relative isolation.

Seed production has been very limited at this orchard. A production of 5.8 kgms clean seed per hectare of orchard area, resulted at age 7, and a figure of 3.1 kgms/hectare was realized at age 9 years. This is well below the Australian average figure of 20 kgms/ha/annum after 10 years.

Delayed graft incompatability has not been a real problem at this orchard. At age 7, this was assessed at 4 per cent of the total plantings, and has increased to 9 per cent at age 11 years. It does not occur at random but appears to be restricted to certain clones. In fact, half of the total losses are found in three clones. This is repeating in the younger Manjimup orchard.

A second seed orchard was commenced in 1969, at West Manjimup. The main reason for selecting this southern location was the observation of increasing flowering intensity in the southern plantations. This was verified in December 1976 by the production of 16 kgms clean seed/hectare from the 1969, and 1970 planted areas. Total orchard area of 15 hectares was completed with the planting of graft stock in 1972.

Appendix 6 contains notes on the Manjimup seed orchard. This will be inspected during the tour.

Progeny testing

In contrast to the very extensive controlled pollination programme for P. pinaster, very few have been manipulated for P. radiata. The few tests that have been planted are, in the main, based on polycross seed collected from seed orchard.

The first tests, planted in 1969 and 1971 used polycross seed with A.C.T., South Australian and Victorian parentage. Testing at this stage was to rank parents for g.c.a. to achieve some information on genetic gains, and an assessment of families grown in the W.A. environment. As parents are from external selection, this series will provide valuable information on genotype-environment-interaction.

The International gene pool project was planted at two sites in 1972. For this half sib or full sib seed from P. radiata plus material, was provided to a central pool from New Zealand, Tasmania, South Australia, Victoria, N.S.W., A.C.T., Queensland, Western Australia, South Africa, Kenya, France and California. Each seed lot was divided into thirteen equal lots, and an equal quota provided to each organization. From seed supplied, it will be possible to test the genotype of 319 separate sources of P. radiata plus trees (Monterey strain) under Western Australian plantation conditions. A secondary objective of this was the establishment of gene sources of P. radiata provenances from Cedros, Guadalupe, and Cambria for study in Western Australia. This provenance trial has a non-statistical design, and was planted separate from the major trial. It is located at the Bussells, and Asplins arboreta.

Local selections were included in comprehensive progeny tests for the first time in 1974. The eleven W.A. clones used in the Gleneagle orchard were collected as polycross seed for this series. Three trials were planted on major plantation site types, Donnybrook sunklands, Blackwood Valley, and yellow sands at Yanchep.

Progeny tests in 1976 were planted at the Donnybrook sunklands using half sib, and full sib seed supplied by the N.S.W. Forestry Commission. Objectives of these tests are to evaluate the N.S.W. clones in the sunkland environment, and the identification of a breeding population.

Seed Procurement

Seed requirements for plantation establishment of *P. radiata* until 1968 were obtained solely by uncontrolled collection in South Australia and New Zealand. This was undesirable both as regards the quality of the future forests, and the reliability of supply.

Seed orchard had been established at Gleneagle and the second orchard at Manjimup was about to be planted. It would be a period of 8 or 9 years before this source could make any significant contributions to the local requirement.

In the interim period, seed was available from specially managed seed production areas. The first of these was established in an old stand of exceptionally formed trees in Grimwade plantation. This 40 ha stand was thinned to 125 stems per hectare, and treated with P and N fertilizer. Cone collection is by felling of seed trees. A single seed tree on the average has produced 80 cones, yielded 0.17 kgms of clean seed, and sufficient seedlings to establish 3.5 hectares of plantation at 3.5 x 2.5 m spacing.

The Grimwade seed stand will be inspected on the first day of the tour. Notes on this are given in Appendix 5.

Supplementary to the Grimwade seed stand, seed has been collected from second and third thinnings in the better quality stands at Grimwade and Mungalup. In 1974, collection was mainly from this source. Such collections have extended the life of the seed production area.

More recently, young seed production stands have been developed in SN1899 stands at McLarty, Myalup, Grimwade, Mungalup and Nannup. This strain has demonstrated exceptional form, branching habit and vigour on this range of W.A. sites, and this makes it an excellent proposition for the future planting of the Sunkland sites.

The low seed yields from the first orchard have been referred to. Consequently, until this time orchard seed has made little contribution to the planting programme. Fortunately, good seed yields are resulting from the second orchard. It is expected that the radiata programme of 4000 hectares per annum can be met wholly by orchard seed, in 1980.

It will be of interest to note that this department has established trials in 1973, for both the *P. radiata* and *P. pinaster* species, to evaluate the potential of improved seed. The radiata trial was planted on a fertile loam pasture site at Kirup, a bushland site at Grimwade and on poor yellow sands at Yanchep. Seed sources in this study are a) orchard, from Gleneagle, b) stand production, from the Grimwade seed area, c) crop tree SN 1899, from Collie; and d) a bulk collection from Collie plantations. This trial will provide valuable information on the relative performance of genetically improved seed on this range of sites.

Tree improvement in the Donnybrook Sunklands

The September 1975 'Statement of Intent - Afforestation with pines in the Donnybrook Sunklands' summarized the project as 'envisaging the conversion of some 60,000 hectares of degraded, dieback-infected native forest into pine plantations over a period of 30 years. The additional softwood area is required to provide the resource base for current industrial developments and to ensure that the major proportion of the State's timber requirement will be met from local sources by 2000. The area selected is scenically unattractive,has few special biological features, or other major attractions, and is the main additional area available for large scale planting. The greater part of the area, approximately 80 per cent, will be retained as natural forest and managed with multiple-use objectives.' Further information on this is contained in Forest Focus No. 16.

The proposed programme will take up to 30 years to complete, and the main species to be planted will be P. radiata. Pinus pinaster will be planted on at least 20 per cent of the area.

A limitation to the planting of Pinus radiata on the sunklands is the lack of a proven genetic seed source adapted to this environment. No large areas of P. radiata have been grown in Western Australia on similar sites. This has made the task of providing an improved seed source even more difficult. As there are no plantations from which to make the selection of adapted trees, it has been necessary to establish a base population from which adapted selections can be made.

There are several ways of achieving this. The method we have adopted is to establish seed production populations by the close planting, and early heavy thinning of stock derived from Australian, New Zealand and South African seed orchards, and the concurrent establishment of a breeding population by the planting of pedigree material. Granted, this does narrow the range by excluding the diverse genetic make-ups from wild unimproved populations, and that this is confounded by the uncertainty of genotype-environment-interaction effects. Ideally, an approach similar to the International gene pool project is required, but this is not forthcoming. The development of seedling seed stands with wide genetic base approach is inexpensive, easy to apply and can be put into effect immediately.

Progress so far has been the 1974 planting of progeny trials of P. radiata and P. pinaster. The P. radiata trial is to evaluate the W.A. plut tree selections, and some of the important Australasian parents on the sunkland site. The P. pinaster test used 80 combinations of the parents included in the Joondalup orchard. This series will be invaluable in determining the suitability of pedigree P. pinaster on the sunklands, as well as providing a direct comparison with the adjacent improved P. radiata. The only other progeny tests are the 1976 tests to evaluate the N.S.W. parents.

Seed production populations will be established in 1977. This will be achieved by the planting of 10 hectare blocks of orchard P. radiata from the A.C.T., South Australia, Victoria, N.S.W., AFH Tasmania, New Zealand, South Africa and the two local seed orchards.

A breeding population is to be established concurrently. This is to be achieved by the planting of all available pedigree material on this site. Here we are dependent upon the donation of surplus stock from associated organizations. Seed, with both parents identified, is most desirable, but open pollinated seed with the single parent known is also useful for evaluating parents on this site.

Other activity has been towards broadening the genetic base of P. radiata selections in this State. Plantations at Pemberton, Grimwade and the Harvey coastal group were searched, and several trees were included in the programme. All of the W.A. plus tree selections, new and old, were grafted, and planted in a clone bank at Pinjar in 1976. This will enable crossings to be easily carried out by staff based at Wanneroo, and will give some guarantee to the provision of pedigree stock for sunkland planting.

SECTION 5 Study tour 6, itinerary detail.

List of participants

D. Destremau	France
M.H. Heybroek and wife,	Netherlands
S.L. Krugman	U.S.A.
C.A. Mohn	U.S.A.
S.T. Olatoye	Nigeria
R.E. Schoenike	U.S.A.
D.P. Siderides,	Greece
T.B. Butcher	Australia (Tour leader)

Forests Department of W.A. Officers

Dr. F.H. McKinnell	on	Day 2
Mr. P.C. Kimber	on	Day 3
Dr. S.R. Shea	on	Day 4
Dr. E.R. Hopkins	on	Day 5
J.J. Havel		"
A.C. van Noort		"
D. Meehan		"

SUNDAY, MARCH 27

Assemble in Perth. Overnight at Chateau Commodore

Day 1, MONDAY, MARCH 28.

Leave Perth at 0830.

Travel south through outer metropolitan suburbs, Kwinana industrial complex, Mandurah holiday resort, Tuart savannah woodland.

Stop 1. (120 km), Appendix 1, McLarty plantation, P. radiata and P. pinaster afforestation, development of SN 1899 seed stands, and classification of plus tree R44.

Stop 2. (145 km). Appendix 2, Hamel nursery and P. pinaster progeny trial YS.17.

continue travel south along margin of coastal plain through rural towns of Harvey and Brunswick. Tour leaves the coastal plain at Roelands, and climbs the Darling escarpment, and on to the plateau proper. Soils are lateritic, infertile and support the jarrah forest stands. Fertile soils have been developed on valley slopes, and have been used for pasture, and for exotic conifer plantation establishment.

Stop 3. (235 km), Appendix 3. Lunch stop, Mungalup plantation P. radiata thinning trials.

Stop 4. (280 km), Appendix 5, Grimwade plantation, seed production area, plus trees, second rotation experiment.

Travel west through Kirup, Donnybrook to Bunbury.

Overnight at Bunbury, Lighthouse Inn.

DAY 2, TUESDAY, MARCH 29.

Leave Bunbury at 0900.

Travel south along coastal plain, through Capel, extensive open cut mining of mineral sands will be noticed. Some of the earliest pine plantings by the department near Ludlow will also be seen.

Stop 1. (25 km) Ludlow. Tuart forest.

Stop 2. (55 km) Jarrahwood, Donnybrook Sunklands reafforestation project, land use, *P. radiata* and *P. pinaster* progeny trials.

Cut lunch.

Stop 3. (85 km) Mt. Folly plantation, *P. radiata* on Blackwood Valley, Agro Forestry.

Travel through Nannup-Balingup valley, land use, new plantings of *P. radiata*.

Travel through Balingup, Bridgetown to Manjimup.

Overnight at Manjimup, Ace motel.

DAY 3, MARCH 30

Leave Manjimup at 0900.

West Manjimup, Karri nursery, *P. radiata* seed orchard (Appendix 6).

Pine creek and Quartz roads, selection cut Karri (1964); clear cut Karri 1-5 and 10 year old regeneration; experimental area KM forest cut for sawlogs and woodchip, Karri seed trees remaining.

Coronation road, chip road and Tramway trail, 45 year old Karri regeneration.

Cut lunch at Big Brook arboretum.

Northcliffe road, Brockman National Park - very fine virgin Karri.

100 year forest

Karri provenance trial, Hayles location

Diamond chipmill

Overnight at Manjimup, Ace motel.

DAY 4, THURSDAY, MARCH 31.

Leave Manjimup at 0830.

Travel along S.W. Highway direct to Harvey.

Clarke Block, dieback infection in Northern Jarrah forest.

Nanga Brook, barbecue lunch.

Yarragil catchment, forest hydrological research programme.

Travel through healthy jarrah pole stands, thinning trials, replanting of dieback sites with other species.

Dwellingup Research Station.

Del Park, Alcoa's bauxite mining operation, replanting, rehabilitation, catchment studies.

Travel down from Darling Scarp, and through eastern suburbs to Perth.

Overnight at Perth Chateau Commodore.

DAY 5, FRIDAY APRIL 1.

Leave Perth at 0830.

Wanneroo Research Station, Nursery.

Lake Joondalup *P. pinaster* seed orchard (Appendix 7)

Mullaloo *P. pinaster* seed orchard (Appendix 8).

Yanchep, species comparison, *P. radiata*, *P. pinaster*, *P. brutia*

Wabling Hill, flora, land use, Management Priority Areas.

Hombrecht road, orchard and routine comparison, operations planting.

Yanchep, Clover road *P. pinaster* provenance and progeny tests (Appendix 9).

Yanchep 100 acre . Hydrological research (Appendix 10).

Jarrah's End. Lunch.

Pigeon road. P1975, P1976 establishment techniques, and P1977 preparation (Appendix 13).

Neaves Road clone bank.

Silver road, Pinus pinaster provenance trial (Appendix 11).

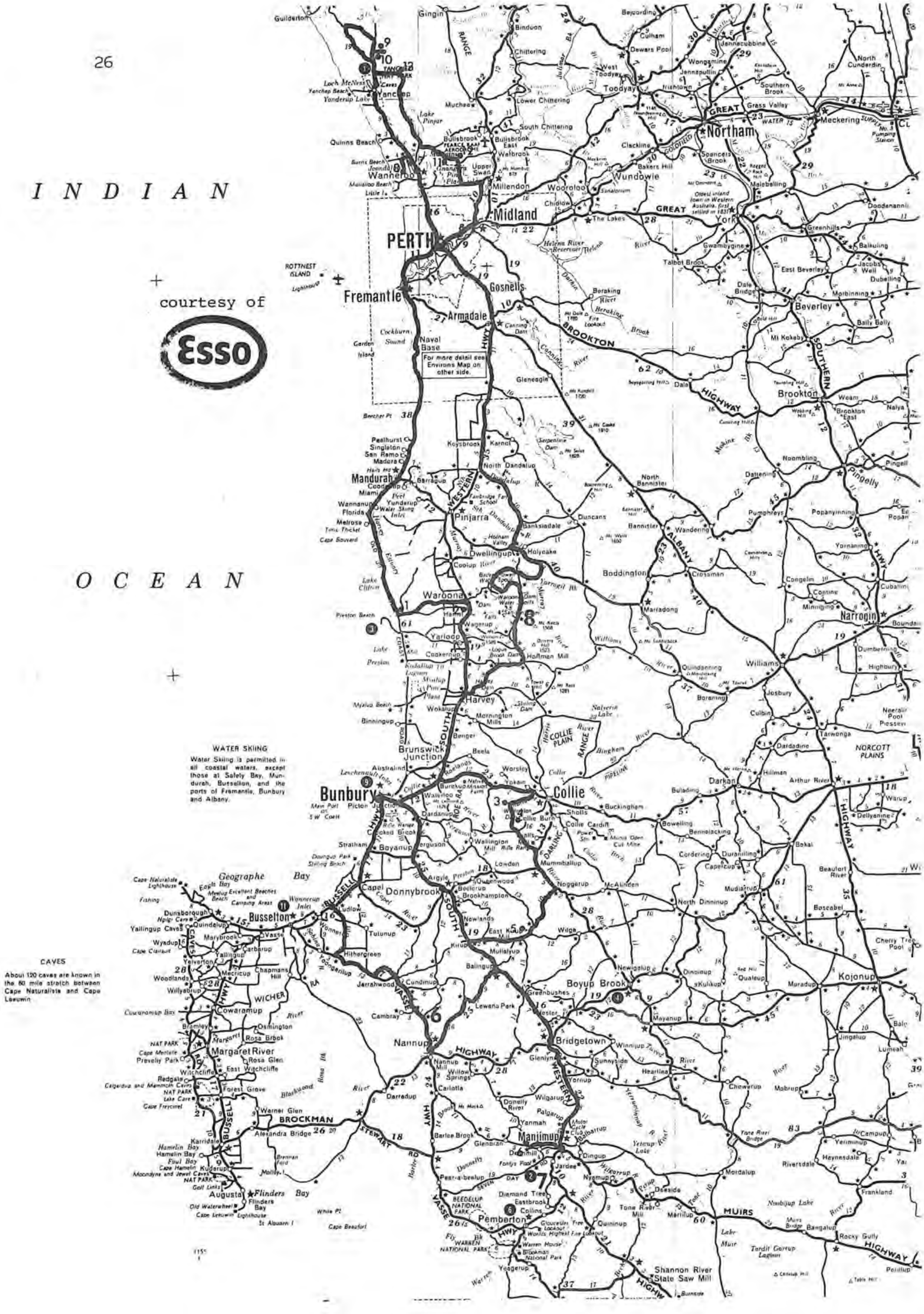
Gnangara Clover Block provenance and progeny trials (Appendix 12).

Gnangara production nursery.

South Lane Poole block, parkland stand of 35 year old Leirian *P. pinaster*.

Sandalfords vineyards, wine tasting.

Overnight at Chateau Commodore.


INDIAN
OCEAN
courtesy of
Esso
WATER SKIING
Water Skiing is permitted in all coastal waters, except those at Safety Bay, Mundurah, Busselton, and the ports of Fremantle, Bunbury and Albany.
CAVES
About 120 caves are known in the 60 mile stretch between Cape Naturaliste and Cape Leeuwin
For more detail see Environs Map on other side.
PERTH
Fremantle
Midland
Gosnells
Armadale
Rottnest Island
Naval Base
Northam
Toodyay
York
Beverley
Brookton
Pingelly
Narrogin
Mandurah
Pinjarra
Dwellingup
Waroona
Yarloop
Harvey
Brunswick Junction
Bunbury
Collie
Donnybrook
Busselton
Capel
Nannup
Boyup Brook
Bridgetown
Manjimup
Pemberton
Margaret River
Augusta
Cowaramup
Kojonup
Williams
Darkan
Boddington
Wandering
Geographe Bay
Flinders Bay
GREAT EASTERN HIGHWAY
ALBANY HWY
SOUTHERN HWY
SOUTH WESTERN HWY
BUSSELL HWY
BROCKMAN HWY
MUIRS HIGHWAY
Shannon River State Saw Mill

Ludlow Tuart Forest

Tuart (Eucalyptus gomphocephala) once occurred over a large area of Western Australia in a long narrow strip of land along the west coastal plain. The Ludlow forest was the best of the original forest and is now the only extensive and secure area of the species remaining. The total area of the Ludlow forest is about 2600 hectares.

Until recent years the forest supported a small sawmilling operation as the timber has rather unique properties for certain uses. Since this operation ceased in 1974, the objects of Management have been changed with the realization that the principal values of the forest were conservation of the gene source, preservation of scenic values in the Ludlow-Wonnerup area and fauna and flora conservation.

The forest is now largely overmature and is deficient in regeneration in many parts. The rather poor regeneration achieved between 1920 and 1970 was due to a combination of insect problems, a policy of exclusion of fire from the forest and failure to control competition after regeneration. There has been an excessive development of the understorey tree peppermint (Agonis flexuosa). Although it is an attractive tree it greatly inhibits young tuart trees.

The current (1976) Working Plan divides the forest into four working circles:

(a) amenity

(b) flora

(c) fauna

(d) production

The amenity working circle comprises those parts of the forest seen from the highway along which the bus passes, the flora priority area is the least disturbed part of the forest where much of the original flora is intact, the fauna working circle comprises a strip of forest adjoining the Vasse and Wonnerup estuaries and along the Abba River. The remainder is allocated to the production working circle. The Plan envisaged virtually no timber production from the forest for some 50 years, until the existing younger age classes become merchantable. The mixed pine/tuart forest (P. pinaster and some P. radiata) around the Ludlow settlement will be returned to pure tuart as soon as circumstances permit utilization of the pine.

Two methods of regeneration are used:

(a) Clear felling with seed trees, with dispersed coupes 0.5 - 2 ha in size. In practice very few tuart now need to be felled, only the understorey peppermint being bulldozed make the ashbeds essential for successful regeneration.

(b) Planting seedlings raised in peat pots.

An average of 25 ha per year is regenerated in the seed trees operation, mainly in the production and flora working circles, the actual area in each year depending on seeding cycles. The seed crop in 1977 is the best for many years.

Planting is used mainly in the amenity and fauna priority working circles where it is desired to avoid felling tuarts, either for preservation of scenic values or because the old trees have a value for fauna breeding. Around the Vasse and Wonnerup estuaries the old trees in the forest are a vital link in some bird breeding systems, e.g. the osprey and the whistling eagle.

The stop point in the forest is on the Bussell Highway in the amenity working circle. The large trees along the road are now unique in W.A., but there is pressure from some organisations to remove them in the interests of road safety. However, there is strong public opinion from the Busselton area in favour of retention of the trees.

The picnic sites along the road receive heavy use by travellers. In the winter of 1977, it is planned to lay out several walking trails leading out from the picnic area.

Section 6

Blackwood Valley Pine Plantations

The Forests Department commenced purchasing farmland for pine planting in the Blackwood River Valley (and its major tributaries) in 1954. The first plantings of P. radiata, the main species used here, were in 1956. Currently, some 1200 - 1300 hectares are planted each year or about half the total Departmental pine planting programme. So far about 15000 ha of land has been repurchased in the area.

Progress in land purchase has been rather slow in recent years, partly due to lack of finance and partly due to opposition to Government purchase of land. The opposition comes from local government bodies, who are concerned at the loss of rate revenue (a valid criticism), since the Crown does not pay rates, and from the local farming population generally. Farmers generally still see themselves in the developmental stage of "winning" farmland from forest and have a deep antagonism to the idea of returning farms to forest. They also blame the Forests Department for the decline in rural population as a result of its land purchase activities. This is a quite unrealistic criticism, as the period of land purchase coincided with a general trend toward amalgamation of farms into larger, more economic units.

Generally, the growth rate of P. radiata in the Blackwood Valley is very satisfactory, mean annual increment being 20 - 22m^3 per hectare per year. The area does have some problems, however. Stands planted between 1956 and 1964 at 2.4 x 2.4 m spacing encountered severe water deficiency problems if unthinned by age 12 - 14 years.

Severe losses due to drought in 1969 were a factor contributing to a change in silvicultural policy in 1970, when all stands were thinned to waste at age 5 and thence maintained at very low stocking until rotation age of 30 years with the objects of

1) avoiding drought losses,

2) minimising the production of small sized material for which there is an inadequate market,

3) growing sawlogs faster.

The silvicultural regime has subsequently been modified to eliminate the thinning to waste by planting at wider spacing, 3.5 x 2.5 m, but in other respects remains essentially the same. Relevant details are:

Year	Operation	Yield
0	Plant 1100/ha	-
5	Low prune all trees to 2.1 m	-
7	High prune crop trees to 5 m	-
12	Thin 1100/250 sph	$100m^3$/ha chipwood
18	Thin 250/125 sph	$80m^3$/ha sawlogs
		$40m^3$/ha chipwood
30	Clear fell	$350m^3$/ha sawlogs

As a consequence of wider initial spacing and the heavy thinning the grass persists under the pines much longer than before. In fact, it is expected there will always be an appreciable amount of grass under the pines. This has led to the introduction of sheep and cattle to graze under the pines on a regular basis. Integration of grazing and pine silviculture is now widely practised in the Valley, the State plantations being leased to farmers in the area.

The technique has many advantages. For the forester it means a reduction in fire hazard in the plantations, increased income from the lease fees and improved nutrient recycling in the ecosystem. For the farmer it means more grazing available without heavy capital expenditure and therefore increased income. The local government obtains rate revenue from the leaseholders and an otherwise wasted resource is used.

At present no utilisation is taking place in the Blackwood Valley plantations but from 1978 there is expected to be large scale thinning for chipwood and sawlogs.

Section 7

The Karri Forest

Occurrence

Karri (Eucalyptus diversicolor) is confined to the extreme southwest corner of Western Australia where its distribution is controlled primarily by rainfall and secondarily by soil type. The species occurs entirely within the 1000 mm isohyet and is confined to areas where the rainfall of the driest month exceeds 16 mm.

It is only found on red earths and on red and yellow podsolic soils. On other types of soil karri is replaced by jarrah (E. marginata).

Karri occurs as pure stands only on red earth (Krasnosem) soils. It grows in mixture with marri (E. calophylla) on podsolic soils.

Harvesting and Regeneration

Sawmill operations using karri started in the period 1913-1916. The silvicultural system practised was clear felling with the retention of a few trees for seed. These were subsequently removed after shedding their seed following the regeneration burn.

In the early 1940's the system was changed to group selection which persisted for almost 20 years. This was eventually abandoned in favour of a return to the clear felling system retaining seed trees. The group selection system had the following shortcomings.

a) The intense slash burn regarded as necessary for successful regeneration invariably damaged some of the retained growing stock.

b) Retained growing stock was subject to dieback in the crown, irrespective of fire damage.

c) The patches of regeneration, scattered over wide areas, were difficult to protect from wildfires.

d) Rates of growth around the edges of the groups of regeneration were retarded by the adjacent old growth trees.

Planting is becoming increasingly important as a regeneration measure. With planting there is no need to hold felled coupes until the seed trees come into bearing (Karri has seed once in every 4 years). Fallen coupes, before the regeneration burn, present a severe fire hazard and having to hold them unburnt for up to 4 years creates an unacceptably hazardous situation.

The present regeneration system is fully described in "Regeneration in the Karri Forest Community" by White and Underwood. (You have been given a copy of this publication).

Other Management Practices

The forest floor is burnt under prescription on a 6 to 8 year cycle as a fuel reduction measure. This lessens the intensity of wild fire when they occur.

The burning regime maintains a legume-rich shrub layer which in turn provides an important input of nitrogen to the forest system. The nitrogen fixing properties of these shrubs are being investigated.

Thinning in karri regrowth stands has not been carried out because of the lack of a market for small trees. With the advent of a woodchipping industry just over a year ago, a market now exists and it is planned to thin regrowth stands at around age 35.

Tour Notes

Stop 1

Karri nursery. Karri planting stock is grown open rooted in beds and handled in a manner almost identical to pines. Seed is pelletted (to increase its size) and sown in October/November. The seedlings are lifted the following May/June and thus spend 7 to 8 months in the nursery.

The main problem in the nursery is to control the rapid growth of the seedlings. This is achieved by a rigorous root pruning regime and by minimizing watering. The seed cannot be sown later than November because the very high temperatures in later months induce dormancy in the seed. The present nursery stock amounts to 0.9 million plants.

Stop 2

Group selection management of Karri. Note the dieback in the crowns of large trees retained for growing stock.

Stop 3

Forest regenerated by clear felling leaving seed trees. A few seed trees remain to be removed from the one year old area. The rapid growth of karri can be gauged from the seven year old regeneration.

Stop 4

Ten year old even-aged regeneration. Note the clumped distribution of karri saplings resulting from natural seeding, and the extremely high density of saplings. Self thinning has begun to take place and the number of karri stems will drop rapidly over the next few years.

Stop 5

45 year old even-aged karri. Thinning will be started in this stand within the next five years.

Stop 6

Brockman National Park. A small area (about 100 ha) of virgin karri forest. The large size of mature karri is well demonstrated here. Notice also the dense shrub layer composed mainly of legumes. The shrub layer is dominated by legumes between the second and tenth year of the succession following prescribed burning. Hence the burning cycle of 6 to 8 years ensures the continuing dominance of legumes which provide an important input of nitrogen to the ecosystem.

Stop 7

One hundred year old regrowth forest. The interesting history of this area can be read from the notice board at the stopping place.

Stop 8

Karri seed orchard - initial development.
This is one of three trials established in autumn 1971 to determine whether there was any large-scale variability existing within and between karri provenances, both within and outside the main karri range. It also will serve as a source of high quality karri seed in future years.

The main karri range can be taken as representing those karri stands that occur in the drainage systems of the following rivers; Warren, Donnelly, Gardner, Deep, Shannon, Frankland and the Walpole. Several outliers do occur on coastal limestone sites, as well as in isolated locations with a sustained high rainfall east of the marri-karri range. Generally though, the species lacks the altitudinal and/or latitudinal variation that is generally required by other eucalypt species to impart broadscale provenance variation.

A measurement performed at age 5½ years indicates that as yet intra-family variation is still far greater than inter-family variation in the majority of cases. Two exceptions to this were families from the Warren Valley when compared with the eastern outlier Mt. Many Peaks and the western outlier at Yallingup. Both of these coastal outliers exhibited extremely poor growth when compared with the superior families from the main range, although their survival rates were quite good. These results were generally replicated in the southern trial which is situated nearer the area generally accepted as producing superior karri stands.

At present this trial is yielding useful information for the initiation of another smaller provenance trial encompassing only the two extremes and the central karri range. It has also facilitated the selection of families for a proposed seed orchard. This is designed to allow for clear felling of blocks for purpose of seed collection.

SECTION 8

Jarrah Forest Tour Notes

0830 Depart Manjimup and arrive at Harvey Divisional Headquarters.

1100 Morning tea at Gumnut Lodge and introduction to Dr. S.R. Shea, Officer in Charge, Dwellingup Research Station who will give a brief outline of the day's programme.

1130 Depart Gumnut Lodge and proceed through Harvey Weir plantation, 8 km along Clarke Road to Nanga Road and turn at Hoffman millsite. Proceed north via Nanga Road and Willowdale Road to Willowdale. Debus and briefly inspect arboretum of Eastern Australian Eucalypts.

1145 Depart via River Road to Nanga Road then move north to corner of Waroona Road. Proceed south to southern corner of location 1380 to compare performance of Eastern Australian species on dieback infected upland laterite soils.

1230 Proceed north via Stawell Road and inspect upland Jarrah forest devastated by Jarrah dieback fungus (*Phytophthora cinnamomi*). Continue via Stawell Road, Nanga Road and finally Park Road to Baden Powell Waterspout picnic area for barbecue luncheon. This site is on the Murray River within the Murray Valley *Pinus radiata* plantation.

After lunch Dr. Shea will review the impact of Jarrah dieback on the northern Jarrah forest and current research priorities. Forest Recreation will be introduced with specific reference to the Murray Valley.

1315 The party will then proceed via Park Road to River Road and continue east along Yarragil Formation. The bus will stop briefly at the P.W.D. gauging weir. At this time the Forest Department's hydrological research programme in the Yarragil catchment will be outlined. This will include discussion of current projects concerned with increasing water yield from forested catchments.

1415 The party will proceed east along Yarragil Formation then north along Murray Road. The party will view healthy Jarrah forest in this section. The bus will turn right on the Boddington Road and view thinned Jarrah pole stands. There will also be the opportunity to see the results of prescribed burning in a healthy Jarrah stand and to inspect a portion of forest which has not been burnt for over 40 years.

1500 Party moves to Dwellingup Research Station for afternoon tea.

1545 Depart from Dwellingup Research Station to Del Park minesite (8 km north of Dwellingup) and inspect mining rehabilitation procedures. A range of trials have been established over the past 5 years for evaluation. This area also contains an experimental catchment used to monitor water and sediment yield.

From the mining area it is possible to see the South Dandalup Dam which is one of many catchments used for Perth's water supply.

1645 Depart from Del Park and travel to Perth.

SECTION 9

Appendix 1 McLarty Plantation Compartment 14. P. 1957.

This is the first scheduled stop of the Tour. Purpose of this stop is an introduction to the department's softwood afforestation programme and more specifically to look at a Pinus radiata plus tree, and a stand managed for purposes of seed production.

The Harvey coastal plantations cover an area of 3000 hectares. Plantings first commenced in 1926, close to the Myalup settlement, and consisted entirely of Pinus pinaster. In 1930, large plots of Pinus halipensis, P. radiata, P. coulteri and Syncarpia hillii were established. Planting resumed in the area in 1950, using P. pinaster. P. radiata is planted on the better soil types in the area, on the dark yellow sands, while the more leached sands are planted to P. pinaster. 2150 ha are planted to P. pinaster and 850 ha to P. radiata.

The seed source of this particular compartment is of interest. SN 1899 seed was received from Nelson in New Zealand, and was collected from an open stand of 38 year old, exceptionally formed parent trees. Seedlings were planted here, at Mungalup (next stop), Grimwade, Nannup and Mundaring. This has given rise to stands of exceptional vigour, form and fine branching habit, and the performance is consistently good on all sites.

SN 1899 areas will be managed for seed production. Initially, areas will be thinned to 4 - 500 s.p.ha., and then be fertilized with P & N fertilizer. Stands would then be frequently, and lightly thinned for cone collection, and possibly refertilized every 4 years to promote good crown development, and hopefully, good cone production.

Plus tree

In selection, most emphasis is placed on tree form, and then leader dominance, tree vigour, branching and crown character. Apparently superior trees are marked in the first cruise, and on second inspection are selected as candidate plus trees. External characteristics of the tree are then assessed, and classified according to the standards adopted by the working group on Forest Genetics.

The relative development of the tree characteristics; a) trunk straightness, b) diameter, c) height, d) volume, e) branch types (1 is uninodal, 2 binodal, 3 multinodal), f) branch thickness, g) branch angle, and h) persistent trunk cones; are recorded in the following way.

The plus tree is compared with 9 adjacent final crop trees (Selected at about 250 trees per hectare) occupying similar site conditions, and the characteristic is rated as :-

1 = superior (better than 2 standard deviations from the mean, or, must be clearly the best of the 10 trees).

2 = better than average (within 1 to 2 standard deviations from mean, or either best or second best of the 10 trees).

3 = average (within 1 standard deviation from mean, or intermediate)

4 = poorer than average (within 1 to 2 sd from mean, or last or second-last of the ten trees)

5 = inferior (further than 2 sd from mean, or must be clearly the poorest of the 10 trees).

Plus tree R44 is to be inspected. This was selected in December 1974, at an age of 17.5 years. Extract of data, for plus tree classification is given.

Character	1/6	2/7	3/8	4/9	5/sd	R44	rating
a) trunk straightness	4	4	4	3	3	1	1
	4	3	3	3			
b) diameter cms	25.00	25.75	34.05	32.25	28.25	32.50	2
	28.35	26.00	24.35	26.80	3.31	+1.40	
c) height m	22.7	21.7	23.9	22.8	24.2	23.0	3
	22.4	23.8	21.2	21.7	1.08	+0.27	
d) volume	Not available.						
e) branch type	2	2	2	1	1	1	1
	1	2	1	1			
f) branch thickness	1	1	2	2	2	1	2
	2	2	2	2			
g) branch angle	2	2	1	2	3	1	2
	2	2	3	1			
h) trunk cones	1	2	2	1	1	2	3
	1	2	1	1			

Appendix 2. Hamel Nursery

In 1897, this nursery was established for the propagation of commercial timber trees for government plantations. The area selected was part of the old de Hamel Estate, about 3 km south of Waroona, and included a large area of rich alluvial soil through which runs the south branch of Samson's Brook.

Many fine trees and shrubs established very early in the nursery's existence still survive. Among the most outstanding are the Norfolk Island pines, now well over 30 m in height, the camellia bushes over 7 m high and a number of plants of the N.S.W. Waratah. Of particular interest is a hugh specimen of cork oak, now over 20 m in height, and 4 m in girth, from the butt of which strippings of commercial cork have been made. A small plantation of pines planted at the beginning of the century is probably the oldest commercial plantation in the State.

Although the nursery was established primarily to supply commercial timber trees for departmental plantations, its functions were soon extended to the raising of ornamental trees for supply to the Education Department for planting in school grounds, to local authorities for street and park planting and to other public bodies and charitable institutions. This range was gradually extended to include landholders who required trees for shade and shelter for stock, for ornamental planting on farms, and for farm woodlots.

The aim of the Forests Department has been to provide from its nurseries hardy trees for every site and purpose. While species from overseas or from the Eastern States have figures largely in the Hamel stocks, those found most suitable for the wheatbelt, and which have been raised at Narrogin, have been mostly Western Australian trees. These latter provide an outstanding variety of form, growth habit and leaf coloration, and bear blossoms of outstanding beauty.

Pinus pinaster progeny trials. Compt. 4, Hamel

This small area was planted with full sib progenies of *Pinus pinaster* to achieve three objectives -

1. to test progenies on a lateritic site
2. to provide a display of progenies employed within the improvement programme for local observation,
3. to provide a small seedling seed orchard.

The first test was planted in 1968. This included 24 families replicated in 7 blocks, and planted in a randomized block design. The plot unit was 3 trees only, planted at spacing of 3 x 1.5 m. Purpose of this was to provide sufficient trees for progeny evaluation, and for selection within the progeny group. Plots were thinned to the single family member in 1976.

Further progeny tests, of similar design were planted in 1969 and 1970.

Seedling seed orchards had not been attempted in Australia and this series was intended as a pilot experiment to assess the possibilities of using this method with *Pinus pinaster*. Selection provided both within and between progeny groups is considered to be inadequate. On solving the problems associated with the design, large scale seedling orchards were established in 1975 and 1976.

Results from the April 1976 measurement of the P1968 trial are tabulated. This is a good site. Height c.a.i. is 1.6 m, and the average standing volume is 150 m^3/ha, at age 8. The high volume production is a factor of the close spacing.

Other parameters of the pedigree stand are as normally expected. These are the high numbers of very straight, and finely branched trees, of the plus crop class. The percentage of acceptable crop stems for stem quality, and for branching was the same at 8.4 per cent.

See Summary of measurement at 8 years.

Summary of measurements at 8 years

Family	Straight r	Straight plus	Branch r	Branch plus	Volume r	Volume m^3	Diameter r	Diameter cms	Height r	Height m
E34 x E41	1	35%	8	15%	19	.064	18	12.05	23	9.05
E41 x E29	2	30	3	35	7	.073	12	12.47	1	10.10
E29 x E14	2	30	16	5	6	.077	5	12.87	4	9.97
E14 x E41	4	24	21	0	2	.082	3	13.21	5	9.92
E40 x E14	4	24	16	5	9	.072	8	12.67	19	9.34
E40 x E41	6	20	21	0	14	.066	13	12.40	18	9.36
E41 x E2	7	19	13	10	14	.066	20	11.98	11	9.65
E29 x E2	7	19	13	10	7	.073	6	12.80	17	9.41
E40 x E29	9	18	1	50	12	.067	15	12.23	9	9.74
E19 x E2	10	14	11	14	22	.058	9	11.58	20	9.33
E19 x E5	10	14	16	5	11	.069	14	12.29	14	9.54
E41 x E14	10	14	21	0	5	.078	6	12.80	15	9.50
E47 x E41	10	14	5	19	19	.064	21	11.84	10	9.70
E19 x E29	14	10	5	19	4	.080	3	13.21	3	10.01
E5 x E29	14	10	4	25	2	.082	2	13.27	1	10.10
E19 x E14	14	10	21	0	1	.083	1	13.46	8	9.77
E19 x E41	14	10	8	15	23	.057	23	11.38	21	9.26
E5 x E14	14	10	8	15	9	.072	10	12.57	6	9.83
E28 x E14	14	10	12	11	18	.065	16	12.17	16	9.43
E47 x E2	20	5	16	5	14	.066	11	12.51	24	8.88
E28 x E29	20	5	2	38	21	.061	22	11.49	12	9.63
E15 x E14	22	0	16	5	12	.067	17	12.16	13	9.57
E45 x E2	22	0	13	10	14	.066	19	12.02	7	9.82
E28 x E28	22	0	5	19	24	.049	24	10.32	22	9.18
mean		14%		14%		$0.069m^3$		12.32 cm		9.59 m

Appendix 3

Mungalup *Pinus radiata* thinning trials. W.P. 12/66

Aim

For *P. radiata* first thinned at height 60ft (18 m) - the time prescribed in the manual:

1. Determine the optimum basal area to which the stand should be reduced.
2. Obtain precise figures for the yield at various intensities of thinning.
3. Follow the growth patterns of *P. radiata* thinned to different basal areas.
4. Observe the effect of site quality on the above.

Location

Mungalup Plantation Section A, compartments 3 and 5 - P.57

Note: this trial is duplicated at Grimwade Section E, compartments 6 and 6B.

Date of inauguration. June, 1966.

Treatments.

1. Thin to 70 sq. ft/ac. (16.1 sq.m/ha).
2. Thin to 90 sq. ft/ac. (20.7 sq.m/ha).
3. Thin to 110 sq. ft/ac. (25.3 sq.m/ha).
4. Thin to 130 sq. ft/ac. (29.8 sq.m/ha).

All treatments thinned annually (if possible) to 5% below prescribed level.

Design

Randomised block with eight replicates of each treatment.

Results - 1976 volume increment.

Treatment	Volume m^3ha^{-1}		Mean tree volume	
	6 cms tdl	18 cms tdl	6 cms tdl	18 cms tdl
16.1 m^2ha^{-1}	24.3	20.0	2.0	1.6
20.7 m^2ha^{-1}	22.8	18.3	1.5	1.2
25.3 m^2ha^{-1}	25.5	20.1	1.4	1.1
29.8 m^2ha^{-1}	27.3	20.9	1.1	0.8

Appendix 4.1 Pinus pinaster progeny trial YS15 (1968).

Introduction.

This trial is part of the 1968 progeny test series to evaluate the performance of pedigree P. pinaster families on a range of environments. This particular test is on a marginal P. radiata site at Collie.

Location

Collie Hills Plantation, Bussells arboretum (D3). Latitude 33°27' Longitude 116°02', altitude 200 m.

Site

Original vegetation was a forest stand of Eucalyptus calophylla, E. patens and E. marginata with understorey of Banksia grandis, Persoonia longifolia and Macrozamia riedlii.

Soil is a sandy red loam, and is marginally suitable for the growth of P. radiata.

Following commercial extraction of timber, the area was clear felled, and then broadcast burnt. The area was then ploughed preparatory to the pine planting.

1 + 0 tubed seedling stock were hand planted within the experimental design in July 1968. Family identity was carefully maintained at all stages.

Fertilizer was first applied to the young trees at age 6 years. The 500 kgms Super Cu Zn plus 250 kgms Urea was hand spread between trees.

Design

The nine families, and a routine unimproved Leirian seed source were replicated in 5 blocks. There were 20 seedlings, planted in rows, for each family in any replicate.

Results

1) Early height growth

	age 3.5	age 4.5	age 8	c.a.i.
mean pedigree	2.76 m	4.14	8.67	1.50 m
routine	2.45	3.77	7.95	1.35

Initial difference of 13% has been reduced to 9%. A probable reason for this is the damage of the leading shoot by the black cockatoo. In numerous instances, it is obvious where the leader has been broken, resulting in loss of years increment. In other trials where no damage has been sustained, the height increment, or difference remains constant. This can be seen by reference to Appendix 12.2.

2) See Table. Measurement Summary at age 8 years.

There has been considerable improvement in the number of acceptable crop stems in terms of straightness and branching character. The value of 24% for routine has increased to approximately 60% for the pedigree material.

Growth has been particularly vigorous on this loamy site. Standing volumes are 113 (mai 14) and 94 m^3/ha (mai 12) for the pedigree and routine stock respectively.

The incidence of severe butt sweep is high in this trial. There is a doubling of the number of trees with negligible sweep for the pedigree stock, but even so more than half of the remaining trees have discernable butt sweep. There is no relationship between vigour and sweep. Possibly the high incidence has been brought about by the incorrect planting of tubed stock on an exposed site.

All parents included in the family crossings form part of the original Joondalup seed orchard population.

2) Measurement summary at age 8 years.

Family	Straight		Branch		Volume		Diameter		Height		Ht. 3.5		Butt Sweep	
	r	%	r	%	r	m^3	r	cm	r	m	r	m	r	%
E29 x E2	1	78	7	49	9	.058	10	11.73	7	8.54	8	2.57	1	63
E41 x E33	2	71	4	64	8	.061	8	12.05	8	8.45	4	2.81	2	47
E41 x E2	3	70	4	64	2	.070	2	12.84	4	8.72	4	2.81	8	36
E47 x E41	4	68	2	70	6	.064	6	12.38	6	8.61	7	2.59	7	37
E5 x E14	5	62	1	76	4	.067	5	12.44	2	8.89	6	2.74	9	32
E19 x E29	6	58	8	42	1	.074	1	13.02	1	8.93	1	3.06	2	47
E45 x E2	7	54	8	42	7	.062	7	12.24	9	8.44	9	2.52	6	39
E19 x E5	8	53	3	69	4	.067	4	12.63	3	8.81	2	2.89	5	44
E19 x E41	9	47	6	50	3	.069	3	12.80	5	8.64	3	2.84	2	47
Routine	10	24	10	24	10	.055	9	11.81	10	7.95	10	2.45	10	21
Family		62		59		.066		12.46		8.67		2.76		43
Routine		24		24		.055		11.81		7.95		2.45		21
Difference		+158%		+146%		+20%		+6%		+9%		+13%		+105%

Appendix 4.2

Bussell's Arboretum.

Species Code.

Planted 1967

A1	P. kesiya	Phillipines
A2	P. roxburghii	Himalaya
A3	P. caribaea	Caribbean (Qld. + tree seed)
A4	P. caribaea	Honduras
A5	P. palustris	E. U.S.A.
A6	P. elliottii	S.E. U.S.A.
A7	P. elliottii	S.E. U.S.A.
A8	P. elliottii var. densa - S. Florida U.S.A.	

Planted 1968

B1	P. pinaster (progeny)	Portugal
B2	P. caribaea	Bahamas
B3	P. caribaea	Bahamas
B4	P. caribaea	Bahamas
B5	P. michoacana	Mexico
B6	P. ayachauite	Mexico
B7	P. taeda	S.E. U.S.A.
B8	P. taeda	S.E. U.S.A.
B9	P. elliottii	S.E. U.S.A.
B10-15	P. taeda	S.E. U.S.A.
B16	P. nigra var. maritima - Corsica	
B17	P. nigra var. austriaca - Austria	
B18	P. halepensis var. brutia - Turkey	
B19	P. oocarpa	Central America
B20	P. thunbergii	Japan
B21	Ar. excelsa (failed)	
B22	P. contorta	Oregon U.S.A.
B23	P. ponderosa	Ser.No.3659 Arizona U.S.A.
B24	P. ponderosa	Ser.No.3660 Colarado U.S.A.
B25	P. ponderosa	Ser.No.3661 Oregon U.S.A.
B26	P. ponderosa	Ser.No.3662 California U.S.A.
B27	P. ponderosa	Ser.No.3741 New Zealand seed
B28	P. halepensis	Mediterranean

Planted 1969

C1	P. montezumae	Mexico
C2	P. greggii	Mexico
C3	P. pseudo-strobus	Central America
C4	P. patula	Mexico
C5	P. halepensis var. brutia - Mediterranean	
C6	P. canariensis	Canary Islands
C7	P. pinaster	Portugal
C8	P. leiophylla	Mexico
C9	P. serotina	S.E. U.S.A.
C10	P. halepensis var. brutia - Cyprus	
C11	P. oocarpa	Central America
C12	P. montezumae var. rudis - Mexico	
C13	P. muricata	California U.S.A.
C14	P. nigra var. austriaca - Austria	
C15	P. pinea	Mediterranean
C16	P. coulteri	California U.S.A.

Species code cont.

Planted 1970

D1	P. radiata	California U.S.A.
D2	P. thunbergii	Japan
D3	P. kesiya	Burma
D4	P. pseudo-strobus	var. tenuifolia. Mexico
D5	P. densiflora	Japan
D6	Seq. sempervirens	S.W. U.S.A.
D7	P. ponderosa	W. U.S.A.
D8	Cup. arizonica	Arizona, U.S.A.
D9	Cup. lusitanica	Mexico
D10	Cup. macrocarpa	California U.S.A.
D11	Cup. sempervirens	Mediterranean
D12	P.caribaea	Caribbean
D13	P. nigra var. maritima	Italy
D14	P. nigra var. maritima	Corsica
D15	P. nigra var. austriaca	Austria
D16	P. roxburghii	Himalaya
D17	P. torreyana	California U.S.A.
D18	P. contorta	Oregon U.S.A.
D19	P. oocarpa	Central America
D20	P. kesiya	Vietnam
D21	P. patula	Mexico
D22	P. pseudo-strobus var. tenuifolia - Mexico	
D23	P. caribaea	Guatemala
D24	P. canariensis	Canary Islands

Planted 1971

E1	P. muricata/radiata	grafted trees
E2	P. clausa	Florida U.S.A.
E3	Cedrus deodara	Himalaya
E4	P. clausa	Florida U.S.A.
E5	Ps. menziesii	N. America (West Coast)
E6	Thuya occidentalis	E. North America
E7	P. jeffreyii	California U.S.A.
E8	Abies religiosa	Central America
E9	Cup. lusitanica	Mexico
E10	Ar. angustifolia	Brazil
E11	Ar. excelsa	Norfolk Island
E12	Ar. cunninghamii	Queensland Aust.
E13	P. jeffreyii	California U.S.A.
E14	P. muricata	California U.S.A.
	P. muricata var. remorata	California U.S.A.
	P. radiata var. binata	Guadalupe Island
E15	P. radiata	California U.S.A. (Scion orchard)
E16	Euc. calophylla var. rosea	S.W. Australia
E17	Mixed species	

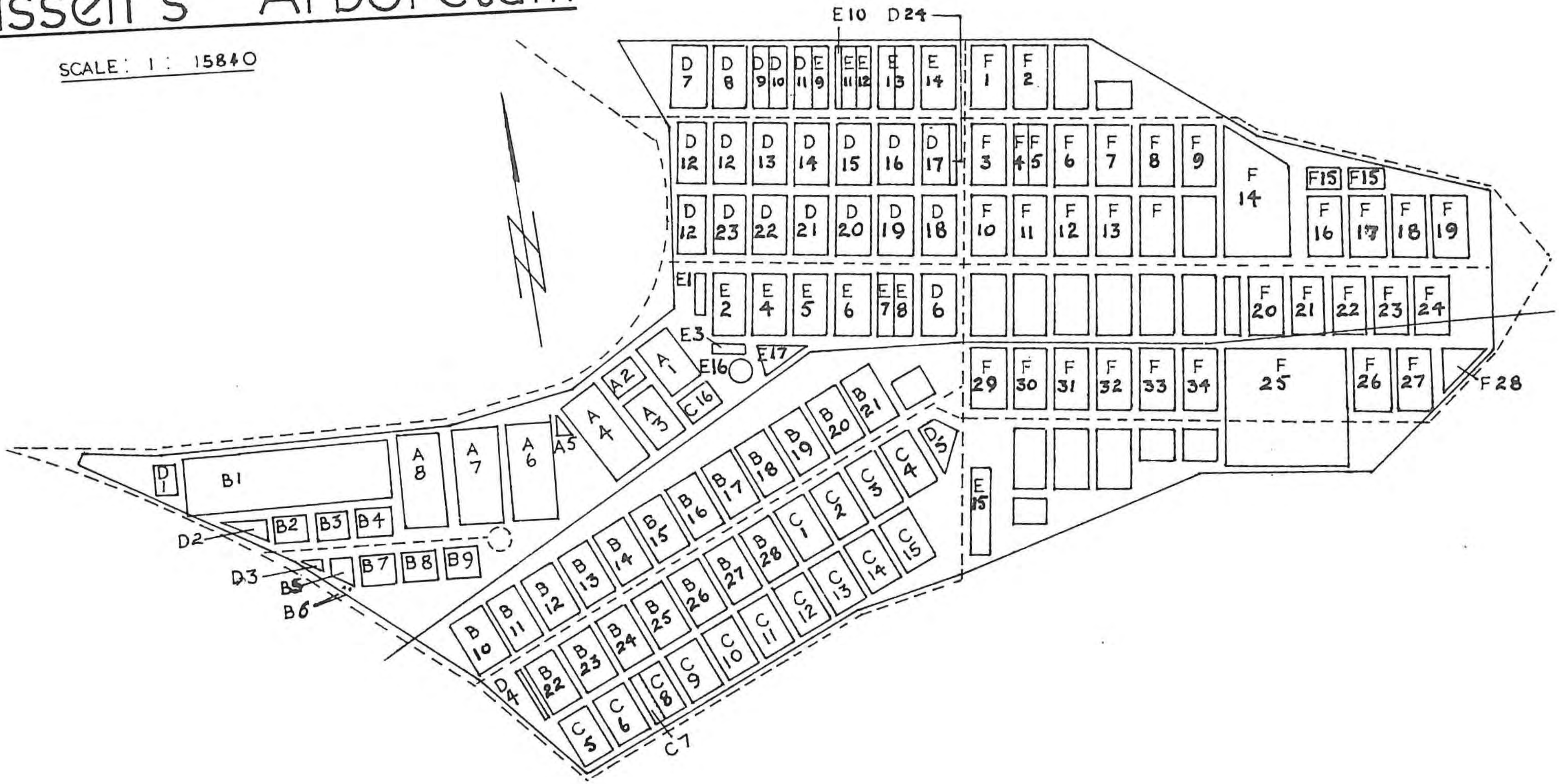
Species code cont.

Planted 1972

F1	Cal. endlicheri	E. Australia
F2	P. halepensis var. brutia	Turkey
F3	P. pungens	E. North America
F4	P. coulteri	California U.S.A.
F5	P. flexilis	W. North America
F6	P. radiata	Guadalupe Prov.
F7	P. radiata	Cambria Prov.
F8	P. radiata	Cambria and Ano Neuvo Prov.
F9	P. radiata	Monterey Prov.
F10	P. rigida	E. North America
F11	P. virginiana	E. North America
F12	P. halepensis var. brutia	Mediterranean
F13	P. glabra	S.E. U.S.A.
F14	Goldfields	Eucalypt species
F15	Euc. globulus	Tasmania, N.S.W. and Victoria
F16	Euc. diversicolor	S.W. Australia
F17	Euc. botryoides	N.S.W. and Victoria
F18	Euc. camaldulensis	Australia
F19	Tristania conferta	N.S.W. and Queensland
F20	Euc. calophylla var. rosea	S.W. Australia
F21-24	Euc. calophylla	S.W. Australia
F25	Acacia species	
F26	Euc. goniocalyx	Victoria and N.S.W.
F27	Euc. oreades	Blue mountains, E. Australia
F28	Euc. gomphocephala	S.W. Australia
F29-34	Mixed Species	

Bussell's Arboretum

SCALE : 1 : 15840



Appendix 5.

Pinus radiata seed production area at Grimwade.

Introduction

Prior to the development of this area, the Western Australian seed requirement was obtained from uncontrolled collections in South Australia, and periodically from New Zealand. This was undesirable.

Seed orchards had been developed concurrently but would not make a substantial contribution to the plantation programme until 1980.

In the interim period, the best *P. radiata* stands in the State would be managed for improved seed production.

Location

Grimwade plantation, A. section, Comts. 1, 2, 3, 4 and 5.
Latitude 33°42', Longitude 116°03'.

Development

Grimwade A section was planted to *Pinus radiata* in 1933. It is on a valley bottom and lower slopes, and is on a deep red loam soil. First thinning was delayed until age 20 years, when it was reduced to a stocking of approximately 900 trees per hectare. The late thinning probably accounts for the very fine branching character, and narrow crown development of the seed trees. Second thinning to 500 s.p.ha, was carried out at age 25, and the third thinning to 200 trees per hectare occurred at about age 32 years.

This area was selected for development as a seed stand, as being the best representative stand of *P. radiata* in Western Australia. Forty five hectares were progressively thinned over the period 1968 to 1971 to retain a stocking of 125 seed trees per hectare. Selection standards were stem form, vigour, coning intensity and crown character. On the average, 75 trees per hectare were removed. These were part of the original final crop, and had a good tree form. Seed was collected from this thinning, and used in the immediate nursery programme. Approximately 5700 seeds trees were developed as the seed production population.

Seed stand was treated with heavy applications of P & N fertilizer one year after thinning treatment. This had a pronounced effect on timber, and seed production.

Collection from the specially treated seed stand commenced in 1971. This involved the stocking reduction of part of the area, from 125 to 100 trees per hectare. Subsequent cone collection involved the gradual thinning of the total area concomitant with seed, and quality sawlog, peeler log requirement.

Seed Yield.

	seed trees removed	cone	clean seed
Nov. 1971	300	182 bushell	63 kgms
Nov. 1972	700	344 "	120 "
Nov. 1973	500	236 "	90 "
Nov. 1974	75	34 "	14 "
Nov. 1975	150	74 "	29 "
Nov. 1976	600	288 "	84 "

From inception in 1968, approximately 2325 seed trees have been removed to yield 400 kgms of seed, giving an average seed tree yield of 0.17 kgms clean seed. On these mature trees, seed is smaller (40,000 per kgm) and an average of 20,000 plantable seedlings per kgm of seed is expected. Using a standard 3.5 x 2.5 metre spacing, or 1140 seedlings per hectare, the 1 kilogram of clean seed will provide for 17.5 hectares of plantation.

Discussion

Cones retain their seed for four years, after this time the chance of a cone containing seed will depend on its exposure to the sun. However, seed viability is poor after four years. Generally the first three to four years of cones are collected, resulting in a collection of 80 to 100 cones per tree.

Seed viability has been found to be very variable, both between individual trees and ages of seed. However, there was a marked trend for viability to decline rapidly after the fourth year.

Fertilizer P and N application to seed trees has consistently produced more cones on these trees. In a comparison between non-fertilized and fertilized seed trees, coning has been increased by 30 per cent, and there was a suggestion of an increase in seed size.

Fertilizer, following the thinning treatment has had a profound effect on tree volume increment. In the first two years after fertilizer, c.a.i. for control trees was $0.17m^3$, and $0.26m^3$ for treated seed trees. This is a 50 per cent increase, in clear wood production, on 40 year old trees.

Appendix 6

Pinus radiata seed orchard - West Manjimup.

Introduction

The department's first seed orchard was established on 4.5 hectares at Gleneagle, to initiate the breeding programme for the species. This site was considered unsatisfactory from the viewpoints of potential for extension and access to management. Maintenance of the orchard has been difficult and unsatisfactory due to its relative isolation.

The second orchard, was located at Manjimup.

Coning is expected to be considerably greater in this southern environment. It is close to the township, and the department's southern Karri nursery is on an adjacent area. Contamination from external pollen should be absent from this area.

The 16 hectares developed orchard should be providing this department with approximately 300 kgms clean seed per annum by 1980. This will cover the department's maximum forecasted afforestation programme of 4000 ha/annum.

Location

Approximately 6 km north west of Manjimup. Latitude 34°12', Longitude 116°05'.

Site

Much of the area was cleared pasture. Soils are predominantly deep, lateritic sandy loams, and yellow and grey sands. Part of the area was excessively wet in winter, but this was later corrected by drainage.

Establishment

The 1 + 1 potted graft stock were planted in ploughed land according to the planting design. Grafts received 50 gms Magamp fertilizer, placed in planting hole, and surface spot application of 80 gms superphosphate (+ Zn and Cu trace element) soon after planting.

Regular maintenance at orchard involved the removal of stock shoots, and the elimination of the most vigorous competing weeds.

Design

Orchard includes the best clones available from Western Australia (33), South Australia (18), Victoria (17), the A.C.T. (10), N.S.W. (10) and New Zealand (3). The seed orchard population of 91 clones was not included in each year's planting, this varied according to the availability of ramets.

Planting spacing was 4.5 x 6.0 m. Orchard blocks usually contained a single ramet for each ortet, and they were completely randomized in each block.

1969	-	1.3 hectares,	48 clones	
1970	-	2.2 "	47 "	
1971	-	6.4 "	55 "	
1972*	-	5.8 "	88 "	

* there were considerable losses in the 1972 planted area. Blanks were refilled with 425 grafts in June 1973.

General

The early growth of grafts has been slow as a result to the extreme grass competition. This was not completely controlled until 1974. After this, the trees have developed very rapidly. Orchard area is now grazed by sheep, or cattle, and the grass as competition or fire hazard is no longer a problem.

A few trees have succumbed to early graft incompatibility, but it is not widespread. Most of the dead trees were noted to be the same clones that suffered in the Gleneagle orchard.

Balanced N + P fertilizer was spread at the orchard in 1974, and again in 1976. A fertilizer cycle of 3-4 years will generally be used.

Cones were collected in summer 1976 from the 1969 and 1970 areas, plus some of the larger cones were harvested from the 1971 area. Seventy five kgms clean seed is expected to result from the extraction. The seed yield from these young 6-7 year old trees is high, and is equivalent to 18 kgms/hectare of orchard area.

The early high seed yield is hartening, after the low coning at Gleneagle orchard. Flowering in the Manjimup orchard suggests that in excess of 200 kgm clean seed could be collected in 1978.

Orchard trees are to be pollarded to a height of 10-15 metres to facilitate cone collection.

Appendix 7

Pinus pinaster - Leiria, seed orchard - Lake Joondalup

Introduction

A breeding programme was commenced in 1957, with the major objective of improving stem form of the Leirian strain *Pinus pinaster*. This first seed orchard was completed in 1964.

The major limitation of the initial breeding programme was a very low selection of plus trees, and a minimal area, 400 ha extent, of the Leirian provenance in Western Australia. Sixteen trees were selected as suitable for orchard parents, and of these, no more than 5 exhibited the desirable standard for both form and vigour. This orchard is hence below standard in both clonal complement, and the quality of the clones.

The genetic quality of this orchard was upgraded in 1966 by the inter-row planting of additional clones. Forty one of the Portuguese selections were used. Although being suppressed by the earlier plantings and cone production being minimal on these trees, contribution to the pollen cloud has increased the genetic component of the orchard.

Location

East Lake Joondalup: Reserve 21176, on Wanneroo Road, 28 km north from Perth. Latitude 31°43'; Longitude 115°47'S. Altitude - 25 m.

Establishment Detail

Design 16 local selections, randomized within 256 tree unit blocks. Planting spacing 6.7 x 6.7 m.

Clones E2, E5, E14, E15, E19, E28, E31, E33
E40, E41, E45, E46, E47, E49, E50, E53

Planting In 1963 and 1964 using 2462 potted 1 + 1 graft stock.
Inter-row planting in 1966, of 546 potted 1+1 grafts of Portuguese selections E105, E107, E117, E118,
E119, E122, E123, E124, E127, E131, E133, E139, E143,
E144, E145, E146, E147, E148, E149, E151, E154, E156,
E158, E161, E162, E164, E165, E166, E167, E168, E169,
E170, E171, E173, E176, E177, E179, E180, E183, E185,
E186.

Area 10.5 ha, containing 2480 trees.
Orchard was thinned in 1974, 75 leaving 1690 trees.

Management Fertilizer

Soils in the orchard area are deep yellow sands of the Spearwood dune series. They are relatively infertile and require the addition of phosphate and trace element fertilizer for satisfactory tree growth. N + P fertilizer has been found to increase cone numbers, and seed size. This is applied at 2 or 3 year intervals.

Thinning

Water is perhaps the critical factor limiting tree growth in our environment. Orchard trees had complete site occupancy at age 8-9 years, and the cone crop was deteriorating. Silvicultural studies have shown how the soil water balance can be controlled by the stand density, or stem numbers. Progeny trials were sufficiently progressed at this time to allow a confident selection of the more suitable clones, and culling of these clones having undesirable traits. Cull trees were removed from blocks 1, 2, 3 and 4 over the period May-July 1974, and from the balance of the orchard in July 1975.

Clones culled on basis of progeny form assessment
E2, E14, E15, E28.

Clones culled on basis of progeny branching assessment
E14, E15.

Clones culled on basis of progeny height growth.
E2, E28, E46, E49

Object of this thinning has been twofold. Firstly, clones illustrating poor character in progeny tests are removed from the orchard population. Secondly, the removal of one third of the tree numbers has significantly increased the period where soil water is available to the tree. This has been seen to reduce the number of conelets aborting.

Fire Protection

Spring cultivation between rows until 1972. Subsequent treatment has relied on slashing, or rolling of grass and pruning debris. Pruning of trees was delayed until 1972, so as to maximize pollen production. Currently, external and internal fire breaks are ploughed in spring and grasses within the orchard are controlled by winter prescribed burning.

Bird damage

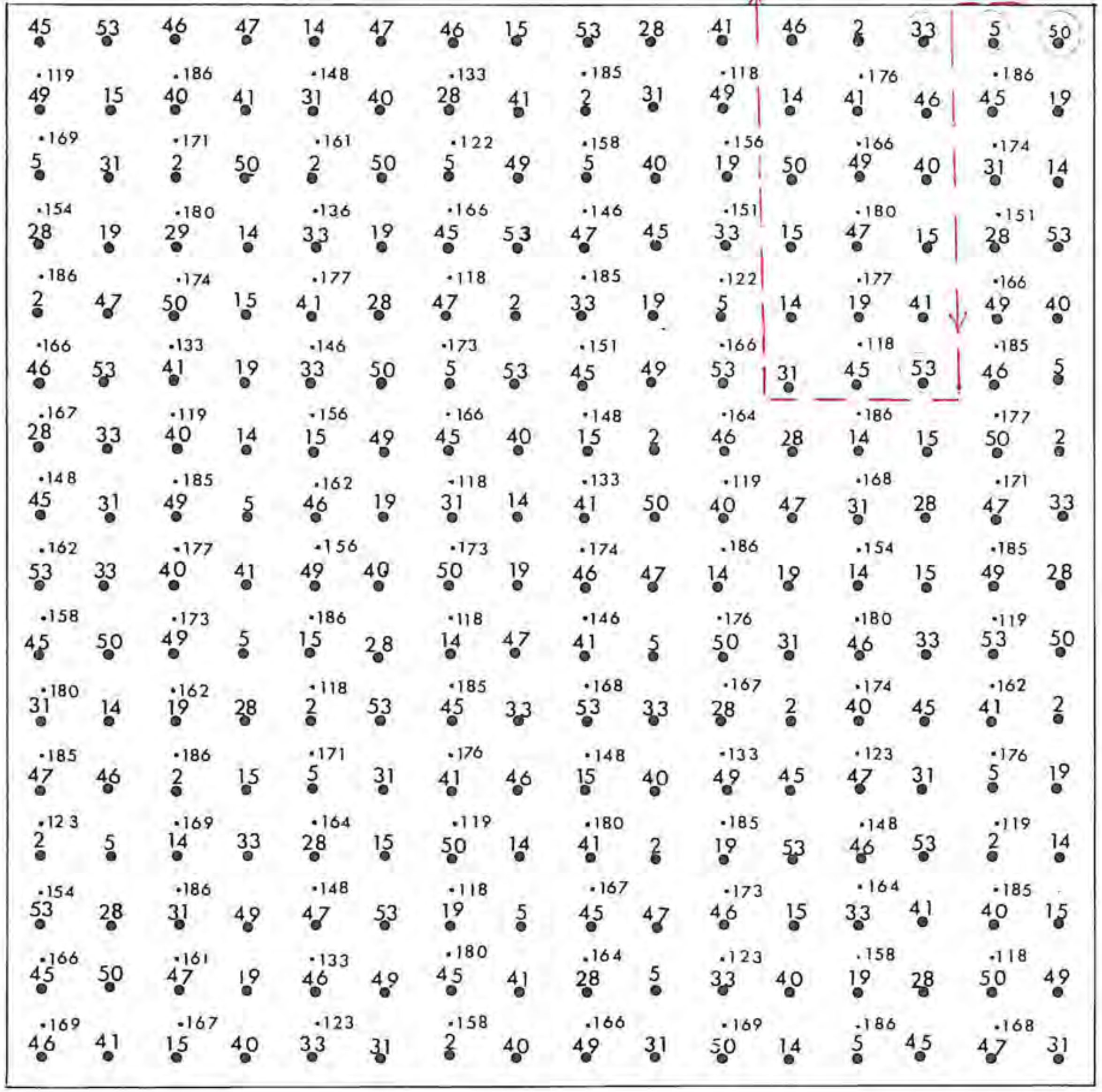
Feeding by the black cockatoo (Calyptorhynchus baudinii) on the pine seed is the greatest management problem. The main danger of cockatoo attack is in the period January to April, although damage outside of this period may be expected from smaller flocks of 100-150 birds. The entire orchard crop can be lost if these birds are not checked.

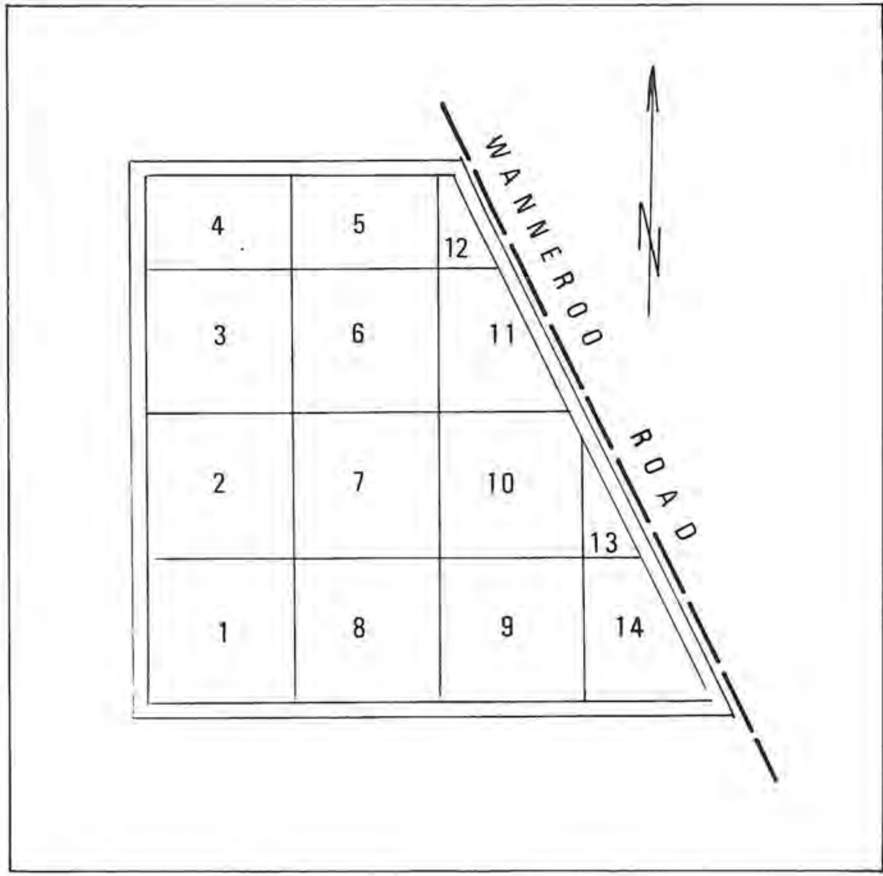
The most effective means of keeping birds away from the orchard has been by the use of gas operated scare guns. The guns function as shotgun intensity explosions, set at intervals of 3-5 minutes.

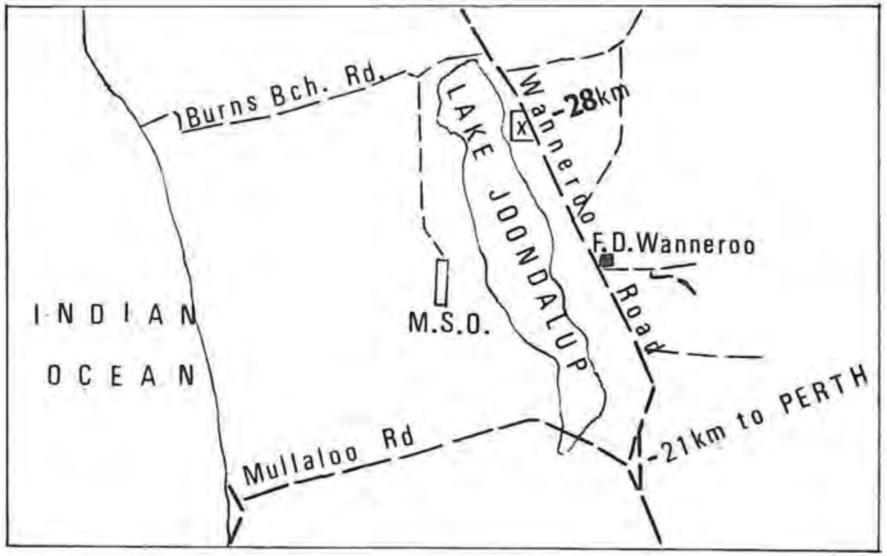
Immature cones are collected in May-June, and stored prior to seed extraction in November. This reduces the length of time on trees when cones are susceptible to cockatoo.

Production History

Year	Total trees	Cone yield	Seed/ cone	100 seed weight	Seed yield	S.N. allocated	Plantation area
				gms	kgm		hectare
1968	2480	3385	85	4.5	13	-	125
1969	2480	11490	81	5.4	49	5008	400
1970	2480	14150	80	6.2	70	5020	450
1971	2480	46640	116	4.3	257	5047	2600
1972	2480	25180	121	4.7	142	5060	1325
1973	2480	11010	121	5.3	64	5063	525
1974	2480	21896	141	5.5	160	5068	1275
1975	2152	22800	-	-	116	5073	960
1976	1690	29700	-	-	155	5083	1280







LAKE JOONDALUP SEED ORCHARD

PLANTED IN 1963-64 BY THE W.A. FORESTS DEPARTMENT

PINUS PINASTER- LEIRIA STRAIN. SPACING - 6.7 × 6.7 m.

Appendix 8

Pinus pinaster - Leiria, seed orchard - Mullaloo

Introduction.

The first P. pinaster orchard was established in 1963-64 using 16 of the most promising phenotypes selected from local stands older than 20 years of age. Limitations of this were recognised at the time. The initial aim of 40 desirable plus phenotypes to commence the orchard programme could not be met from the local plantations, and would not be achieved in the immediate future. Rather than accept this unsatisfactory, though necessary commencement and possible delay to the breeding programme it was decided to turn to the natural stands of the species.

From October 1963 to November 1965, Mr D.H. Perry, an Officer of the Western Australian Forests Department was stationed in Portugal to select plus material with the 'Forest of Leiria' and to forward vegetative material to Australia for propagation.

Conal material from Portugal, together with local selections were immediately planted in a second orchard located at Mullaloo.

Location

Western side of Lake Joondalup. Location 1556. Is at the end of Quinlan Road, off Burns Beach Road.

Latitude 31°45', Longitude 115°46'. Altitude 40 m.

Establishment Detail

Design Embraces 7816 grafted trees planted at 3 metre spacing in rows aligned at a repetitive 3 metre then 6 metre pattern. The wide spacing every second row assists crown development while allowing access for future collection equipment. Planting out of 1 + 1 stock, grafted at Wanneroo commenced in 1969 and was completed in 1972.

The design allows for high, and early seed yields, and a reduction from 740 stems per hectare (96 clones) to 125 stems per hectare (20 to 25 clones). A final spacing of 9 x 9 metres average is envisaged.

Clone 96 individual superior clones comprise this seed production population. 55 parents were selected from native stands in Portugal, 3 and 38 parents were selected from plantations in South Australia and Western Australia respectively. 11 of the most promising local clones had double the number of ramets planted to ensure adequate representation in the orchard. This was considered desirable to restrict possible vigour depression from the early seed crops, through the use of untested Portuguese plus trees in the Australian environment.

Parents selected in Western Australia,

E2, E5, E8, E12, E13, E14, E15, E16, E17, E18, E19, E21, E26, E27, E28, E29, E31, E33, E34, E35, E37, E40, E41, E45, E46, E47, E49, E50, E52, E53, E54, E58, E60, E63, E65, E66, E67, E70.

Parents selected in Portugal.

E102, E103, E104, E105, E107, E109, E112, E115, E117, E118, E119, E122, E123, E124, E131, E132, E133, E135, E137, E139, E141, E142, E143, E144, E145, E146, E147, E148, E149, E150, E151, E154, E156, E157, E158, E160, E161, E162, E164, E165, E166, E167, E168, E169, E170, E171, E175, E178, E179, E180, E181, E182, E183, E185, E186.

Parents in South Australia. P2, P85, P86.

Area

P1969 - planting of 929 grafts of 54 clones, area of 1.3 hectares
P1970 - planting of 2668 grafts of 78 clones, area of 3.7 hectares
P1971 - planting of 3264 grafts of 94 clones, area of 4.5 hectares
P1972 - planting of 955 grafts of 92 clones, area of 1.4 hectares

Total planting of 7816 grafts of 96 clones, an area of 10.9 hectares.

Management

Fire Control Spring cultivation of fire breaks, and scraping of vegetation cover between pine tree rows. Low pruning was undertaken at an early age to offset an accumulated slash problem.

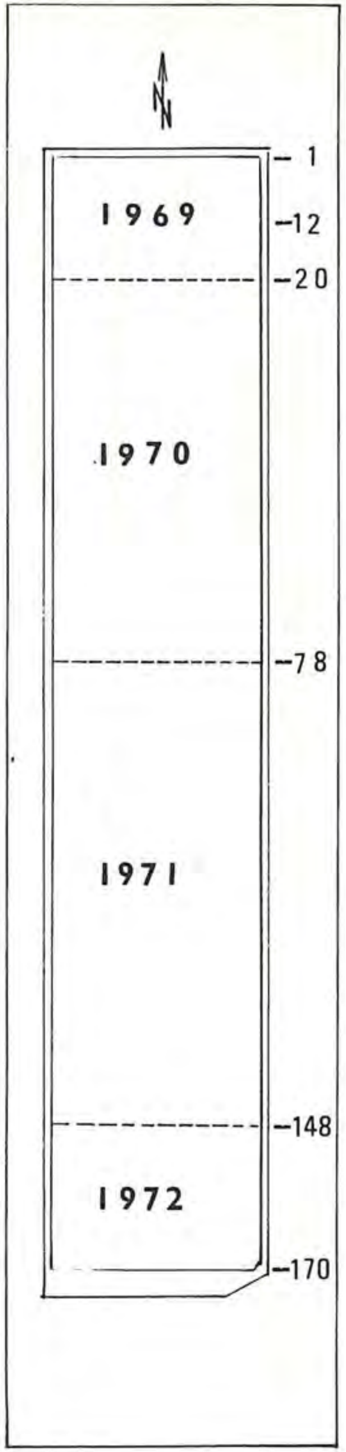
Fertilizer P + N fertilizer is applied every 3 to 4 years.

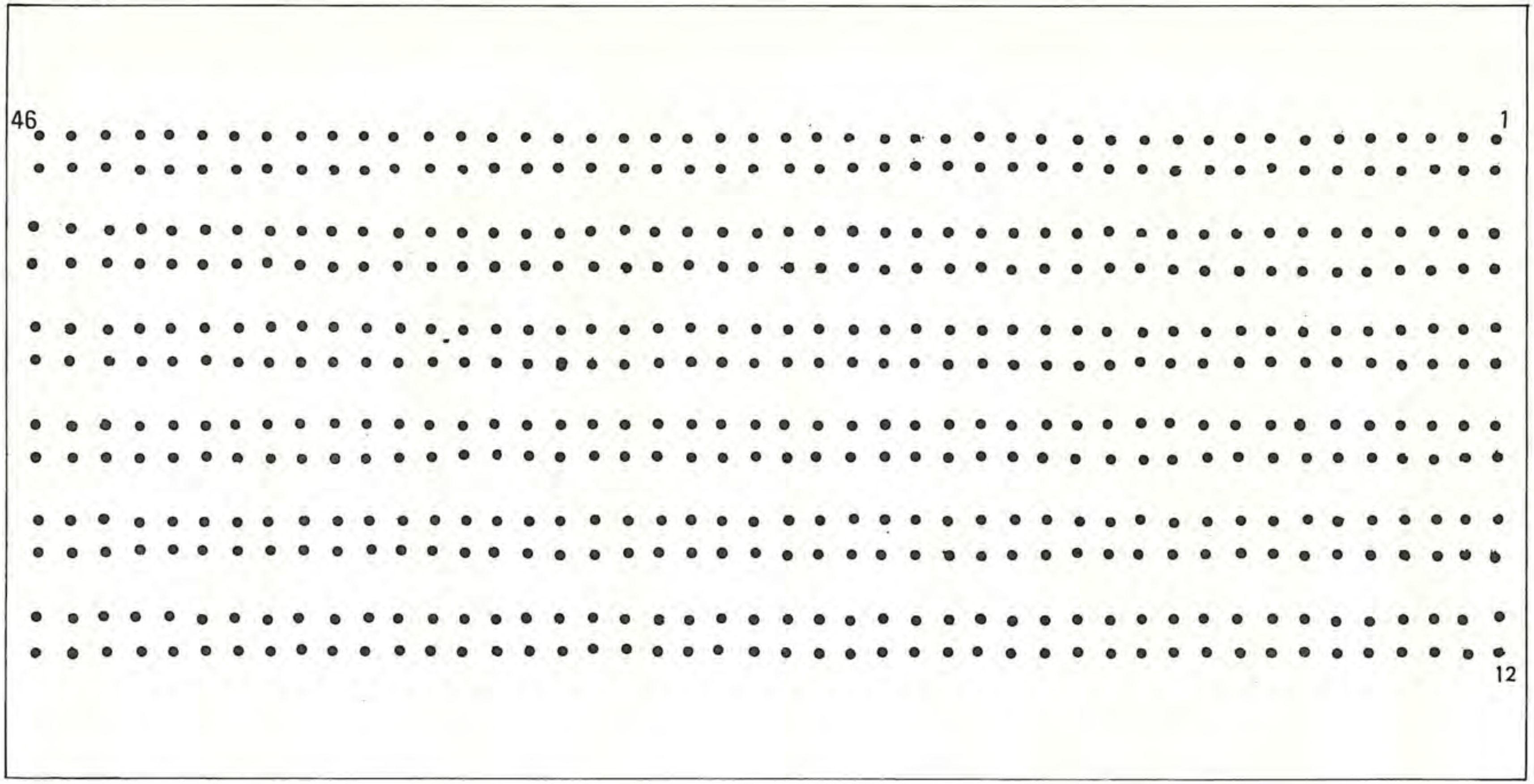
Bird Control Feeding by the black cockatoo (*Calyptorhynchus baudinii*) on the pine seed is the greatest management problem. The entire orchard crop can be lost if the birds are not checked. Gas operated, automatic scare guns are positioned in the orchard in December, and they operate through to May. These guns are checked once weekly.

Thinning First thinning is schedules in 1977, in the 1969 and 1970 planted areas. Culling is based on progeny test information.

Cone Production

Year	Total trees	Cone yield	Seed/ cone	100 seed weight	Seed yield	S.N. allocated
1975	3600	5100	-	-	24 kgm	5072
1976	3600	13500	-	-	77	5084



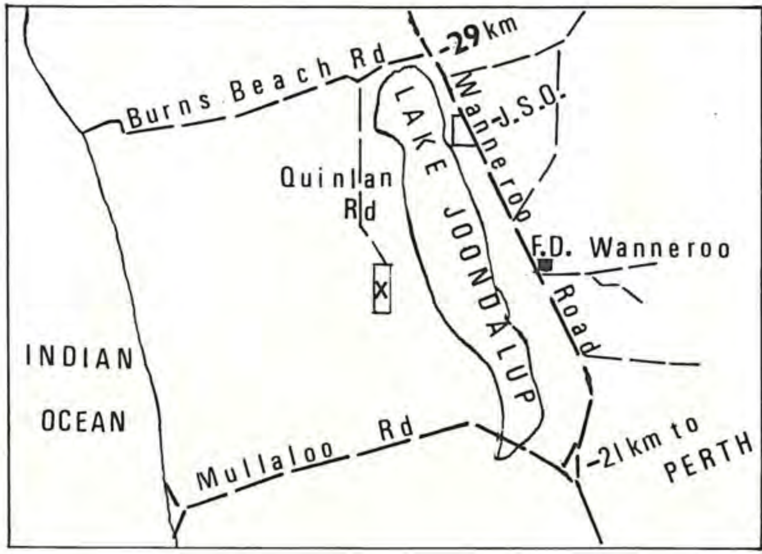


MULLALOO SEED ORCHARD

PLANTED IN 1969–72 BY W.A. FORESTS DEPT.

PINUS PINASTER—LEIRIA STRAIN

SPACING–/3,6/× 3 m.



Appendix 9.1

Pinus pinaster provenance trial XS 12

Introduction

This provenance trial has a unique design. It incorporates three provenances, Leirian, Landes and Corsican, but what makes it so interesting are the within provenance comparisons. Leirian provenance is represented by two pedigree lines based on W.A. parents, a mixture of seed collected from the Portugal plus trees and the normal source used in plantation establishment. Landes provenance is also pedigree stock, with the two lots as seed collected from individual plus trees. The four Corsican sources were each collected from the best trees in the stand, and they are based on the higher elevation locations for this strain.

In this trial, comparisons of the provenances, based on genetically improved material, can be made.

Location

Yanchep plantation, compartment 46A. Approximately 60 kms north of Perth. Latitude 31°29', Longitude 115°42', Altitude 40 m.

Site

Low, sclerophyllous woodland of Banksias, with some Eucalypts. Soil is a dark yellow, deep sand of the Spearwood dune series. Area was cleared, and burnt in 1965. Following cultivation, and furrow lining, this trial was pegged, and planted with the provenance groups in June 1967.

Seedlings received the spot application of 100 gms superphosphate (Zn and Cu trace element) at planting, and the broadcast spreading 500 kgms super plus 200 kgms urea per hectare, in 1976,

Design

Randomized block. 10 Prov/fam x 5 replications.
Square plot of 36 trees, spacing 2.4 x 2.4m.
Planting in June 1967, using tubed stock.

Provenance/family information

Leiria E5 x E40	- control crossing of W.A. plus parents
Leiria E19 x E40	- control crossing of W.A. plus parents
Leiria M.P.D.L.	- mixture of seed from Portugal plus trees
Leiria routine	- SN3697, unimproved bulk collection from Portugal
Landes 64445	- seed collected from plus tree 38.27
Landes 64435	- seed collected from plus tree 71.05
Corsica 3749	- Vivario, alt. 800m, seed collected from good trees in stand
Corsica 3750	- Porto Vecchia, alt. 900m seed collected from good trees in stand
Corsica 3751	- Zonza, Alt. 700 m, seed collected from good trees in stand
Corsica 3752	- Ghisoni, alt. 800 m, seed collected from good trees in stand.

Results - data summary at age 7.5 years

Provenance family	Straight acceptable		Volume mean		Diameter mean		Height mean		Height 3.5 yr	
		%		m³		cm		m		m
Leiria E5 x E40	7	79	1	.017	1	10.8	1	8.1	1	3.3
Leiria E19 x E40	6	81	2	.015	2	10.0	2	8.0	1	3.3
Leiria M.P.D.L.	9	75	3	.013	2	10.0	3	7.1	3	3.0
Leiria routine	10	61	4	.011	4	9.2	4	6.8	3	3.0
Landes 64445	5	85	5	.008	6	8.3	5	5.9	5	2.2
Landes 64435	8	76	8	.005	8	7.5	6	5.1	5	2.2
Corsica 3749	1	90	7	.006	7	7.7	9	4.8	8	1.9
Corsica 3750	3	87	8	.005	9	7.2	8	4.9	7	2.0
Corsica 3751	2	89	8	.005	9	7.2	10	4.7	8	1.9
Corsica 3752	4	86	6	.007	5	8.5	7	5.0	8	1.9
LSD				.004		1.5		0.9		0.1

Provenance summary

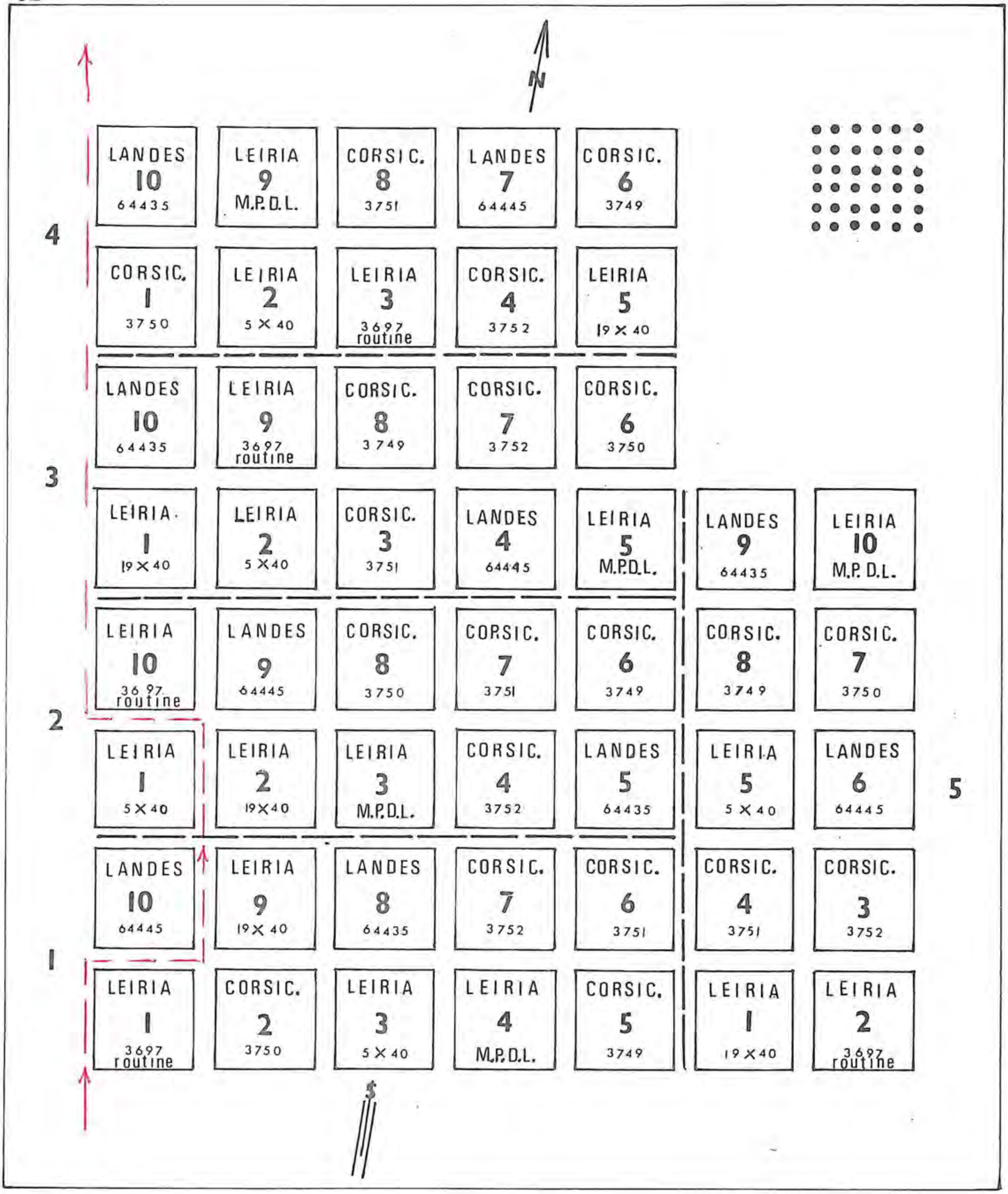
Leiria - pedigree	78	+28%	.015	+36%	10.3	+12%	7.7	+13%	3.2	+7%
Leiria - routine	61	=	.011	=	9.2	=	6.8	=	3.0	=
Landes	80	+31%	.007	-41%	7.9	-14%	5.5	-19%	2.2	-27%
Corsica	88	+44%	.006	-48%	7.6	-17%	4.8	-29%	1.9	-37%

Discussion

Hopkins (1960)* examined the original P1931 provenance stands, and classified tree form, based on stem quality and branching character. Results indicated that the percentage of acceptable crop trees and plus trees in the Corsican population is double that of the other races, while the Portuguese race is slightly superior to the others. Data from this trial expresses stem straightness in terms of the number of acceptable crop trees. Here the Corsican provenance is 44% superior to the Portuguese strain. By stem selection, and breeding, the Leiria strain has been improved by approximately 30 per cent. The Landes plus tree sources have demonstrated a similar high number of acceptable formed crop trees.

The Leirian height, diameter and volume growth is superior to other provenances. Differences in volume growth are of the order of 40 and 50 per cent for the Landes and Corsican strain respectively. The same order of magnitude exists between the improved, and the base Leirian population. Differences of 55 and 36 per cent were measured for the local full sib crossings. These three parents are retained in the seed orchards. There was an 18 per cent volume increase over the routine for MPDL source. This is wild, half sib seed and it does show that vigour character has been transmitted in the W.A. environment.

*Hopkins, E.R. (1960). "Variation in the growth rate and quality of <u>Pinus pinaster</u> Ait. in Western Australia". Bulletin 67 Forests Department of W.A.



PINUS PINASTER PROVENANCE TRIAL

XS 12

PLANTED AT YANCHEP B-46A IN 1967

Appendix 9.2

Pinus pinaster progeny trial YS.13 (1968)

Introduction

The 1968 test series is the first comprehensive evaluation of all parents planted in the Joondalup seed orchard. Earlier tests have included some parents, but the current tests include a large number of families, of all parents in the orchard. Expression of the mean family value is indicative of orchard growth character, and as trials also include the unimproved seed source used in routine afforestation, a measure of gain is forthcoming.

The other feature of the 1968 trials is the large number of planting environments tested. This particular test was duplicated at Gnangara, and a number of the families are common to trials at Mundaring, Hamel, Collie and Pemberton. Trials at Hamel (appendix 2) and Collie (appendix 4) will be inspected during the field trip.

Butcher (1974) used this progeny test series to investigate G.E.I effects with Pinus pinaster and concluded that the families were stable, and highly adaptable to the environments in which they were tested.

Location

Yanchep plantation, Compartment B60. Latitude 31°29', Longitude 115°42' Altitude 50m.

Site

Natural vegetation consisted of a scattered tree cover of predominantly Banksia menziesii, with some Eucalyptus todtiana, Banksia attenuata and Nuytsia floribunda. The ground cover was particularly dense, characterized by Jacksonia sternbergiana, Calothamnus sanguineus, Eremeae pauciflora, Melaleuca scabra and Petrophilia serruriae.

Soil is of the Spearwood dune sand series. It has been only lightly leached, and is dark yellow in colour. Near the northern end of the experiment, in block 1 of the design, soil is slightly shallower in depth and is deeper in colour as it approaches a limestone ridge.

Area was scrub rolled, burnt and cultivated. Furrow lines, to concentrate rainfall along planting lines were drawn in the ploughed land at 3 metre intervals. Field trial design was pegged in the field, and tubed 1 + 0 planting stock, height 30 cms were planted in June 1968.

Fertilizer was applied at planting as a spot application of 110 gms superphosphate, with zinc and copper trace element. The same fertilizer was hand broadcast over the trial area at pine age of 6 years, using a rate of 500 kgms per hectare. 250 kgms per hectare urea was also applied.

Trial Design

Randomized block statistical design was employed for this progeny test, and indeed for most of the Western Australian breeding programme tests. There are 29 pedigree families, and a single unimproved Leirian seed source used as the operations planting stock in the design. Families have been replicated x 8.

In this test, the design was split into A - 10 tree line plots, and B - 5 tree line plots, to evaluate the effect of plot size on family performance. Measurement summaries that are presented will refer to the 10 tree plot trial.

This test has been duplicated in its entirety on grey sands, shallow to water table at Gnangara.

Mating Design

Controlled crossings were based on the NCll design using 5 pollens. Unfortunately, each parent was not crossed with all of the pollens to give a complete design, although there were sufficient of these to allow some parental, as well as family evaluation.

Results

January 1972	-	tree height at age 3.5 years
January 1973	-	tree height at age 4.5 years *
March 1976	-	tree height and diameter at age 7.8 years
August, 1976	-	tree form and branching assessment
January 1977	-	evaluation of branching codes

Data from the 8 years measurement is summarized on the following page.

Discussion

1. Early height growth

Age	3.5yr.	4.5yr.	7.8yr.	cai
mean pedigree	2.92 m	4.40	8.13	1.30 m
routine	2.59	3.86	7.30	1.18
diff.	+13%	+14%	+11%	

Growth of the routine is representative for this site type. Pedigree height is significantly greater than this.

An unfortunate aspect of this trial has been the considerable damage to the trees caused by black cockatoos (Calyptorhynchus baudinii). This was first observed in the fifth growing season. Growing tips were broken, or debarked on one side resulting in a large bend in main leader. Damage was general over the whole area, but most damage was sustained on the more vigorous families where the leader was dominant above the canopy. For the same reason, least damage was afforded to the selfed lines and to the routine lot where height growth was much reduced.

Measurement summary at age 8 years

Family	Straightness plus R	plus %	acc. R	acc. %	Volume tree R	Volume tree m^3	Diameter tree R	Diameter tree cms	Height tree R	Height tree m	Branch thickness plus R	plus %	Acc. R	Acc. %	Branch angle plus R	plus %	acc. R	acc. %
E29 x E29	1	33	5	88	26	.047	26	11.14	27	7.77	12	9	5	83	2	30	3	96
E29 x E2	2	30	2	90	6	.062	7	12.55	13	8.22	22	4	23	65	16	6	16	83
E40 x E33	3	21	17	79	4	.064	4	12.70	9	8.30	10	11	17	70	7	14	12	85
E40 x E29	4	19	9	85	3	.065	3	12.80	7	8.31	19	6	25	64	27	4	4	91
E41 x E2	4	19	9	85	21	.055	21	11.80	15	8.19	8	13	5	83	10	13	16	83
E47 x E41	4	19	15	80	18	.056	20	11.85	13	8.22	17	8	23	66	16	6	27	72
E41 x E29	4	19	21	76	6	.062	9	12.48	2	8.42	12	9	22	68	11	11	4	91
E47 x E2	8	16	13	83	13	.059	12	12.27	18	8.15	20	5	20	69	27	4	28	64
E19 x E5	9	15	5	88	15	.058	16	12.05	5	8.33	5	15	2	90	1	31	1	99
E19 x E33	9	15	8	87	6	.062	8	12.54	2	8.42	7	14	4	86	3	25	1	99
E45 x E41	9	15	3	89	13	.059	14	12.14	10	8.27	3	19	13	77	7	14	19	81
E28 x E33	9	15	15	80	27	.045	28	10.71	22	7.94	1	24	2	90	16	6	21	78
E28 x E29	13	14	25	75	16	.057	17	12.02	10	8.27	11	10	10	80	23	5	21	78
E41 x E41	14	13	3	89	29	.040	29	10.14	28	7.56	17	8	1	92	27	4	24	77
E34 x E41	14	13	5	88	30	.036	30	9.74	30	7.26	12	9	7	83	16	6	20	79
E19 x E2	14	13	11	84	24	.053	21	11.80	26	7.83	4	16	20	70	16	6	21	78
E5 x E14	14	13	17	79	9	.061	11	12.35	7	8.31	12	9	7	81	5	19	11	86
E40 x E41	14	13	19	78	2	.066	2	12.85	5	8.33	20	5	16	71	14	8	12	85
E41 x E14	14	13	21	76	1	.067	1	12.90	1	8.48	27	3	17	70	16	6	8	89
E28 x E14	14	13	25	75	25	.052	25	11.58	23	7.93	22	4	15	73	30	3	30	63
E40 x E2	21	11	11	84	21	.055	18	11.99	25	7.85	12	9	17	70	23	5	12	85
E45 x E14	21	11	19	78	5	.063	5	12.67	18	8.15	22	4	27	58	12	10	15	84
E45 x E2	23	10	13	83	18	.056	18	11.99	21	8.08	22	4	12	78	14	8	25	75
E19 x E41	24	9	1	91	23	.054	24	11.70	15	8 19	8	13	14	76	12	10	10	87
E40 x E14	24	9	21	76	16	.057	13	12.19	24	7.89	27	3	28	49	23	5	16	83
E5 x E41	24	9	21	76	11	.060	15	12.13	2	8.42	2	23	7	82	6	15	4	91
E19 x E29	27	8	27	74	11	.060	10	12.47	20	8.14	27	3	26	59	7	14	8	89
E19 x E14	28	6	28	68	9	.061	6	12.57	17	8.16	22	4	30	47	16	6	25	75
E41 x E33	28	6	30	58	18	.056	21	11.80	12	8.26	5	15	10	81	4	20	4	91
3697	30	3	28	68	28	.044	27	11.03	29	7.30	27	3	29	48	23	5	28	64
Pedigree		14		81		.057		12.00		8.13		10		73		11		83
Routine		3		68		.044		11.03		7.30		3		48		5		64
Diff.		+367%		+19%		+28%		+9%		+11%		+233%		+52%		+120%		+30%

2. NCII, mean tree volume for 12 families

	paternal E29	E14	E33	maternal mean
maternal E40	$0.0648m^3$	0.0568	0.0638	0.0618
E41	0.0620	0.0671	0.0561	0.0617
E19	0.0604	0.0611	0.0625	0.0613
E28	0.0571	0.0522	0.0447	0.0513
paternal mean	0.0611	0.0593	$0.0567m^3$	

paternal LSD - 26, maternal LSD - 30, Pat. x Mat. LSD - 52

NCII - percentage of plus crop straight/branch trees

	paternal E29		E14		E33		maternal mean	
maternal								
E40	19%	6%*	9	3	21	11	16	7
E41	19	9	13	3	6	15	13	9
E19	8	3	6	4	15	14	10	7
E28	14	10	13	4	15	24	14	13
paternal mean								
	15	7	10	4	14	16		

*first figure is tree strightness, second refers to branch thickness.

There is considerable variation in growth, and the number of very straight and finely branches trees. The seven parents shown were all included in the Joondalup seed orchard. In the first cull thinning in 1974, parents E28 and E14 were removed.

3. demonstration blocks 1 and 2

For the consultation, block 1 was thinned in July 1976 to 540 s.p.ha, and remaining trees were pruned to a height of 4.5 m. All trees in block 2 were also high pruned.

	Before thinning	After thinning
stocking	1080	540 s.p.ha
mean height	8.69	8.89 m
mean diameter	13.57	14.06 cm
mean volume	0.0751	$0.0824\ m^3$
stand volume	81	$45m^3/ha$

Appendix 10

Yanchep plantation hydrological studies

Summary

The major factor determining *Pinus pinaster* growth potential, within the Mediterranean climate of the Swan coastal plain, is soil moisture availability. This in turn is governed by the depth, and moisture holding capacity of the porous sand which limits the magnitude of moisture storage during the winter, and by the density of the stand, which controls the rate of exhaustion of the stored water during the spring and summer season.

Manipulation of the stand density by thinning increases the throughfall and hence the recharge of the soil moisture system. Withdrawal over the long summer drought period is regulated by a lower density of trees. Cambial growth is concentrated by thinning on high value crop trees. In dense stands, cambial growth stops in November, but continues into April in open stands. Effectiveness of fertilizer application is dependent on moisture condition of the soil profile.

Location

Study was conducted in the 'Hundred Acre Block' of the Yanchep plantation complex at Latitude 31°29'S and Longitude 115°42'. This is approximately 55 km north of Perth and 10 km from the ocean. Elevation is 45m, and depth to ground water is approximately 16m.

Study

A large thinning experiment was established in the P1952 study area in 1966, with the objective of relating increment to stand density levels. Stand density, expressed as basal area was to be maintained by periodic thinning at 25, 17, 11 and 7 m^2ha^{-1}. Each treatment plot was duplicated, and repeated on five different site types. The duplication of plots allowed the 1972 testing of a fertilizer factor. Treatment involved the application of 0.5 tonnes Superphosphate with zinc and copper trace element plus 0.25 tonnes ammonium sulphate per hectare.

In 1968, detailed hydrological studies were grafted onto this basic design as the importance of soil water to pine growth potential was realized.

Results

Canopy interception of rainfall, stem flow and through fall was studied at the trial area in 1968, and again in 1970. Of rain falling annually on the *Pinus pinaster* forest, the portion that is intercepted at leaf and stem surfaces was found to be 10 per cent in the open $7m^2ha^{-1}$ stand, increasing to 26 per cent in the dense $25m^2ha^{-1}$ forest. The amount of intercepted rainfall replenishing soil moisture reserves as stem flow is relatively insignificant, being 6 per cent of intercepted water at both levels.

The inverse relationship between stand density and throughfall, or effective rainfall, has a major bearing on the recharge of the soil moisture reservoir, and through this the potential for pine growth. Increasing the basal area of a stand to $25m^2ha^{-1}$ effectively reduces the average annual rainfall at Yanchep of 780 mms to 590 mms. In an open stand, throughfall is 708 mms, which is higher than the amount received at the soil surface under the native woodland.

The soil wetting front under the dense stand has not been observed in the study period to go beyond the 6 m soil depth. This results from a considerably lowered uptake, and a concurrent greater evapotranspirative demand through the greater density of trees. Considerable discharge of moisture below the 7 metre sampling depth has been recorded for the native woodland and open pine stands.

Figure 1 shows a plot of data from an open $7m^2ha^{-1}$ stand and a dense $25m^2ha^{-1}$ stand. It is a composite figure detailing the moisture stored in the soil profile and its depletion over a summer period, and relates the average tree increases in diameter to these factors.

Moisture storage in the open stand is near field capacity at the end of the rain season. Withdrawal is uniform until mid-January, and then continues at a reduced level over the remaining drought period. Water is not limiting, and diameter growth at the maximum rate is possible. After January, greater evapotranspirative demands on a diminishing moisture supply slows the rate of diameter growth.

In the dense stand, the soil profile is saturated to a 4.5 m depth only. There is a rapid withdrawal of available water, culminating in mid-November. This immediate exhaustion of soil moisture is reflected in the graph of tree diameter growth. Growth ceases at this date.

Results of cumulative summer moisture withdrawal and winter recharge for the 1972 hydrological year are presented in Figures 2 and 3 for native woodland and three pine stands. Any change in the profile during the summer period, due to evapotranspiration, or deep drainage is defined as moisture withdrawal. In each graph, the zero line represents the soil profile moisture condition at the commencement of the phase. In Figure 2, this line approximates the saturated profile in September.

In each Figure 2 graph, there is an approximate linear transgression of the soil moisture withdrawal curves with time. They indicate a similar extraction of water through the 7m profile, and suggest a uniform distribution of plant roots within this depth. A higher concentration of plant roots is indicated in the surface 2 metres under both pine and native woodland, by a more rapid moisture depletion at this depth.

For each treatment class, the moisture profile at the end of April, which is the driest part of the season is similar from year to year. This condition approximates the wilting point, and when it is reached, the deep rooting plants enter a state of dormancy.

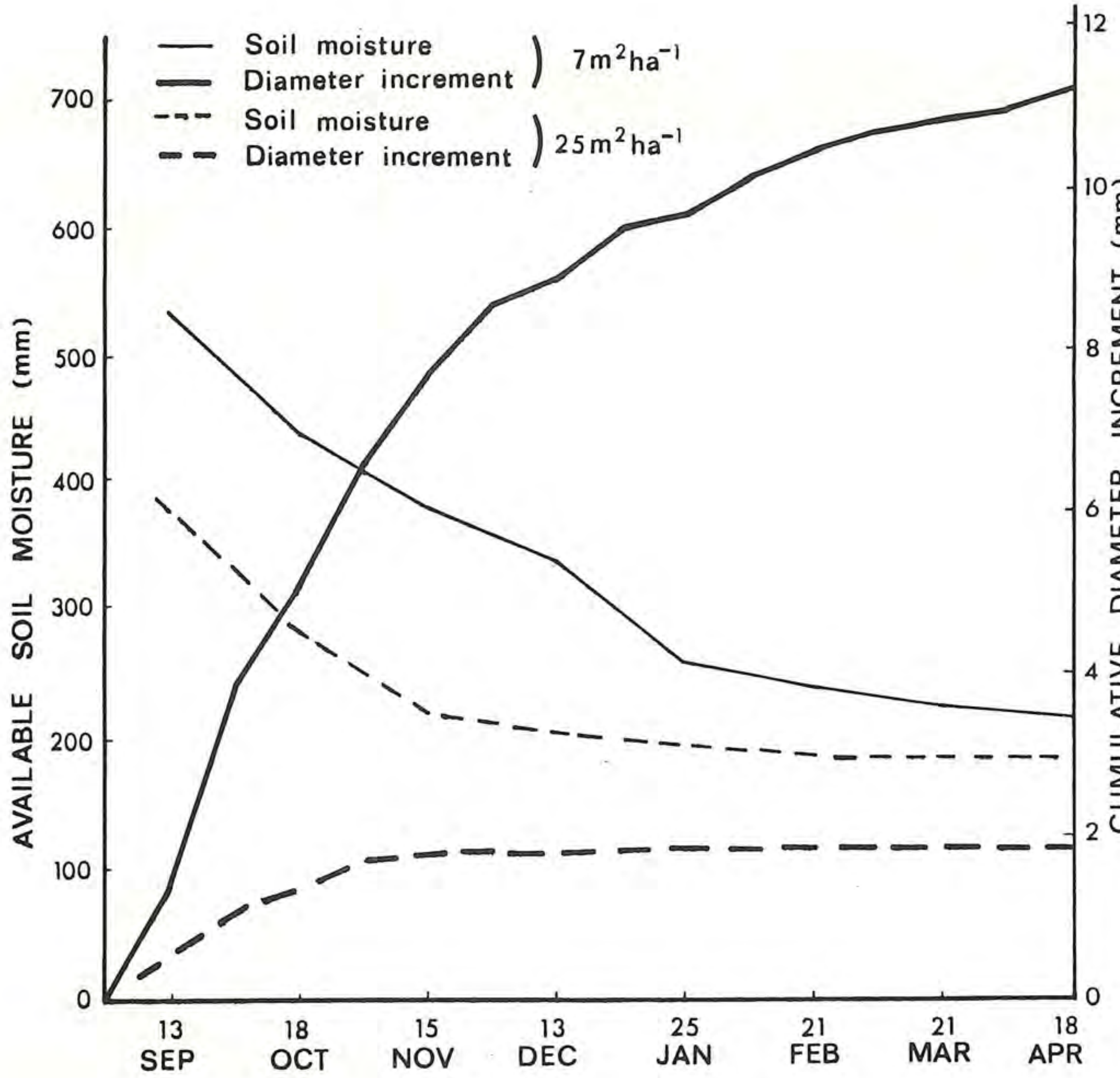


FIGURE 1.

Total soil moisture withdrawal and related diameter increment over the summer drought period. *P. pinaster*.

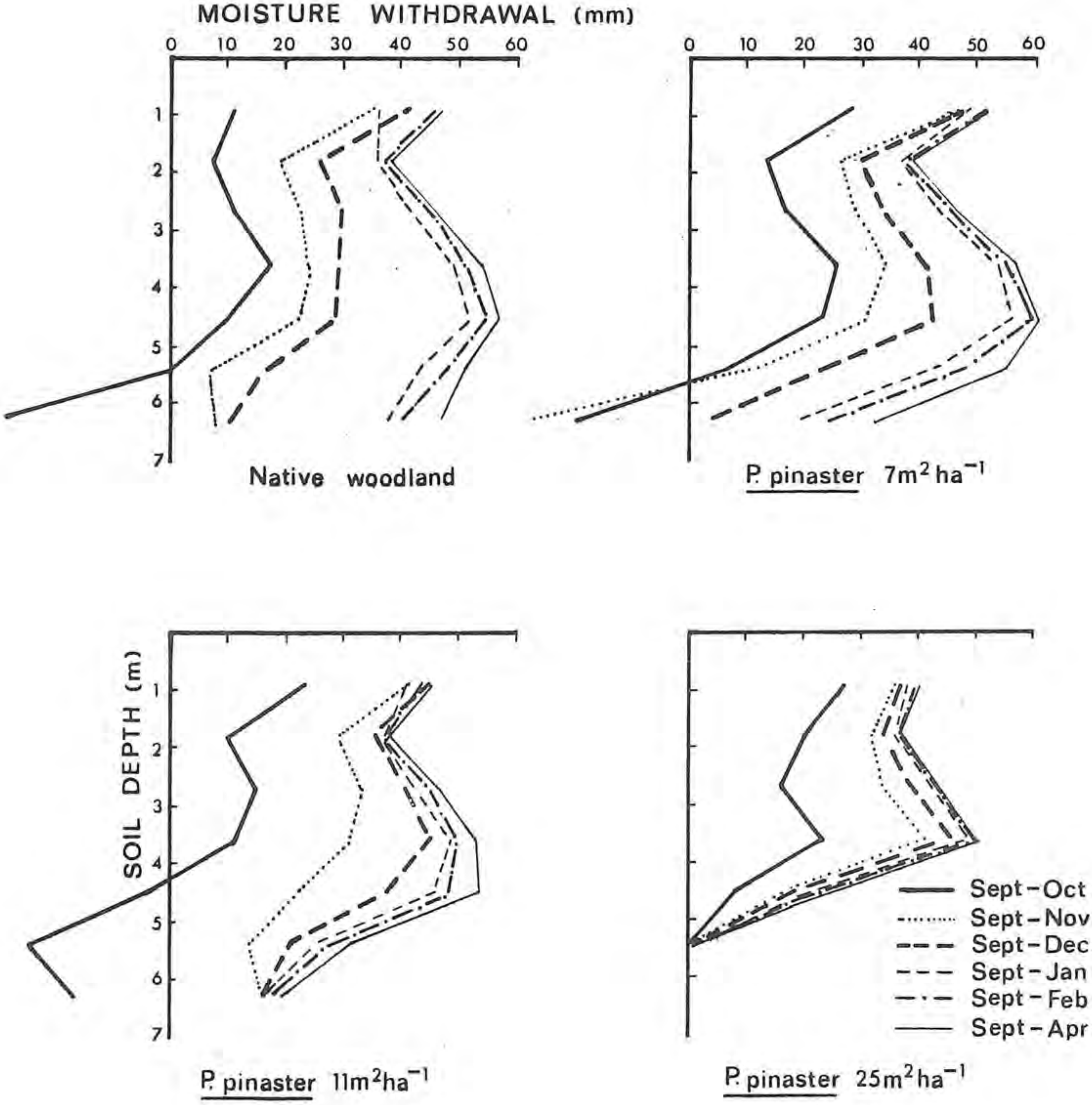


FIGURE 2

Patterns of progressive moisture withdrawal with depth for native woodland and pine stands.

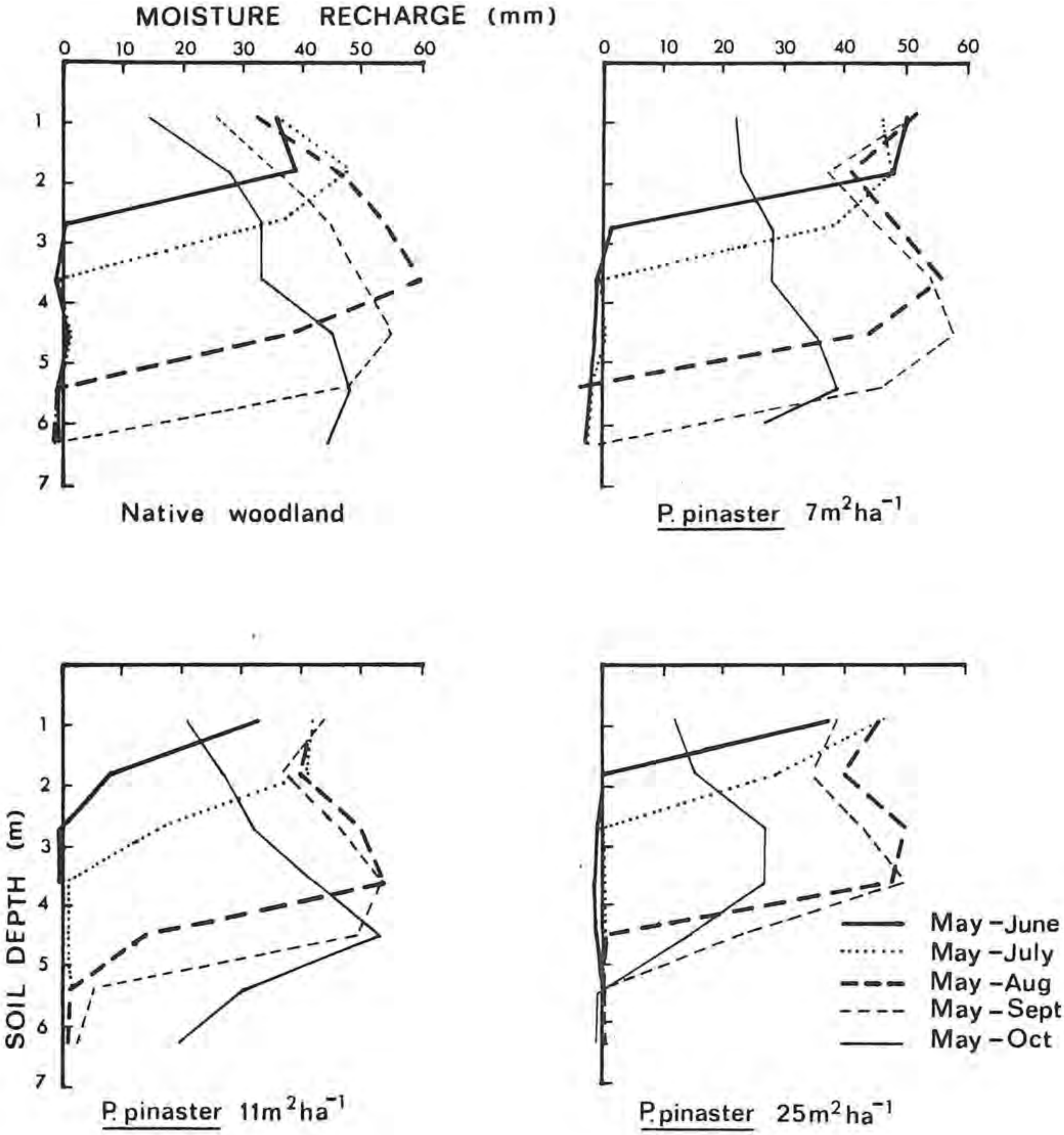


FIGURE 3

Patterns of progressive moisture replenishment with depth for native woodland and pine stands.

Reference

Butcher, T.B. (1977). 'Impact of moisture relationships on the management of Pinus pinaster Ait. plantations in Western Australia. Journal of Forest Ecology and Management (in press).

Butcher, T.B. and Havel, J.J. (1976). 'Influence of moisture relationship of thinning practice.' New Zealand Journal of Forest Science 2.

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Appendix 11

Pinus pinaster provenance trial - WP 3/65

Introduction

Provenance trials comparing stock from forest centres scattered over the natural range of the species were established from 1929 to 1939. As a result of this investigation, all seed used in the Western Australian plantation programme since 1940 has been of Portuguese origin.

Trial design of these early large plantings did not permit sound statistical interpretation of the measurement data obtained. Plans were then made to repeat the provenance tests, with a statistically designed trial. This was to serve as a field demonstration of the provenances, as well as providing statistical data.

This new trial was fortuitous, as the major provenance trial, planted in 1931 on Gnangara compartment A19, was destroyed by wildfire, on January 22nd, 1962.

Location

Gnangara plantation, section G, compartment 101, Latitude 31°43', Longitude 115°53', Altitude 60m.

Site

Moist sand, with dark grey humusoid surface, and organic horizon at depth, occurring in flat-swamp transition of the Bassendean dune sands.

Site has a dense understorey vegetation cover, much of which is still present. Species include Hypocalymma angustifolium, Pultenaea reticulata, Xanthorrhoae preissii, Adenanthos obovata, and Leptospermum ellipticum.

Part of the experimental area was inundated by water in winter 1965.

Design

The five provenances in this study were planted in a Latin Square experimental design. Plot size was 0.06 hectare, and contained 128 trees at 2.4 x 1.8 m spacing.

1 year old tubed seedlings for each provenance were hand planted on the prepared site in June 1964.

Plots were thinned in December 1970 to retain 42 trees, equivalent to 740 stems per hectare. Thinning on the basis of form, vigour and spacing.

Measurement

December 1969, age 5.5 years - tree height, number of whorls per tree, number of branches in whorl nearest 1.3 m height, branch angles for largest and smallest angles in this whorl, production of pollen or cones.

January 1973, age 8.5 years, height and diameter.

January 1975, age 10.5 years, height and diameter, volume, and subjective assessment of tree form and branching.

Results

Comparison of provenances at age 5.5 years

Origin	Height mean m	Number whorls per meter of height	number of branches whorl	Average branch angle at 1.3 m height		Per cent trees in 1969 with	
				largest	smallest	pollen	cones
Leiria	3.8	1.7	5	66°	44°	99	45
Lucca	3.7	1.6	5	66	44	99	53
Landes	2.6	2.1	6	62	41	9	1
Corsica	2.6	2.2	6	62	41	17	1
Italy	2.5	2.4	5.5	63	44	73	13

The height superiority of the Portuguese provenance, its tendency to uninodal habit and early flowering characteristic are clearly evident from the data in the table. The Luccan stock is almost identical in appearance and growth characteristics within the trial. An inspection of the original stand at Val Freddano in Italy confirms that it is atypical, although considered to be indigenous. The Italian provenance in the table is representative of normal Italian stands.

Comparison of provenances at age 10.5 years

Origin	Height mean m	Diameter mean cm	Volume m^3/ha ob. stand	6 cms crop	Straightness per cent trees plus	accep.	Branch thick. plus
Leiria	8.7	13.1	31	12	34	93	20%
Lucca	8.3	12.7	28	10	32	86	20
Landes	6.0	10.1	1	0	56	96	21
Corsica	6.0	10.4	1	0	53	94	20
Italy	5.8	9.8	1	0	9	78	18
LSD	0.7	1.0	8	3			

This data pertains to the thinned stand. There has been a selection of 1:3 practiced in the thinning treatment, and mainly on the tree form character. The stem strightness, and branch thickness character refers to the percentage of trees in a class, and is for a selected population. Consequently, values are considerably higher.

PINUS PINASTER PROVENANCE TRIAL

W.P. 3/65

PLANTED AT GNANGARA G-101 IN 1964

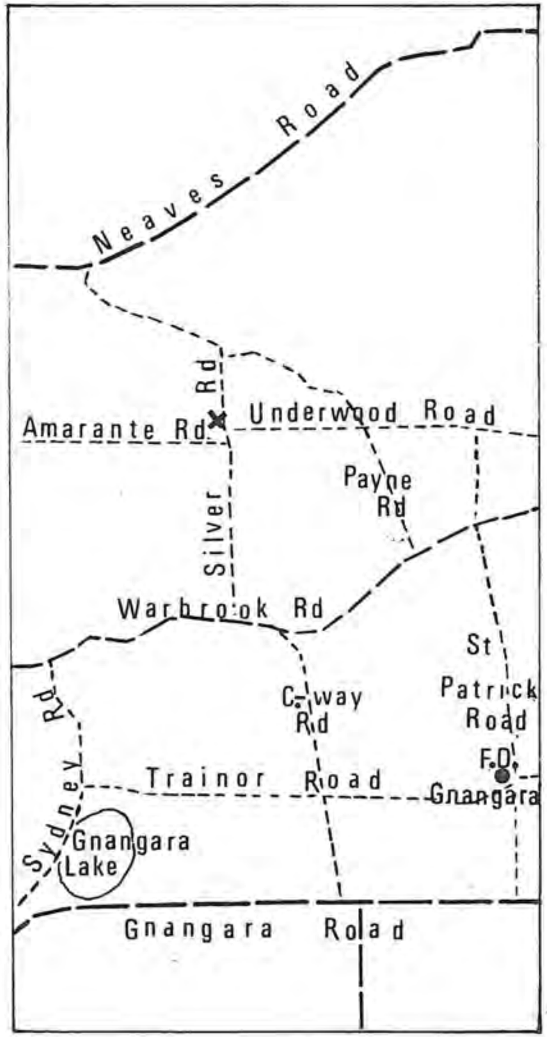
ITALIAN 2864	LANDES 2865	LUCCA 2855	CORSICAN 2897	LEIRIA 2866
LANDES 2865	ITALIAN 2864	CORSICAN 2897	LEIRIA 2866	LUCCA 2855
CORSICAN 2897	LUCCA 2855	LEIRIA 2866	ITALIAN 2864	LANDES 2865
LEIRIA 2866	CORSICAN 2897	LANDES 2865	LUCCA 2855	ITALIAN 2864
LUCCA 2855	LEIRIA 2866	ITALIAN 2864	LANDES 2865	CORSICAN 2897

N

5	6	15	16	25
4	7	14	17	24
3	8	13	18	23
2	9	12	19`	22
1	10	11	20	21

Underwood Road

Silver Road



Appendix 12.1

Pinus pinaster progeny trials XS7 (1966)

Location

Gnangara Plantation F section Compartment 7. Latitude 31°43. Longitude 115°54'. Elevation 65 m. Approximately 32 km north of Perth.

Object

To compare the performance of 39 open pollinated families with each other, and with a "routine" control. The significance of this trial is that the half sib seed was collected from parent trees in the Forest of Leiria, Portugal. Wherever possible, Mr D.H. Perry picked cones from his selections, and forwarded this seed to Australia. Unfortunately, cones from each of his 85 selections were not always available.

Site

Original vegetation consisted of scattered *Banksia menziesii* and *B. attenuata* trees (4 - 6 m) and a rich ground cover comprising *Boronia purdieana*, *Astroloma xerophyllum*, *Leucopogon conostephioides* and *Scholtzia involucrata*. This vegetation is characteristically developed on deep, dry pale grey sands, which are strongly leached throughout, occurring on dune crests within the Bassendean Dune System.

Area was scrub rolled, burnt and cultivated. Furrows were scribed in the ploughed land at 3 m intervals. Seedlings were planted in June 1966, as 1 + 0 o/r stock.

Fertilizer was applied at planting as 110 gms superphosphate per seedling broadcast at age 5 as 0.5 tonne per hectare superphosphate, and again in 1976 at age 10, as 0.5 tonne per ha superphosphate plus 0.2 tonne per ha urea.

Design

Randomized block, the 40 treatments are replicated x 12, and the plot unit is ten trees in a line. Spacing was 3 x 1.5 m or half the norm used with tubed stock, to guarantee adequate stocking. Stocking was reduced to 5 trees per line at age 5.

Results

1) January 1970, age 3.5 - all trees measured for height.
2) January 1974, age 7.5 - all trees measured for height diameter, and subjectively rated for stem and branching quality.

Correlation of these two measures r = 0.9
height c.a.i. 0.8, illustrates the very poor quality of this site type.

Height and diameter growth for routine and mean pedigree is similar. However, tree form has been substantially improved. The number of straight trees was increased from 53 to 85 per cent, and very straight trees from 7 to 14 per cent. Also, the number of trees with low angled, moderate size branches has been increased from 53 to 72 per cent.

If only the top 10 parents are considered, E124, E149, E152, E154, E157, E158, E160, E164, E165 and E182, there is a gain of 7 per cent in height growth, together with a three fold increase in the percentage of very straight trees. If only these trees comprised the clonal seed orchard, it would be reasonable to expect a 14% increase in height growth, and a very large, 370% increase in the number of very straight trees.

Remembering that there is no land race in this trial, and that all seed has come from Portugal, either as selected or non selected material, the tabular results for stem straightness ranks all parents above the routine. Heritability for this character is high at $h^2 = 0.6$. These selections from Portugal will make a very significant contribution to the improved stem form of progeny from the Mullaloo seed orchard.

This trial was planted on an extremely poor site, but 16 of the families were planted on a good sandy loam site at Mundaring. Four years height growth c.a.i. at Gnangara was 0.8 m, while at Mundaring it was 1.3 m. The important result here was the similar performance of families regardless of the environment, i.e. there is a no apparent genotype-environment-interaction.

Certain outstanding parents have been indicated from this trial. Of particular note is parent E165. This has top ranking for stem form, vigour and branching character. E165 will be looked at in the field trial.

Measurement summary at age 7.5 years

Parent	Stem straightness				Height		Basal area		Branching	
	r	plus	r	acc.	r	m	r	cm^2	r	acc
E101	37	5%	36	75%	7	5.49	4	53	16	72%
E102	24	10	32	78	30	5.06	19	45	39	53
E103	12	15	23	85	34	4.96	38	38	5	82
E104	12	15	31	80	14	5.35	15	49	16	72
E105	8	18	1	95	32	5.03	28	43	38	58
E107	24	10	11	88	25	5.15	28	43	7	80
E110	20	13	18	87	24	5.16	19	45	31	67
E111	24	10	27	83	27	5.14	28	43	11	75
E112	2	23	3	93	40	4.75	38	38	23	68
E113	24	10	33	77	18	5.31	28	43	19	70
E115	20	13	11	88	11	5.41	9	50	16	72
E117	24	10	29	82	10	5.42	9	50	5	82
E118	12	15	23	85	29	5.11	28	43	23	68
E123	24	10	18	87	31	5.04	19	45	35	65
E124	5	20	1	95	14	5.35	19	45	19	70
E132	12	15	7	90	35	4.94	40	37	23	68
E134	12	15	23	85	20	5.18	27	44	7	80
E141	40	2	37	73	23	5.17	15	49	19	70
E143	20	13	18	87	32	5.03	36	39	1	87
E146	20	13	29	82	8	5.48	3	54	37	63
E149	5	20	6	92	13	5.37	9	50	31	67
E152	2	23	11	88	2	5.76	4	53	11	75
E154	12	15	7	90	1	5.86	1	62	23	68
E157	4	22	23	85	20	5.18	19	45	23	68
E158	9	17	11	88	11	5.41	7	52	2	83
E160	12	15	11	88	6	5.52	9	50	2	83
E161	37	5	11	88	27	5.14	19	45	23	68
E162	24	10	18	87	4	5.65	7	52	11	75
E164	5	20	7	90	5	5.59	4	53	23	68
E165	1	30	3	93	3	5.68	2	56	9	77
E168	24	10	7	90	19	5.25	28	43	2	83
E171	24	10	33	77	39	4.76	36	39	31	67
E172	12	15	18	87	37	4.92	18	47	35	65
E173	24	10	39	62	37	4.92	35	41	31	67
E174	37	5	38	72	9	5.44	9	50	11	75
E178	9	17	11	88	36	4.93	19	45	19	70
E180	24	10	3	93	20	5.18	34	42	23	68
E181	24	10	33	77	16	5.34	15	49	9	77
E182	9	17	27	83	17	5.32	19	45	11	75
Routine	36	7	40	53	25	5.15	9	50	39	53
pedigree mean		14%		85%		5.25m		$47cm^2$		72%
difference		+100%		+60%		+ 2%		- 6%		+36%

PINUS PINASTER PROGENY TRIAL

XS 7

PLANTED AT GNANGARA F-7

IN 1966

182	132
102	164
180	149
157	113
181	178
103	173
112	171
104	124
118	117
r	134
172	168
162	146
105	160
174	152
115	107
161	158
143	111
110	165
123	101
141	154

146	161	r	105	146	181	143	160	162	172
181	104	173	124	165	154	149	180	118	158
171	168	174	182	161	174	110	158	160	168
134	180	160	107	162	117	132	123	123	117
154	160	178	123	113	158	r	165	161	154
113	149	146	117	101	160	174	117	107	105
157	112	104	149	r	102	182	164	174	173
124	103	181	161	143	171	152	102	115	111
117	172	165	172	103	123	113	168	182	164
123	178	141	152	172	134	161	162	180	146
158	132	134	157	178	104	118	154	103	171
182	111	168	180	118	149	105	171	104	178
143	118	154	162	110	180	107	141	157	101
141	107	118	112	152	157	115	134	141	149
165	105	143	113	115	105	104	146	112	110
110	173	132	101	168	112	101	103	132	143
101	164	103	110	173	182	178	172	181	165
162	152	111	171	107	111	157	111	124	r
174	102	158	164	164	132	181	173	134	102
115	r	115	102	141	124	112	124	152	113

165	143	124	113	103	168
123	124	164	162	143	123
110	162	118	152	172	107
172	180	161	171	161	157
182	146	123	172	173	110
168	112	174	158	134	146
103	154	160	168	160	117
115	158	173	101	165	141
152	r	115	134	113	102
164	174	105	178	132	171
173	102	180	r	180	118
101	132	107	117	112	115
134	178	102	104	101	154
105	107	141	181	174	149
171	160	154	149	152	164
141	157	103	111	124	158
111	113	132	182	105	178
149	117	157	165	181	111
118	104	110	146	162	104
181	161	112	143	182	r

172	173	161	141	158	104
r	117	113	168	180	154
124	168	182	132	161	164
149	118	124	180	165	117
134	112	112	118	178	181
107	141	165	146	146	105
162	111	110	160	168	112
178	174	103	101	174	110
154	132	104	174	149	101
181	110	152	143	111	118
123	165	107	111	113	132
102	152	105	102	141	172
115	103	158	172	173	143
146	164	134	162	107	160
113	105	157	115	r	115
180	104	178	173	157	134
143	157	171	149	103	171
182	171	r	117	162	124
160	161	123	181	102	182
101	158	154	164	152	123

Appendix 12.2

Pinus pinaster progeny trial YS 1 (1965)

Introduction

This is the first progeny trial of the P. pinaster breeding programme. It was planted in 1965, adjacent to the area on which XS7 was later established. Detail on location and site is provided in appendix 12.1

The intended site for this trial was on land prepared alongside the 1964 provenance trial (appendix 11) but this was inundated with water shortly before planting was scheduled to commence. The present site had already been cleared, and so the area was quickly pegged to facilitate this progeny test. Unfortunately, this site type is very poor (Havel G), and nowadays would not be considered for afforestation. Results however, from this trial have been outstanding.

Design

The experiment was planned with a Latin Square design, in an attempt to eliminate all site variation from the analysis. Six control pollinated families, involving 7 W.A. parental selections, and a bulk unimproved seed source from the Leirian stand, used in routine afforestation, are planted in this design. Each family is represented by a 9 tree square plot, and spacing is 3 x 3 metre.

Results

January 1970, age 4.5 height measurement.
April 1974, age 9, height and diameter measurement. Assessment of tree form and branching character.

January 1977, age 11.5, height and diameter measurement.

Height summary at the various ages is given on page 14 of the notes, to illustrate the constancy of the height superiority of the pedigree stock. This was 25 per cent at each of the measured ages. The early height measurement was well correlated with these later measures (age 9, $r = 0.9$ and age 11.5, $r = 0.8$).

A most noticeable feature of this trial is the very small variance within the family units, contrasted with the extreme growth variation in each of the routine plots. This will be demonstrated at the field stop by standing in the centre of any routine plot and looking along the columns and rows of the Latin Square, into Pedigree stock.

Data summary - mean tree

Family	Vol. 9 yr	Diam 9 yr	Vol. 11.5 yr	Diam 11.5 yr	Height 11.5 yr	Straight plus
E27 x E2	$.037^{m3}$	10.4 cm	$.067^{m3}$	13.4 cm	9.1 m	6%
E40 x E2	.037	10.4	.062	13.1	9.0	6
E21 x E2	.033	9.9	.059	12.8	9.0	6
E16 x E2	.032	9.7	.056	12.6	8.9	18
E28 x E5	.033	9.8	.054	12.3	8.8	5
E21 x E5	.033	9.7	.054	12.2	8.8	10
Routine	.020	8.0	.031	10.3	7.2	2
LSD	.004		.009	0.7	0.4	
Mean pedigree	$.034^{m3}$	10.0 cm	$.059^{m3}$	12.8 cm	9.0 m	8%
difference	+70%	+25%	+90%	=24%	+25%	+300%

Differences in all measured characters have been large between the pedigree families, and the routine source. This being the first breeding test, has been very gratifying to the breeding team.

In particular, the difference in mean tree pedigree volume, and the routine has been extremely large, and was measured as 90 per cent at age 11.5 years. One reason for this large difference is the variation within the routine lot. After thinning treatment, and the removal of small routine trees, the average volume should increase dramatically. In the uniform pedigree lines, mean tree volume will not alter appreciably with thinning, and this large difference will decrease.

Tree volumes were calculated by the department's A.D.P. section using the Gnangara regression equation at age 9, and again at age 11.5 years. Pedigree c.a.i. is 11 m^3ha on a poor dry grey sand, in comparison to 4 m^3/ha for ordinary stock.

Height c.a.i. for a seven year period was 0.9 m for mean pedigree, and 0.7 m for routine.

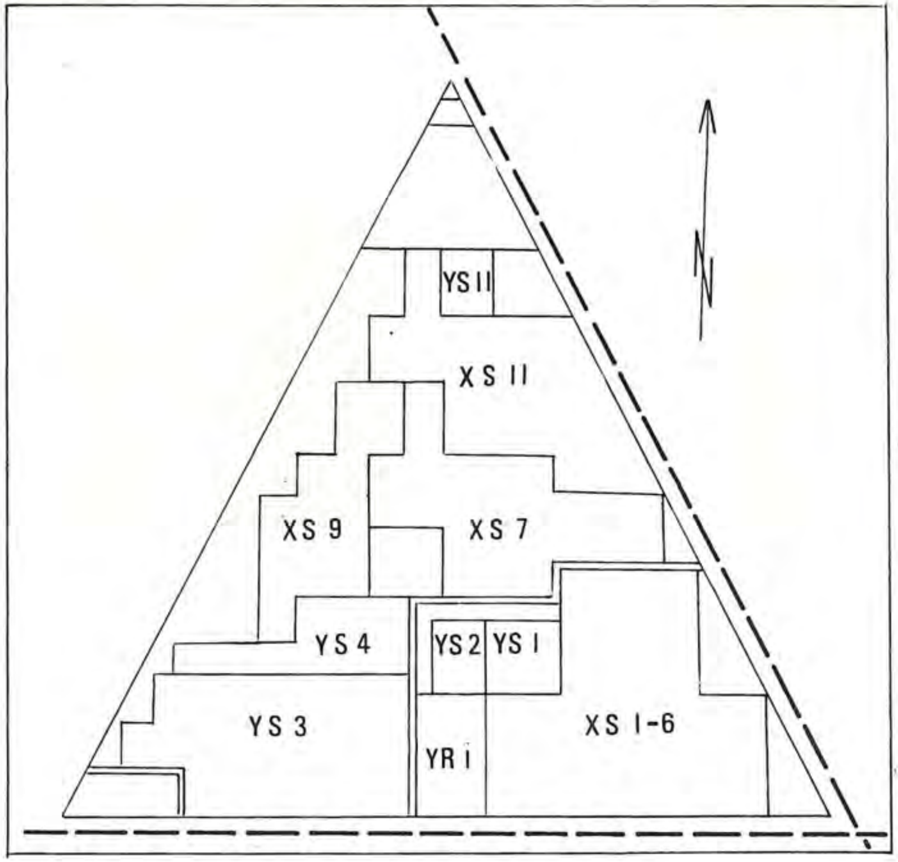
PINUS PINASTER PROGENY TRIAL

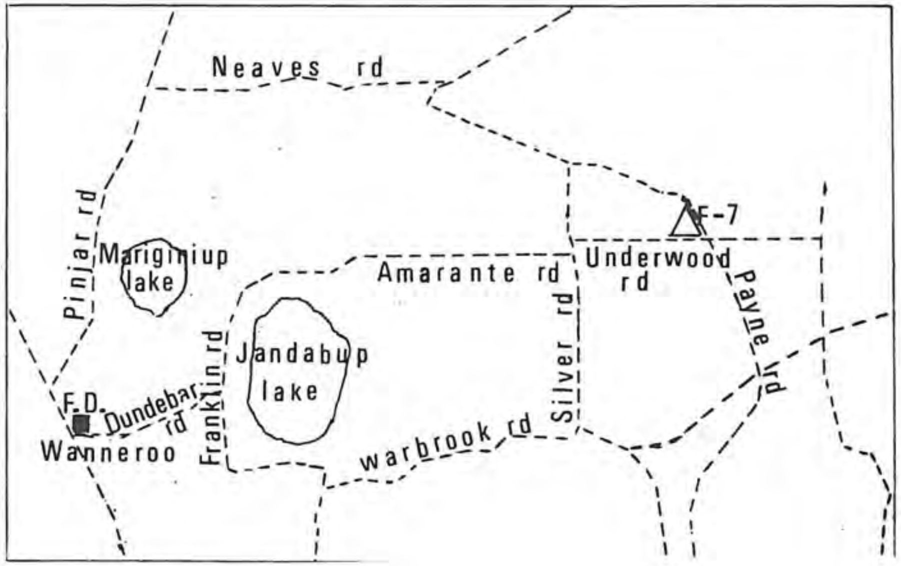
YS - I

PLANTED AT GNANGARA F-7

IN 1965

21x2	28x5	21x5	40x2	3056	16x2	27x2
28X5	21x5	16X2	27X2	21x2	40X2	3056
16X2	40X2	27x2	21X2	21X5	3056	28X5
40X2	27X2	3056	28X5	16X2	21X2	21x5
3056	21X2	28x5	16x2	27x2	21x5	40x2
27x2	3056	21x2	21x5	40X2	28X5	16X2
21x5	16x2	40X2	3056	28X5	27X2	21X2





Appendix 13

Pinus pinaster plantation establishment on the Northern Swan coastal plain

Summary

A resume of *Pinus pinaster* plantation establishment in the Wanneroo Division is given. The reason why certain techniques are used and possible new techniques being considered are mentioned.

Introduction

Since 1967 the annual planting rate in the Wanneroo Division has been 1,000 ha. Planting such a large area in a relatively short time (the planting season runs from approximately mid June to the end of July) requires extensive pre planning and close day to day supervision to ensure a good result. In contrast to more southern Divisions the natural vegetation for the majority of the plantable coastal plain is Banksia bush with a small percentage of Jarrah (*Eucalyptus marginata*). This is important as the cost of clearing Banksia bush is substantially lower than the cost of clearing jarrah bush.

Initial clearing

Initial clearing, the process whereby the standing vegetation is chained down, involves using two large bulldozers (usually D7 size) moving parallel to each other up to 40 metres apart and pulling a heavy chain. No ball is required on the chain as the Banksia bush is readily pulled down using this technique.

In the heavier jarrah bush the dozers move closer together and a third dozer is required to lift the chain off the ground making it easier to pull the heavier trees down.

As close to December 15 (December 15 is the start of the prohibited burning season) as possible, 12 months after the chaining, the area is subject to a broadcast burn. Usually this results in a hot burn which makes the job of final clearing so much easier. Cost of chaining $3.02/ha.

Final clearing

This can and usually does begin immediately following the broadcast burn. Final clearing is carried out by private contractors and it has been found that close supervision is required to ensure an adequate job result. The supervising officer ensures that a minimum amount of debris remains on the ground and that heaps of logs etc are stacked at least 40 metres inside the boundary.

Machinery used in final clearing varies from year to year. In 1977 for example dozers (D 7) with 5.5 metre rakes were used. In 1976 a rubber tyred Michigan with an 8.5 metre rake was used. In all cases a small rubber tyred tractor fitted with a blade has been found to be essential to follow the larger machines and push up small logs missed by the larger machines.

Final clearing should be completed as early as possible to allow the subsequent operations of ploughing and furrow lining to begin in sufficient time to allow these operations to be completed prior to the opening of the planting season.

1977 cost: $14.80/ha in the predominantly Banksia area

$27.00/ha in the predominantly Jarrah area.

Ploughing

The progress of the final clearing is planned to facilitate ploughing. The usual procedure is for the ploughing to begin in one section while the final clearing is still progressing in other sections.

The area is ploughed to a depth of 17½cm. However, it is felt locally that a depth of 30 cm would result in the twofold effect of less scrub regrowth in the initial years following planting and better root development of the young pine seedlings.

As an alternative to ploughing immediately being followed by planting, a technique involving ploughing in autumn, applying 245-T in spring and planting during the following winter is being experimented with during 1977. The advantages of this technique would be better scrub control and lower costs.

Cost of present ploughing operation $8.18/ha.

Furrow lining

Furrow lining begins as soon as ploughing has progressed sufficiently.

Purpose of furrow lining:

1) The 12-15 cm furrow formed by the furrow liner enables the dry sandy soil to collect moisture from a minimum amount of rain. Thus the newly planted pine seedling can survive the otherwise dry environment.

2) Furrow lining provides some protection against scrub competition.

Cost $3.02/ha.

Pine planting

This operation begins as soon as sufficient rain has fallen, usually mid June and lasts until the end of July. Should the season be extended beyond the end of July the young pine seedlings root development would be insufficient to cater for the long dry summer.

Depth of planting has been found to be critical in this harsh environment. Last planting season, a very dry season, seedlings almost fully buried survived whereas seedlings planted normally, that is, to a depth of 2-5 cm below the nursery line, in many cases died.

Sixty grams of superphosphate is applied to each plant at the time of planting. The superphosphate is stored in a 150 kg hopper attached to the planting machine. The device used to deliver the fertilizer is semi automatic, requiring only a lever to be activated by the planter as he plants the pine seedling.

The planting machines used, have been modified from the original Lowther tree planting machines which were imported from the United States of America in 1950. These machines have been modified to allow for, ease of movement through the deep loose sand of the coastal plain, better seating for the planter, and the addition of an automatic fertilizing device.

Spacing for P. pinaster at present is 3.5 x 2.5 m resulting in 1,100 plants/ha.

However, our tree breeding section have developed a superior type of P. pinaster which locally, we call orchard stock as compared to the routine P. pinaster.

As the orchard stock is more vigorous and straighter than the routine stock, planting at wide spacing, for example 3.5 x 4.0 metres (700 spha) is being considered. However before we attempt to plant the orchard stock at this wider spacing we must be able to guarantee:

1. 95% plus survival rate - we already have this.

2. Better quality final clearing. No longer can we afford to miss planting one or two pines when debris is encountered.

Advantages:

1. Fewer plants required to be raised in nursery and planted in field.

2. Saving fertilizer cost.

3. Saving in pruning cost (55/ha).

4. Less chipwood from first thinning.

Cost of planting $33.41/ha.

Total cost of establishment predominantly Banksia bush $62.44 per ha.

Total cost of establishment predominantly Jarrah bush $74.64 ha.

SECTION 10

LIST OF DEPARTMENT PUBLICATIONS INCLUDED WITH TOUR NOTES

Batini, F.E. (1973). Bulletin No. 84. Jarrah dieback - a disease of the jarrah forest of W.A.

Forest Focus No. 12. December, 1973. The Marri woodchip project.

Forest Focus No. 15. August, 1975. Inland Eucalypts - a valuable ecological resource.

Forest Focus No. 16. December, 1975. Sunklands multiple use land management.

Forest Focus No. 17. April, 1976. Forest Policy.

Havel, J.J. (1968). Bulletin No. 76. The potential of the Northern Swan coastal plain for *Pinus pinaster* Ait., plantations.

Hopkins, E.R. (1960). Bulletin No. 66. Germination stimulation in *Pinus pinaster* Ait.

Hopkins, E.R. (1960). Bulletin No. 67. Variation in the growth rate and quality of *Pinus pinaster* Ait., in Western Australia.

Hopkins, E.R. (1971). Bulletin No. 82. Drought resistance in seedlings of *Pinus pinaster* Ait.

Hopkins, E.R. (1971). Research Paper No. 6. Early response to thinning in stands of *Pinus pinaster*.

Lennon, I.G. et al 1976. Forests Department of W.A. Information sheet 38. Publications list.

McKinnell, F.H. (1971). Research Paper No. 2. Commercial thinning in radiata pine.

Perry, D.H. and Hopkins, E.R. (1967). Bulletin No. 75. Importation of breeding material of *Pinus pinaster* Ait. from Portugal.

Shea S.R. (1975). Bulletin No. 85. Environmental factors of the northern jarrah forest in relation to pathogenicity and survival of *Phytophthora cinnamomi*.

White, B.J. (1971). Research Paper No. 4. Regeneration methods in mixed marri-karri stands.

White, B.J. and Underwood R.J. (1974). Regeneration in the karri forest community.