EVALUATION OF NORTHERN JARRAH FOREST ARBORETA FOR POTENTIAL REAFFORESTATION SPECIES

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(C.A.L.M. TECH PAPER)

(i) A NOTE ON THE STRUCTURE OF THIS PUBLICATION

This publication has been divided into 6 booklets.

The first, and major booklet contains the introduction, background information on each of the arboreta and a description of the analyses used in the 1985 Arboretum Survey, and concludes with a summary of results and general discussion.

The remaining booklets constitute a field guide for the arboreta. For the convenience of field observervation, each arboretum has been dealt with in a separate booklet.

These latter booklets entitled "Field Guide and 1985 Performance Analysis" contain location maps, ground plans for the arboreta, provenance information and comprehensive plot-by-plot graphs and tables of the 1985 Analysis results.

CONTENTS

CONTENTS (CONTINUED)

ATTACHMENTS

(SEPARATE BOOKLETS)

P A R T A

INTRODUCTION AND BACKGROUND

FIGURE 1 : Location Of The Northern Jarrah Forest

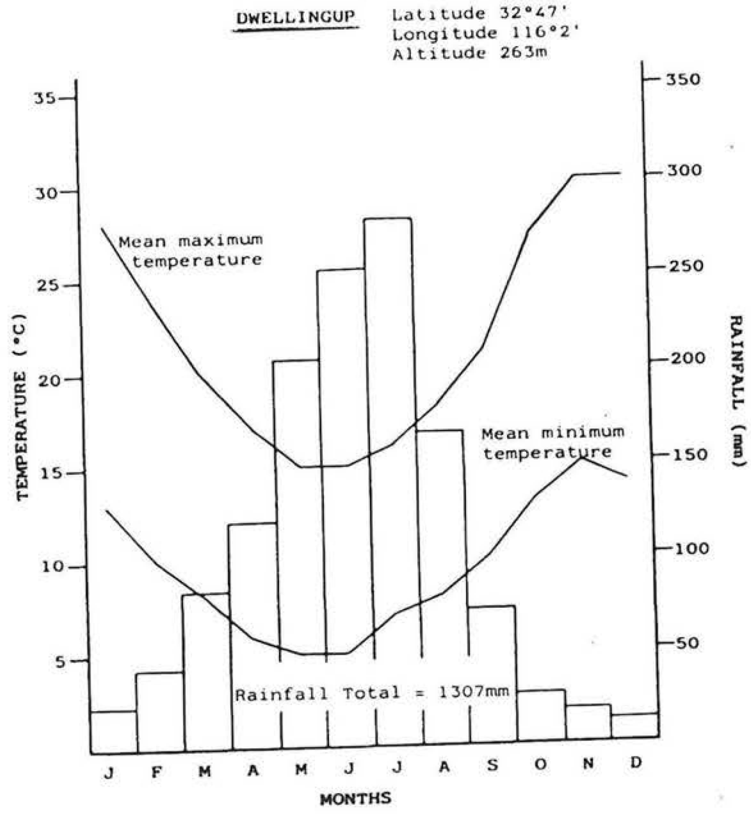
1. INTRODUCTION

European man entered the jarrah forest less than 100 years ago but in that short time his impact on its ecology has been profound. Although it is highly adapted to its harsh soil and climatic environment there is concern that the forest lacks resilience in the face of man induced changes. This is particularly apparent in the Northern Jarrah Forest, an area of about 10^6ha on the wet (800-1300mm rainfall) western fringe of the Darling Plateau of Western Australia. This area is especially well endowed with resources of timber, water and minerals and is close to the major coastal plain population centres of Perth and Bunbury (Fig. 1). It has suffered the most severe impact of man.

Concern for the lack of resilience of the forest is partly attributable to the dominance and vulnerability of the single species jarrah (Eucalyptus marginata D.Donn.). It forms a nearly pure overstorey on the entire area, masking otherwise quite apparent variation in site types (Havel, 1975). Concern also arises from the nature of the problems of disease and salinity afflicting the forest and from the intensity of the uses to which is is subjected.

In the mid 1970's the rapid expansion of bauxite mining in the Northern Jarrah Forest triggered a intensification of research effort (TAG report). The general aim of this work was to develop the capacity to restore and/or maintain effective forest ecosystems in disturbed jarrah forest areas. A major component of this work was to identify overstorey species suitable to replace or augment jarrah, should this be required. For this purpose a series of large arboreta were established on typical disturbed sites to provide a base from which the performance of potential replacement species could be evaluated (Bartle & Shea, 1978).

This report presents background information on the location and design of the arboreta, the selection of species for inclusion, and results of the initial (1985) measurements, including an analysis of performance. It is presented in a format suitable as a guide for field inspection.



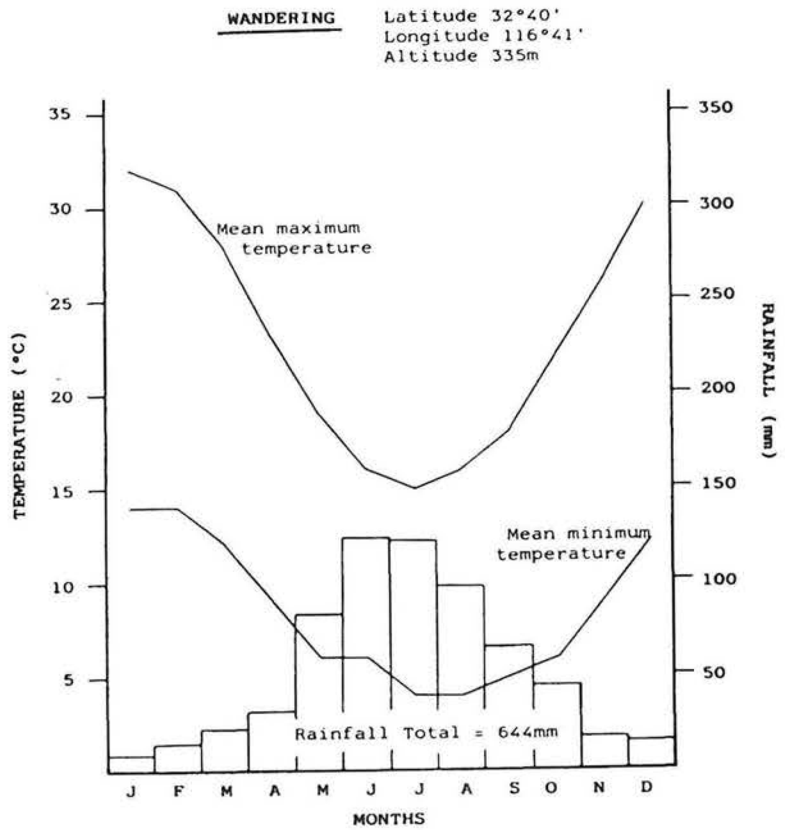


FIGURE 2 Climatic Data For The Northern Jarrah Forest

2. GEOGRAPHY OF THE REGION

2.1 ENVIRONMENT AND ECOLOGY

The Northern Jarrah Forest region has a Mediterranean type climate, though warmer and wetter then is typical (Aschman, 1973). Climatic data for two locations representing the extremes of the west-east rainfall gradient across the forest are given in Fig. 2. Overnight winter frosts occur on some 10-20 days per year, the lowest minimum temperature recorded being -4°C (Hall et al, 1981).

The jarrah forest stands on a low, undulating peneplain with a mean elevation of 300m. It is an ancient, geologically stable surface on which the predominantly granite basement rocks have been exposed to a long period of in-situ weathering to form a deep laterite mantle. The upper horizons of the laterite profile, made up of accumulated weathering resistant iron and aluminium oxides and quartz, are typically 4-5m thick and quite permeable. This is underlain by a kaolin clay horizon averaging 25m thick (Bettanay et al, 1980). The permeability of this layer is enhanced by discrete vertical channels (Johnston et al, 1983, Dell et al, 1983). Being highly weathered the jarrah forest soils are of poor fertility.

In terms of the effectiveness of rainfall, a crucial determinant of plant growth in Mediterranean climates, the jarrah forest is outstanding. The low relief, permeable surface horizons and large depth of permeable clay subsoil provide considerable potential for water infiltration and storage. The jarrah forest is clearly adapted to exploit this water storage (Dell et al, 1983). As a consequence the forest is notable for the dominance of its water balance by evapotranspiration, its low stream yield and accumulation of salts in the soil profile (Low & Stokes, 1981).

2.2 HISTORY OF LAND USE

Early timber cutters introduced the fungus <u>Phytophthora cinnamomi</u> Rands, a soil/water borne root invading pathogen. It causes the disease, jarrah dieback, which on susceptible sites results in complete mortality of the jarrah overstorey and dramatic decline in the diversity and vigour of the understorey (Podger, 1972). The early spread of the fungus was quite slow but accelerated rapidly with the post-war mechanization of logging. It now occurs over some 14% of the forest (Forests Dept., 1982), mostly in the high rainfall zone (>1100mm pa) and locally favours seasonally water logged sites. Severely affected sites, i.e. those with extensive jarrah overstorey mortality, probably make up about half of the infected area. The severity of disease is strongly site dependent. It ranges from extreme on highly susceptible sites to trivial on resistant sites. Current research aims to develop a site classification system so that the possible future course of disease can be predicted and appropriate preventative or rehabilitation methods can be developed. Prevention in the form of hygiene (measures to avoid the spread of potentially infected soil) is already well established (Underwood & Murch, 1984).

Early agricultural development made no inroads into the main belt of the Northern Jarrah forest since it was well protected by an established logging industry, infertile lateritic soils, and, after the Forests Act of 1918, security of tenure as dedicated forest. However, inland of about the 800mm rainfall isohyet, where the forest was of poorer quality and the laterite less well developed, alienation of land for agriculture continued up to the 1960's. Removal of forest in this zone (i.e. less than 900mm rainfall) caused severe secondary salinity and degradation of stream water quality (Peck, 1978). It is now known that potential for salinity extends into the main forest area as far as the intermediate rainfall zone (900-1100mm pa). Only the high rainfall zone (greater then 1100mm pa) is free of the problem (Bartle et al, 1982). Some of the major forest streams which drain from the low rainfall zone have had extensive agricultural development and have been greatly degraded in water quality (Ref). A major reafforestation programme has been commenced in the Collie River Basin to reverse such a problem and further clearing has been banned on several other catchments (Ref).

In recent decades the water catchement function of the forest has displaced timber production as the dominant, on-going use (Forests Dept., 1982). All major streams, with the exception of the Murray River, are or will soon be harnessed for water supply. Some 80% of city supplies come from the Northern Jarrah Forest (Ref). The salinity problem both developed and potential is a serious threat to this use.

The large bauxite reserves of the Northern Jarrah Forest were committed for exploitation in 1961 before the significance of the jarrah dieback and salinity problems was fully realized. From initially modest scale operations mining has expanded rapidly and now extracts some 17 million tonnes of ore from some 350ha of forest per annum. Bauxite occurs as discrete upland ore bodies and consists of the upper porous horizons of the laterite profile (where alumina content is sufficient). The ore is extracted from shallow (average 4.5m) open pits. Pits make up some 25% of the landscape in current mining areas and so the operation directly affects, through access, drainage and aesthetics, some four times the area actually mined. Rehabilitation is an integral part of the operation (Bartle & Shea, 1979, Dept. Cons. & Environment, 1984). With the exception of the small Worsley Alumina operation on the already salt degraded Murray River, mining is limited to the high rainfall zone. Since some 40% of ore reserves occur in the intermediate and low rainfall zone there is a committment to develop rehabilitation methods which will be successful in preventing salinity. In this respect, the risk of disease being spread and potential for existing disease to be intensified by the mining operation is a major concern.

In addition to its production of tangible resources the Northern Jarrah Forest is also important as a recreational venue and for conservation. These uses add a level of public scrutiny and pressure to the development of sound rehabilitation practices.

3. SETTING UP THE ARBORETA

In view of the uncertain prospects for [illegible] and the absence of adequate existing arboreta a proposal [illegible] in 1976 to [illegible] a [illegible] series of arboreta commenced in 1976

3.1 SITE SELECTION

In the project, replicate plantings of a large range of prospective rehabilitation species were established on all major disturbance site types. The character of each disturbance site is determined partly by the natural site variation in the environment and partly by the type of disturbance to which it has been subject. The major sources of natural site variation are the west-east climatic (largely rainfall) gradient and the topographic gradient in edaphic conditions. To adequately sample this variation arboreta should ideally be replicated on at least two rainfall levels (higher rainfall zone - 1300mm, and lower rainfall zone - 800 to 900mm) and at two topographic levels (upper laterite ridge and lower truncated laterite profile). Three major disturbance types occur i.e. bauxite mining, dieback degraded and agriculturally developed. Full replication of these disturbance types for each level of rainfall and topographic position is not required since bauxite mining only occurs on upper topography, agricultural development is only a problem in the lower rainfall zone, and dieback can occur anywhere, though high rainfall, low ~~dieback~~ topography sites are well endowed with existing arboreta (Hart, 1978).

By this analysis seven arboreta sites were targeted. To date five have been established (Table 1).

3.2 SPECIES SELECTION

The species to be tested in the arboreta were limited to the genus Eucalyptus and to two Pinus species commonly used in Western Australia plantation forestry. Restricting the species to eucalypts was partly arbitrary since there could well be species from other genera and other parts of the world which would be successful. But the limit was also rational in that eucalypts are well adapted to the characteristic Australian environment of low fertility, drought and fire proneness. Eucalypts also have the advantage of aesthetic compatibility with the remnant jarrah forest, in association with which all rehabilitation plantings would be made. Another constraint was seed availability. Though some collections were specially commissioned most had to come from existing supplies, mostly those available from the CSIRO Seed Section in Canberra.

The species were selected according to one or some of the following criteria:-

- apparent adaption to drought prone, infertile and saline environments.
- previous indications of good performance in the Northern Jarrah Forest.
- tolerance of fire and Phytophthora cinnamomi.
- timber production potential.
- other forms of production (honey, oils).

TABLE 1

ARBORETUM SITES

ARBORETUM	RAINFALL(mm)	TOPOGRAPHY	DISTURBANCE TYPE
Del Park	1300	upper	bauxite mining
Marrinup	1300	upper	dieback
George upper	800	upper	dieback
George lower	800	lower	dieback
Bingham River	800	lower	agriculture

TABLE 2

ARBORETUM	DATE EST.	NO.SPEC.	NO.SEEDLIST	REPL.PLOTS	TOTAL PLOTS
Del Park					
Marrinup					
George upper					
George lower					
Bingham River					

- native to regions with a Mediterranean type climate (southern South Australia, western and central Victoria and south west New South Wales).

For the potentially more important species up to several seed lots were selected in order to demonstrate likely within species variation in performance.

The present arboreta were established over a four year period and during this time the availability of many seed lots lapsed. This compromised the objective of establishing complete replicate arboreta at each site. However, where one seed lot became unavailable it was attempted to replace it with a geographically near substitute.

Number of species and seed lots for each arboreta is shown in Table 2.

3.3 LAYOUT AND DESIGN

Plot size was made as large as practicable in order to minimize edge effects and provide the option of doing analysis of individual plot effects on ground water, soil water storage and plant water relations. A plot size minimum of 0.5ha was aimed for. Plots of species with more than one seed lot were juxtaposed.

Plot shape was near to square to provide maximum distance from edge for a given area. In both Del Park and Marrinup arboreta this aim was compromised in favour of making the plots more rectangular in order to better sample the considerable local site variation apparent at these locations.

The large plot size and number of plots (Table 2) reduced the scope to replicate plots within each arboretum. Replication was therefore confined to a core group of species and for these only duplication was possible.

Borefields from which to monitor ground water level were established at three sites i.e. George upland, George lowland and Bingham River.

3.4 ESTABLISHMENT

At the George arboreta, the only two to carry a substantially intact native forest cover, detailed site-vegetation mapping was carried out prior to clearing to establish the arboreta.

Standard operational establishment procedures were used. Ground preparation depended on site. The three arboreta in forest or remnant forest were cleared and raked with bulldozers and the trash burnt. The ashbeds were carefully aligned to lie along access roads so as not to add to the variability within plots. The bauxite pit site (Del Park) was given standard pit preparation for planting (Department Conservation and Environment, 1984). The farmland site (Bingham River) was deep ripped in autumn and herbicide sprayed to control germinating pasture in winter. For each site six month old seedlings in peat pots were planted into speared openings in the soil in mid winter. An application of 200gms. of mon-ammonium phosphate (N:P,12.22) was applied in a split dose at planting and 6-9 weeks.

Planting was on spacing of 4m within rows and 4m between rows to give a total of 625 seedling per ha.

With the exception of Bingham River which was previously fertilized farmland, all sites had 500kg/ha. of superphosphate (with copper zinc and molybdenum trace elements) applied aerially. The rationale of this treatment is that it is a plausible operational procedure which in addition to directly improving phosphate nutrition may enhance nitrogen input by stimulating native legume growth. The Del Park arboretum was also planted with native legume shrub understorey, now a standard procedure in pit rehabilitation (Department Conservation and Environment, 1984).

An exploratory treatment being tested at the two upland arboreta (Marrinup and George upland) is the shattering by blasting of the indurated upper horizon of the lateritic profile (known as caprock). This layer was seen as a potential impediment to root access into the profile for introduced species though it is apparently not so for the native jarrah. Subsequently, this layer has been implicated in impeding drainage into the deeper profile and creating conditions highly favourable for Phytophthora (Shea et al, 1982). The treatment was applied to duplicate plots of 12 major species.

All plots were checked for mortality in their first summer/autumn. Where establishment was less than 75% refilling was carried out in the second winter.

The previously forested sites suffered considerable native eucalypt regeneration from lignotubers and stumps. This was controlled over years 1-3 after establishment by poisoning with glyphosate.

P A R T B.

ASSESSMENT OF ARBORETA

4) PERFORMANCE ASSESSMENT METHOD

Field measurements were performed between October 1984 and September 1985.

Within each arboretum, original planting design was such that plots consisted of up to 20 rows of trees. Each row consisted of between 25 and 45 trees. Plots were bounded at either end by access roads, and in the majority of cases had plots to either side. To minimise edge effects, the sample population was limited to the central rows so that the final sample accounted for approximately 10% of total tree positions in each plot. The remainder of the plot was treated as a buffer.

Given time restraints, the number of plots and intensity of observations required for this study and sampling limitations imposed by edge effects, it became apparent at the outset that an inventory assessment programme based on a randomized sampling procedure was out of the question. analyses would not be adequate. "Perform", a transect-based tree performance analysis system was developed to streamline field-data collection and provide an interactive computer database through which arboreta, plots, trees and individual parameters could be compared. Using this system, two practised observers could assess (15 observations) and book a tree within one minute.

To further save time, where tree performance was extremely poor or the majority of trees appeared to be missing, sampling was restricted to one row only (giving a sample size of between 5 and 10% of total plot locations).

For each tree position, the following information was obtained and noted on the booking sheet (Appendix 1.1) :

1. Tree (position) number

2. Height (absolute)

3. Diameter (at 1.3M overbark)

4. Form (via systematic table)

5. Vigour (via systematic table)

6. Defect information (wind-throw, borer evidence, crown damage etc)

Tree number

A number was allotted sequentially to every planting location along each row. Where a tree was absent, this was recorded by skipping that position number on the booking sheet (see Appendix 1.1). Where a tree had more than one stem originating below 1.3M, separate readings were taken for each stem - (in such cases, all stems shared the same tree number).

Tree height

For trees taller than four metres, the observer moved to a convenient location where both the top and base of the tree could be seen. Percentage slopes from eye to top and from eye to base were measured using a 'Suunto' clinometer and recorded along with horizontal distance from tree to observer. No allowance was made for tree lean.

Trees between 2 and 4 metres tall were measured by either clinometer (as described above) or height sticks.

Trees less than two metres were estimated.

Diameter

Diameter was measured overbark at 1.3 metres with a diameter tape. Diameters of less than 20mm were estimated.

Form

Form was estimated systematically by following stem and crown observations through a "Form Performance Table" (Appendix 1.2). In this way, each tree was given a score between 0 and 4 for form. A tree was initially allotted the maximum 4 points. Deductions were then made for various stem and crown defects as follows:-

* Two stems originating below 1.3 metres ..(-1)

* Three or more stems originating below 1.3 metres ..(-2)

* One twist or bend in the stem ..(-1)

* Two or more bends in the stem ..(-2)

* Crown forked ..(-1)

* Crown lopsided ..(-1)

* Crown with large limbs ..(-1)

Hence, to obtain a perfect score for form, a tree had to be single-stemmed, with a straight bole, small limbs, an even crown and single dominant crown leader.

Vigour

Vigour was estimated systematically through the "Vigour Performance Table" (appendix 1.3). Again, trees were initially allotted the maximum (4 points) score. Points were then deducted for the following defects:-

* Crown stationary (not expanding) ..(-1)

* Crown "Unhealthy" (evidence of epicormics, some dead branches) ..(-1)

* Crown "Very unhealthy" (>25% of branches dead) ..(-2)

* Leaf Area Index (visual est.) approximately 2-3 ..(-1)

* Leaf Area Index approximately 1-2 ..(-2)

* Leaf Area Index less than 1 ..(-3)

Hence, to obtain the maximum vigour rating of 4, a tree required a crown which is actively expanding,no dead branches or epicormics and a leaf area index of three or more (on a 4X4 metre spacing).

Approximate leaf area index was determined by comparison with sample photographs of various tree crowns covering a range of L.A.I's (at a 4x4 metre spacing).

Defect Observations

Trees were inspected for external evidence of damage by borers or termites, stem splits, damage by wind,or indications of any other malady. These were noted in the "comments" area of the data form (Appendix 1.1).

A more intensive, separate survey of all plots for borers,termites and stem ("cambial") splits was undertaken after the conclusion of the performance measurements. Kino bleeds, scars and holes in the stem were all followed back through the bark and into the wood in an attempt to determine their origin. Information on the presence of borers, termites and cambial splits was drawn from both of these studies.

Analysis of Data

Performance data analysis was achieved through the "Perform 7" transect analysis computer system (Davey, W.A. Department of Conservation and Land Management). This system enables a flexible "weighting" to be applied to each measured parameter. Looking at one parameter at a time, the measurement for each tree is compared with the best measurement expected from all trees in the study (alternatively, the system has an option whereby it will search the data and extract the actual maximum reading for each parameter for comparison). The tree's performance as measured by this parameter is expressed as a percentage of that maximum achievable value. This value is then multiplied by the "Weighting Factor" nominated by the user. The resultant values for all parameters are combined to produce a "Rating" for each tree which is expressed as a percentage of the maximum possible performance.

Throughout the analysis, the "Perform" system keeps each tree individually identified. Hence "rating" is calculated for each tree (rather than being determined at "Plot" level from plot mean height, diameter, form and vigour). This facilitates the statistical analysis of "rating" as a separate tree parameter, enabling statistically valid comparisons of this parameter both between plots and between arboreta.

The system also enables ranges to be set for each parameter, and includes an option to produce a profile graph (along each transect) for any combination of parameters measured. The graph can present values along the transect either tree-by-tree or as a travelling mean, and provides a useful tool for the field verification of data.

For the purpose of this publication, all factors were weighted equally (25% each), hence Rating for each individual tree was obtained by the following formula:-

$$\text{RATING of tree (\%)} = \left[\frac{Ht}{Hm} \times \frac{1}{4} + \frac{Dt}{Dm} \times \frac{1}{4} + \frac{Ft}{Fm} \times \frac{1}{4} + \frac{Vt}{Vm} \times \frac{1}{4} \right] \times \frac{100}{1}$$

where

Ht = height of sample tree
Hm = maximum height expected (20m)
Dt = diameter of sample tree
Dm = maximum diameter expected (25 cm)
Ft = form of sample tree
Fm = maximum form (4)
Vt = vigour of tree
Vm = maximum vigour (4)

Values for individual trees were averaged to give mean values for height, diameter, form, vigour and rating for each plot.

Survival was not included in the rating as this would have down-graded the Bingham River Arboretum which suffered a wildfire in late Spring of 1981. The occurrence of this wildfire in Bingham River arboretum must be kept in mind when comparing arboreta for stem damage and insect attack. Sites of fire stem-damage may have provided easy access for insects (McCaw 1983).

5) ARBORETUM BY ARBORETUM RESULTS SUMMARY

5.1) DEL PARK RESULTS

Detailed, Plot by Plot Results - (Field Guide Booklet)

Detailed plot by plot results are presented in the booklet : "Dell Park Arboretum - A Field Guide and 1985 Performance Analysis." in Attachment 1 (towards the end of this publication).

Information within this booklet includes :-

- Location Map . . . . .Figure DP-1
- Plan of Arboretum . . . . . Figure DP-2
- Plot / Species Listing . . .Table DP-1

Plot by plot (sequential) graphs of :-

- Height . . . . .Figure DP-3
- Diameter . . . . .Figure DP-4
- Form . . . . .Figure DP-5
- Vigour . . . . .Figure DP-6
- Survival. . . . . Figure DP-7
- Rating . . . . .Figure DP-8

- Plot by Plot listing of results for all parameters .Table DP-2

Only an overview is provided here.

Overview of Del Park Results

A graph of mean rating for each plot (including 95% confidence limits) is presented in figure 5.1. For ease of comparison, plots are presented in order (from highest to lowest rating).

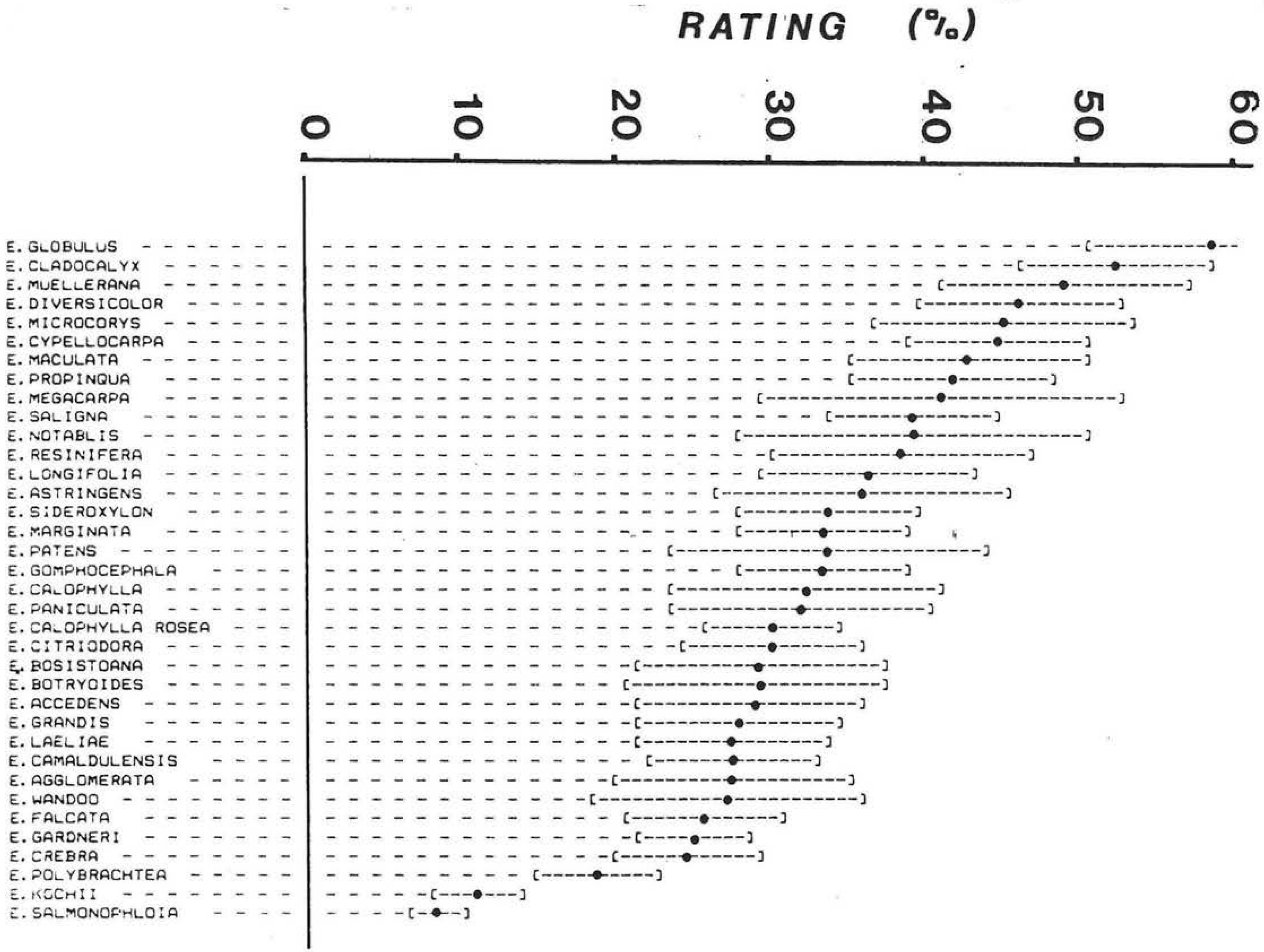


FIGURE 5.1 DEL PARK RATING

Comparing the mean rating of each of the plots, the top 10 plots (ranked from best to worst) are listed in Table 5.1 .

TABLE 5.1 BEST 10 SPECIES AT DEL PARK

B E S T

PLOT	SPECIES	SEEDLOT	DEFECT
12	E.globulus	unknown	B C
34	E.cladocalyx	"	B
8	E.muellerana	"	
2	E.diversicolor	"	B C
22	E.microcorys	"	B
13	E.cypellocarpa	"	
11	E.maculata	"	C
35	E.propinqua	"	B
6	E.megacarpa	"	C
10	E.saligna	"	

SYMBOLS : B = BORER OCCURRENCE NOTED IN PLOT
T = TERMITE OCCURRENCE NOTED IN PLOT
C = CAMBIAL SPLITS NOTED INPLOT
S = SURVIVAL LESS THAN 50%

5.2) MARRINUP RESULTS

Detailed Plot by Plot Results - (Field Guide Booklet)

Detailed plot by plot results are presented in the booklet : "Marrinup Arboretum - A Field Guide and 1985 Performance Analysis." in Attachment 2 (towards the end of this publication).

Information within this booklet includes :-

- Location Map . . . . .Figure MA-1
- Plan of Arboretum . . . . . Figure MA-2
- Plot/Provenance Listing . . .Table MA-1

Plot by plot (sequential) graphs of :-

- Height . . . . .Figure MA-3
- Diameter . . . . .Figure MA-4
- Form . . . . .Figure MA-5
- Vigour . . . . .Figure MA-6
- Survival. . . . . Figure MA-7
- Rating . . . . .Figure MA-8

- Plot by Plot listing of results for all parameters .Table MA-2

Overview of Marrinup Results

A graph of mean rating for each plot (including 95% confidence limits) is presented in figure 5.2. For ease of comparison, plots are presented in order (from highest to lowest rating).

TABLE 5.2 LISTING OF TOP 20 PLOTS (IN ORDER OF RATING)

PLOT	SPECIES	SEEDLOT	DEFECT	
				BEST ↑
6	E.cladocalyx	6470		
28b	E.botryoides	7340		
28a	E.botryoides	12104		
28d	E.botryoides	7509		
28c	E.botryoides	12134		
31b	E.robusta	9424		
34e	E.maculata	10865	C	
56	Pinus radiata	5086/7		
33d	E.resinifera	11963		
55	E.diversicolor	6521	B T C	
32b	E.cladocalyx	10756	B	
34i	E.maculata	11181	C	
5	E.saligna	4729	C	
35b	E.citriodora	11640	C	
57	Pinus pinaster	5083	S	
34h	E.maculata	12135	C	
10a	E.paniculata	12137		
32a	E.cladocalyx	11834		
37	E.gomphocephala	6090	T	

SYMBOLS : B = BORER OCCURRENCE NOTED IN PLOT
T = TERMITE OCCURRENCE NOTED IN PLOT
C = CAMBIAL SPLITS NOTED IN PLOT
S = SURVIVAL LESS THAN 50%

5.3) GEORGE UPLAND RESULTS

Detailed Plot by Plot Results - (Field Guide Booklet)

Detailed plot by plot results are presented in the booklet : "George Upland Arboretum - A Field Guide and 1985 Performance Analysis." in Attachment 3 (towards the end of this publication).

Information within this booklet includes :-

- Location Map . . . . .Figure GU-1
- Plan of Arboretum . . . . . . Figure GU-2
- Plot/Provenance Listing . . . .Table GU-1

Plot by plot (sequential) graphs of :-

- Height . . . . .Figure GU-3
- Diameter . . . . .Figure GU-4
- Form . . . . .Figure GU-5
- Vigour . . . . .Figure GU-6
- Survival. . . . . Figure GU-7
- Rating . . . . .Figure GU-8

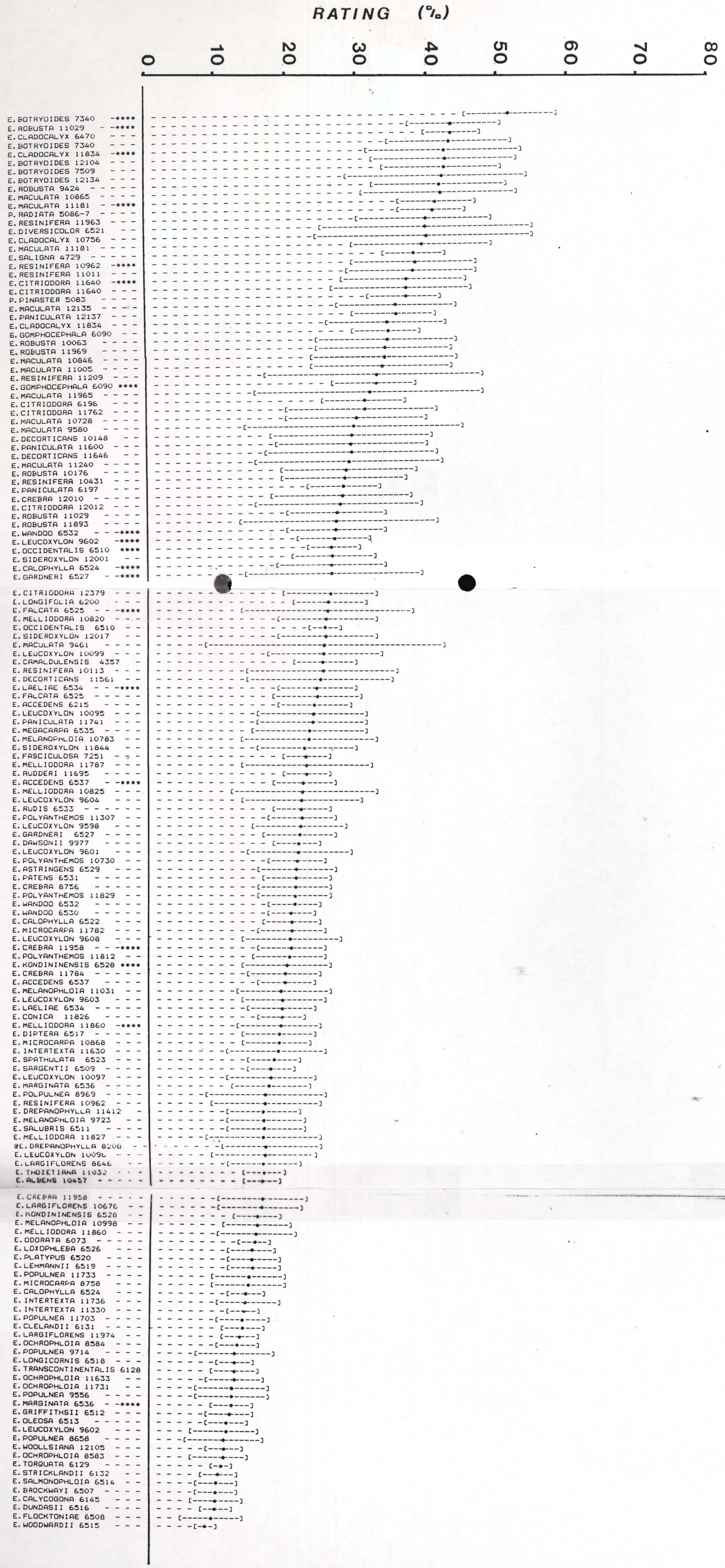
- Plot by Plot listing of results for all parameters .Table GU-2

Overview of George Upland Results

A graph of mean rating for each plot (including 95% confidence limits) is presented in figure 5.3. For ease of comparison, plots are presented in order (from highest to lowest rating).

FIGURE 5.2 : GRAPH OF MARRINUP MEAN PLOT RATING

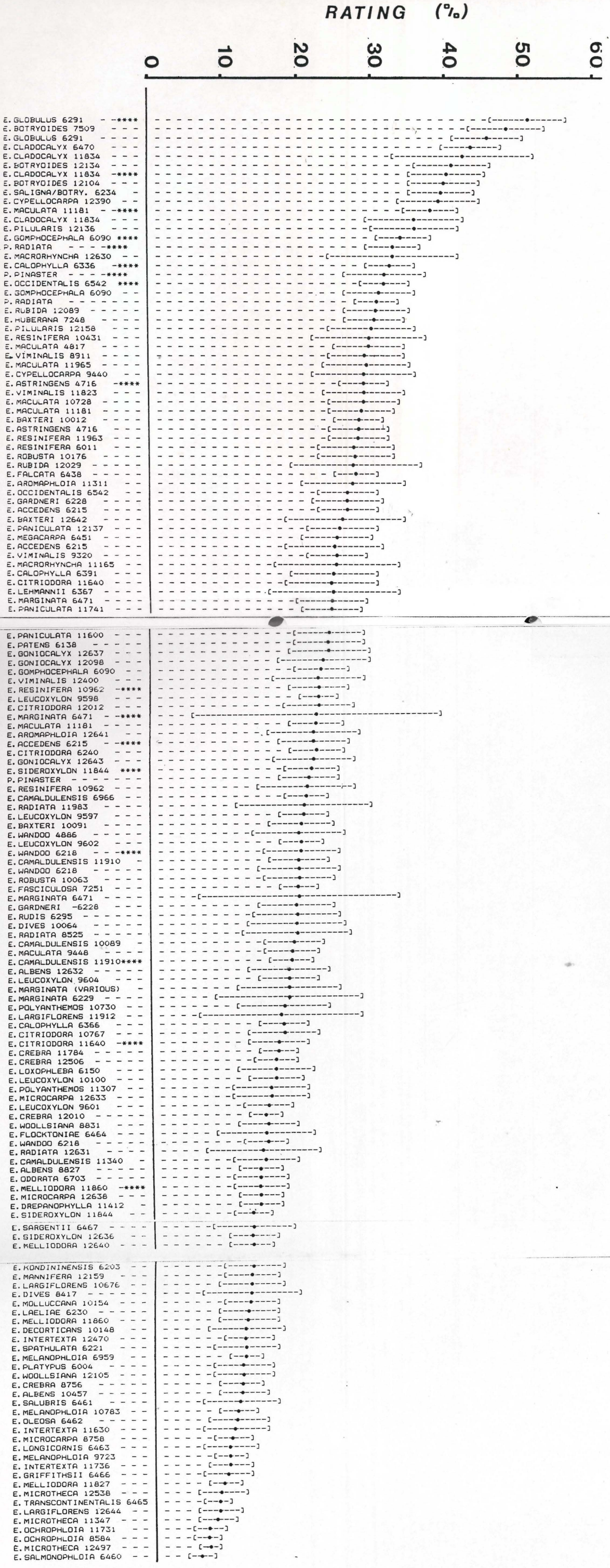
(PLOTS RANKED FROM BEST TO WORST)


RATING (%)
0
10
20
30
40
50
60
70
80
E. BOTRYOIDES 7340 ****
E. ROBUSTA 11029 ****
E. CLADOCALYX 6470
E. BOTRYOIDES 7340
E. CLADOCALYX 11834 ****
E. BOTRYOIDES 12104
E. BOTRYOIDES 7509
E. BOTRYOIDES 12134
E. ROBUSTA 9424
E. MACULATA 10865
E. MACULATA 11181 ****
P. RADIATA 5086-7
E. RESINIFERA 11963
E. DIVERSICOLOR 6521
E. CLADOCALYX 10756
E. MACULATA 11181
E. SALIGNA 4729
E. RESINIFERA 10962 ****
E. RESINIFERA 11011
E. CITRIODORA 11640 ****
E. CITRIODORA 11640
P. PINASTER 5083
E. MACULATA 12135
E. PANICULATA 12137
E. CLADOCALYX 11834
E. GOMPHOCEPHALA 6090
E. ROBUSTA 10063
E. ROBUSTA 11969
E. MACULATA 10846
E. MACULATA 11005
E. RESINIFERA 11209
E. GOMPHOCEPHALA 6090 ****
E. MACULATA 11965
E. CITRIODORA 6196
E. CITRIODORA 11762
E. MACULATA 10728
E. MACULATA 9580
E. DECORTICANS 10148
E. PANICULATA 11600
E. DECORTICANS 11646
E. MACULATA 11240
E. ROBUSTA 10176
E. RESINIFERA 10431
E. PANICULATA 6197
E. CREBRA 12010
E. CITRIODORA 12012
E. ROBUSTA 11029
E. ROBUSTA 11893
E. WANDOO 6532 ****
E. LEUCOXYLON 9602 ****
E. OCCIDENTALIS 6510 ****
E. SIDEROXYLON 12001
E. CALOPHYLLA 6524 ****
E. GARDNERI 6527 ****
E. CITRIODORA 12379
E. LONGIFOLIA 6200
E. FALCATA 6525 ****
E. MELLIODORA 10820
E. OCCIDENTALIS 6510
E. SIDEROXYLON 12017
E. MACULATA 9461
E. LEUCOXYLON 10099
E. CAMALDULENSIS 4357
E. RESINIFERA 10113
E. DECORTICANS 11561
E. LAELIAE 6534 ****
E. FALCATA 6525
E. ACCEDENS 6215
E. LEUCOXYLON 10095
E. PANICULATA 11741
E. MEGACARPA 6535
E. MELANOPHLOIA 10783
E. SIDEROXYLON 11844
E. FASCICULOSA 7251
E. MELLIODORA 11787
E. RUDDERI 11695
E. ACCEDENS 6537 ****
E. MELLIODORA 10825
E. LEUCOXYLON 9604
E. RUDIS 6533
E. POLYANTHEMOS 11307
E. LEUCOXYLON 9598
E. GARDNERI 6527
E. DAWSONII 9977
E. LEUCOXYLON 9601
E. POLYANTHEMOS 10730
E. ASTRINGENS 6529
E. PATENS 6531
E. CREBRA 8756
E. POLYANTHEMOS 11829
E. WANDOO 6532
E. WANDOO 6530
E. CALOPHYLLA 6522
E. MICROCARPA 11782
E. LEUCOXYLON 9608
E. CREBRA 11958 ****
E. POLYANTHEMOS 11812
E. KONDININENSIS 6528 ****
E. CREBRA 11784
E. ACCEDENS 6537
E. MELANOPHLOIA 11031
E. LEUCOXYLON 9603
E. LAELIAE 6534
E. CONICA 11826
E. MELLIODORA 11860 ****
E. DIPTERA 6517
E. MICROCARPA 10868
E. INTERTEXTA 11630
E. SPATHULATA 6523
E. SARGENTII 6509
E. LEUCOXYLON 10097
E. MARGINATA 6536
E. POLPULNEA 8969
E. RESINIFERA 10962
E. DREPANOPHYLLA 11412
E. MELANOPHLOIA 9723
E. SALUBRIS 6511
E. MELLIODORA 11827
E. DREPANOPHYLLA 8208
E. LEUCOXYLON 10096
E. LARGIFLORENS 8646
E. THOZETIANA 11032
E. ALBENS 10457
E. CREBRA 11958
E. LARGIFLORENS 10676
E. KONDININENSIS 6528
E. MELANOPHLOIA 10998
E. MELLIODORA 11860
E. ODORATA 6073
E. LOXOPHLEBA 6526
E. PLATYPUS 6520
E. LEHMANNII 6519
E. POPULNEA 11733
E. MICROCARPA 8758
E. CALOPHYLLA 6524
E. INTERTEXTA 11736
E. INTERTEXTA 11330
E. POPULNEA 11703
E. CLELANDII 6131
E. LARGIFLORENS 11974
E. OCHROPHLOIA 8584
E. POPULNEA 9714
E. LONGICORNIS 6518
E. TRANSCONTINENTALIS 6128
E. OCHROPHLOIA 11633
E. OCHROPHLOIA 11731
E. POPULNEA 9556
E. MARGINATA 6536 ****
E. GRIFFITHSII 6512
E. OLEOSA 6513
E. LEUCOXYLON 9602
E. POPULNEA 8658
E. WOOLLSIANA 12105
E. OCHROPHLOIA 8583
E. TORQUATA 6129
E. STRICKLANDII 6132
E. SALMONOPHLOIA 6514
E. BROCKWAYI 6507
E. CALYCOGONA 6145
E. DUNDASII 6516
E. FLOCKTONIAE 6508
E. WOODWARDII 6515

MARRINUP

FIGURE 5.3 : GRAPH OF GEORGE UPLAND MEAN PLOT RATING

(PLOTS RANKED FROM BEST TO WORST)



GEORGE UPLAND

TABLE 5.3 LISTING OF TOP 20 PLOTS (IN ORDER OF RATING)

PLOT	SPECIES	SEEDLOT	DEFECT	BEST
90	E.botryoides	7509		
16	E.globulus	6291		
104	E.cladocalyx	6470	C	
105	E.cladocalyx	11834	C	
108	E.botryoides	12134		
89	E.botryoides	12104		
129	E.saligna/botryoides	6234		
149	E.cypellocarpa	12390		
7	E.cladocalyx	11834		
151	E.pilularis	12136	B	
78	E.macrorhyncha	12630		
3	E.gomphocephala	6090	C	
44	Pinus radiata	5086/7		
107	E.rubida	12089	C	
106	E.huberiana	7248	C	
152	E.pilularis	12158	B	
156	E.resinifera	10431	B	
116	E.maculata	4817		
82	E.viminalis	8911		
115	E.maculata	11965		

SYMBOLS : B = BORER OCCURRENCE NOTED IN PLOT
T = TERMITE OCCURRENCE NOTED IN PLOT
C = CAMBIAL SPLITS NOTED IN PLOT
S = SURVIVAL LESS THAN 50%

5.4) GEORGE LOWLAND RESULTS

Detailed Plot by Plot Results - (Field Guide Booklet)

Detailed plot by plot results are presented in the booklet : "George Lowland Arboretum - A Field Guide and 1985 Performance Analysis." in Attachment 4 (towards the end of this publication).

Information within this booklet includes :-

- Location Map . . . . .Figure GL-1
- Plan of Arboretum . . . . . Figure GL-2
- Plot/Provenance Listing . . .Table GL-1

Plot by plot (sequential) graphs of :-

- Height . . . . .Figure GL-3
- Diameter . . . . .Figure GL-4
- Form . . . . .Figure GL-5
- Vigour . . . . .Figure GL-6
- Survival. . . . . Figure GL-7
- Rating . . . . .Figure GL-8

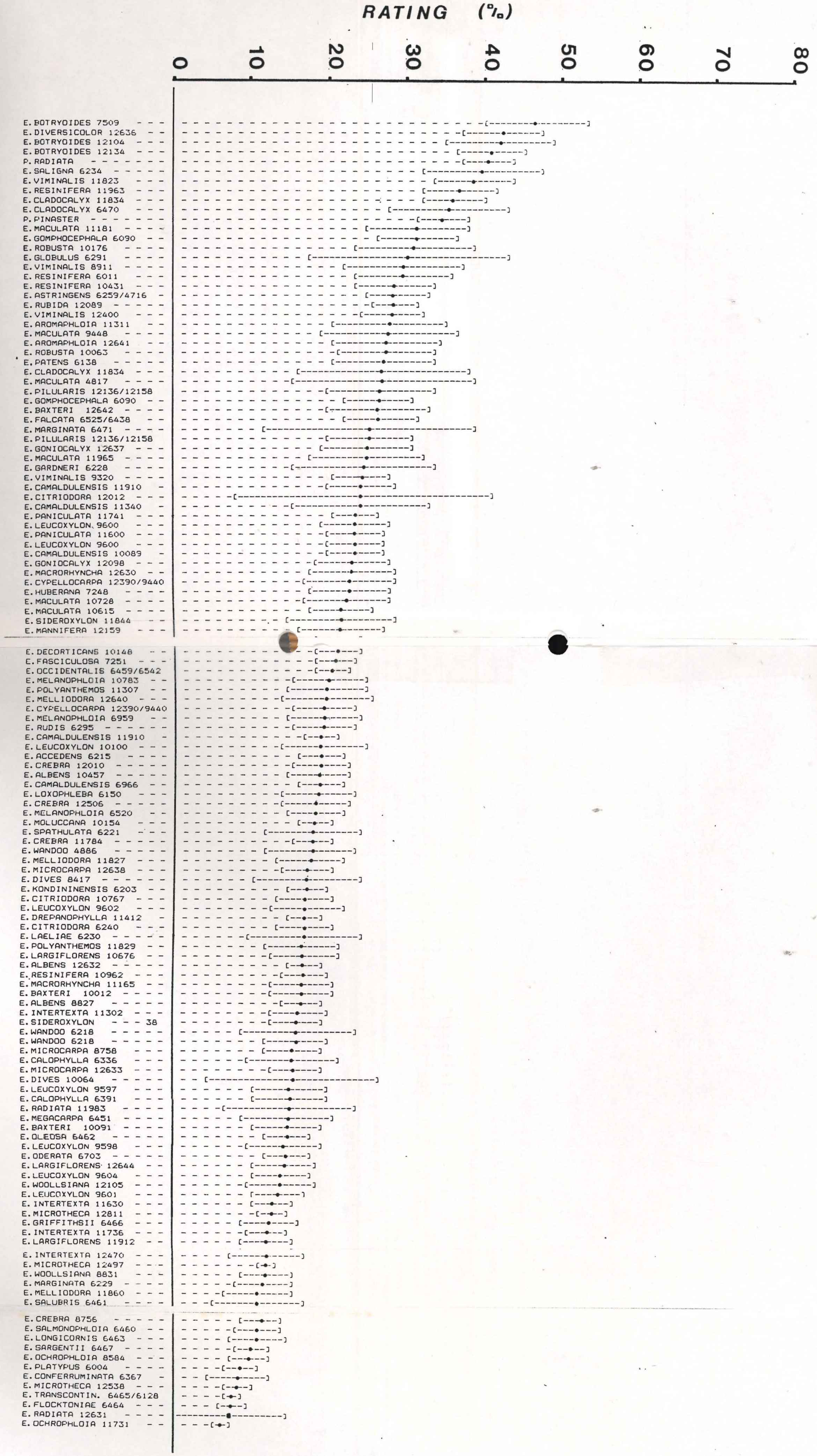
- Plot by Plot listing of results for all parameters .Table GL-2

Overview of George Lowland Results

A graph of mean rating for each plot (including 95% confidence limits) is presented in figure 5.4. For ease of comparison, plots are presented in order (from highest to lowest rating).

FIGURE 5.4 : GRAPH OF GEORGE LOWLAND MEAN PLOT RATING

(PLOTS RANKED FROM BEST TO WORST)



GEORGE LOWLAND

TABLE 5.4 LISTING OF TOP 20 PLOTS (IN ORDER OF RATING)

PLOT	SPECIES	SEEDLOT	DEFECT	BEST
121	E.botryoides	7509		
40	E.diversicolor	12636	B	
116	E.botryoides	12104		
117	E.botryoides	12134		
90	Pinus radiata	5086/7		
87	E.saligna/botryoides	6234		
29	E.viminalis	11823		
113	E.resinifera	11963	B	
11	E.cladocalyx	11834		
80	E.cladocalyx	6470		
89	Pinus pinaster	5083		
114	E.maculata	11181		
128	E.gomphocephala	6090		
120	E.robusta	10176		
127	E.globulus	6291	B	
31	E.viminalis	8911		
124	E.resinifera	6011	B	
94	E.resinifera	10431	B	
65	E.astringens	6259/4716		
42	E.rubida	12089		

SYMBOLS : B = BORER OCCURRENCE NOTED IN PLOT
T = TERMITE OCCURRENCE NOTED IN PLOT
C = CAMBIAL SPLITS NOTED IN PLOT
S = SURVIVAL LESS THAN 50%

5.5) BINGHAM RIVER RESULTS

Detailed Plot by Plot Results - (Field Guide Booklet)

Detailed plot by plot results are presented in the booklet : "Bingham River Arboretum - A Field Guide and 1985 Performance Analysis." in Attachment 5 (towards the end of this publication).

Information within this booklet includes :-

- Location Map . . . . .Figure BR-1
- Plan of Arboretum . . . . . Figure BR-2
- Plot/Provenance Listing . . .Table BR-1

Plot by plot (sequential) graphs of :-

- Height . . . . .Figure BR-3
- Diameter . . . . .Figure BR-4
- Form . . . . .Figure BR-5
- Vigour . . . . .Figure BR-6
- Survival. . . . . Figure BR-7
- Rating . . . . .Figure BR-8

- Plot by Plot listing of results for all parameters .Table BR-2

Overview of Bingham River Results

A graph of mean rating for each plot (including 95% confidence limits) is presented in figure 5.5. For ease of comparison, plots are presented in order (from highest to lowest rating).

FIGURE 5·5 : GRAPH OF BINGHAM RIVER MEAN PLOT RATING

(PLOTS RANKED FROM BEST TO WORST)

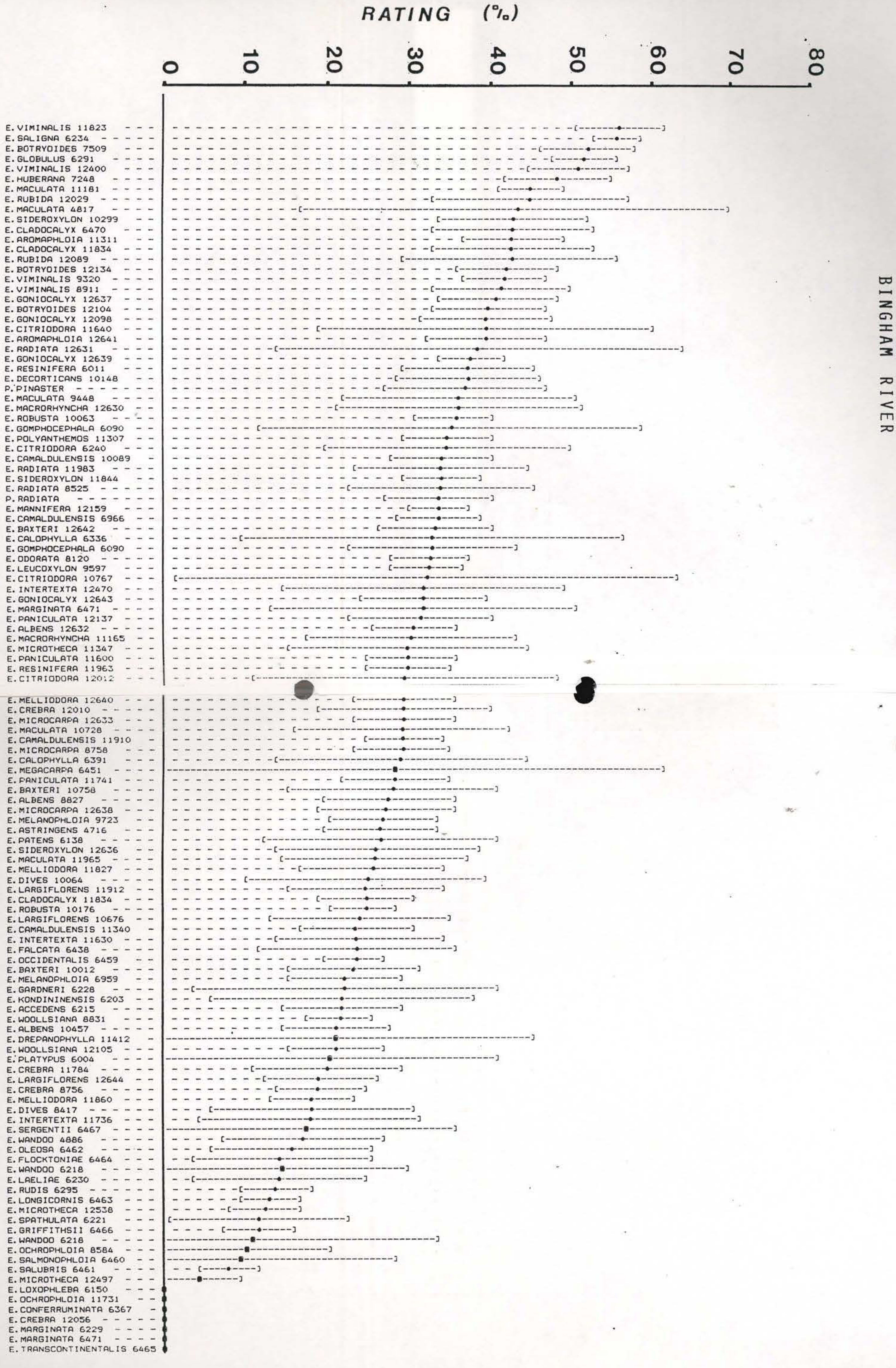

RATING (%)
0
10
20
30
40
50
60
70
80
BINGHAM RIVER
E. VIMINALIS 11823
E. SALIGNA 6234
E. BOTRYOIDES 7509
E. GLOBULUS 6291
E. VIMINALIS 12400
E. HUBERANA 7248
E. MACULATA 11181
E. RUBIDA 12029
E. MACULATA 4817
E. SIDEROXYLON 10299
E. CLADOCALYX 6470
E. AROMAPHLOIA 11311
E. CLADOCALYX 11834
E. RUBIDA 12089
E. BOTRYOIDES 12134
E. VIMINALIS 9320
E. VIMINALIS 8911
E. GONIOCALYX 12637
E. BOTRYOIDES 12104
E. GONIOCALYX 12098
E. CITRIODORA 11640
E. AROMAPHLOIA 12641
E. RADIATA 12631
E. GONIOCALYX 12639
E. RESINIFERA 6011
E. DECORTICANS 10148
P. PINASTER
E. MACULATA 9448
E. MACRORHYNCHA 12630
E. ROBUSTA 10063
E. GOMPHOCEPHALA 6090
E. POLYANTHEMOS 11307
E. CITRIODORA 6240
E. CAMALDULENSIS 10089
E. RADIATA 11983
E. SIDEROXYLON 11844
E. RADIATA 8525
P. RADIATA
E. MANNIFERA 12159
E. CAMALDULENSIS 6966
E. BAXTERI 12642
E. CALOPHYLLA 6336
E. GOMPHOCEPHALA 6090
E. ODORATA 8120
E. LEUCOXYLON 9597
E. CITRIODORA 10767
E. INTERTEXTA 12470
E. GONIOCALYX 12643
E. MARGINATA 6471
E. PANICULATA 12137
E. ALBENS 12632
E. MACRORHYNCHA 11165
E. MICROTHECA 11347
E. PANICULATA 11600
E. RESINIFERA 11963
E. CITRIODORA 12012
E. MELLIODORA 12640
E. CREBRA 12010
E. MICROCARPA 12633
E. MACULATA 10728
E. CAMALDULENSIS 11910
E. MICROCARPA 8758
E. CALOPHYLLA 6391
E. MEGACARPA 6451
E. PANICULATA 11741
E. BAXTERI 10758
E. ALBENS 8827
E. MICROCARPA 12638
E. MELANOPHLOIA 9723
E. ASTRINGENS 4716
E. PATENS 6138
E. SIDEROXYLON 12636
E. MACULATA 11965
E. MELLIODORA 11827
E. DIVES 10064
E. LARGIFLORENS 11912
E. CLADOCALYX 11834
E. ROBUSTA 10176
E. LARGIFLORENS 10676
E. CAMALDULENSIS 11340
E. INTERTEXTA 11630
E. FALCATA 6438
E. OCCIDENTALIS 6459
E. BAXTERI 10012
E. MELANOPHLOIA 6959
E. GARDNERI 6228
E. KONDININENSIS 6203
E. ACCEDENS 6215
E. WOOLLSIANA 8831
E. ALBENS 10457
E. DREPANOPHYLLA 11412
E. WOOLLSIANA 12105
E. PLATYPUS 6004
E. CREBRA 11784
E. LARGIFLORENS 12644
E. CREBRA 8756
E. MELLIODORA 11860
E. DIVES 8417
E. INTERTEXTA 11736
E. SERGENTII 6467
E. WANDOO 4886
E. OLEOSA 6462
E. FLOCKTONIAE 6464
E. WANDOO 6218
E. LAELIAE 6230
E. RUDIS 6295
E. LONGICORNIS 6463
E. MICROTHECA 12538
E. SPATHULATA 6221
E. GRIFFITHSII 6466
E. WANDOO 6218
E. OCHROPHLOIA 8584
E. SALMONOPHLOIA 6460
E. SALUBRIS 6461
E. MICROTHECA 12497
E. LOXOPHLEBA 6150
E. OCHROPHLOIA 11731
E. CONFERRUMINATA 6367
E. CREBRA 12056
E. MARGINATA 6229
E. MARGINATA 6471
E. TRANSCONTINENTALIS 6465

TABLE 5.5 LISTING OF TOP 20 PLOTS (IN ORDER OF RATING)

PLOT	SPECIES	SEEDLOT	DEFECT	BEST
94	E.viminalis	11823	B	↑
5	E.saligna/botryoides	6234	B C	
32	E.botryoides	7509		
6	E.globulus	6291		
75	E.viminalis	12400	C	
82	E.huberiana	7248	C	
104	E.maculata	11181	C	
12	E.rubida	12029	C	
88	E.maculata	4817	C S	
80	E.sideroxylon	10299	B	
121	E.cladocalyx	6470		
91	E.aromaphloia	11311	B C	
122	E.cladocalyx	11834		
96	E.rubida	12089	B C	
34	E.botryoides	12134	B	
93	E.viminalis	9320	B	
14	E.viminalis	8911	C	
73	E.goniocalyx	12637		
33	E.botryoides	12104	B C	
52	E.goniocalyx	12098		

SYMBOLS : B = BORER OCCURRENCE NOTED IN PLOT
T = TERMITE OCCURRENCE NOTED IN PLOT
C = CAMBIAL SPLITS NOTED IN PLOT
S = SURVIVAL LESS THAN 50%

6. GENERAL RESULTS AND DISCUSSION

6.1 COMPARING ARBORETA

1. Overall Growth Performance

Tree height is generally accepted as the best indicator of site quality (or forest production potential) for established forests (Carron 1968). A "Rating" value is likely to be more robust for estimating the site quality under a young stand as it reflects a combination of both long term (height, diameter, bole form) and short term (crown vigour, leaf area, crown form) expressions of the site/tree interaction.

Figure 6.1 presents class frequency distributions of rating and height for each of the five arboreta. Because the number of plots varies from arboretum to arboretum, frequency of plots in each class has been expressed as a percentage of the total number of plots in each arboretum.

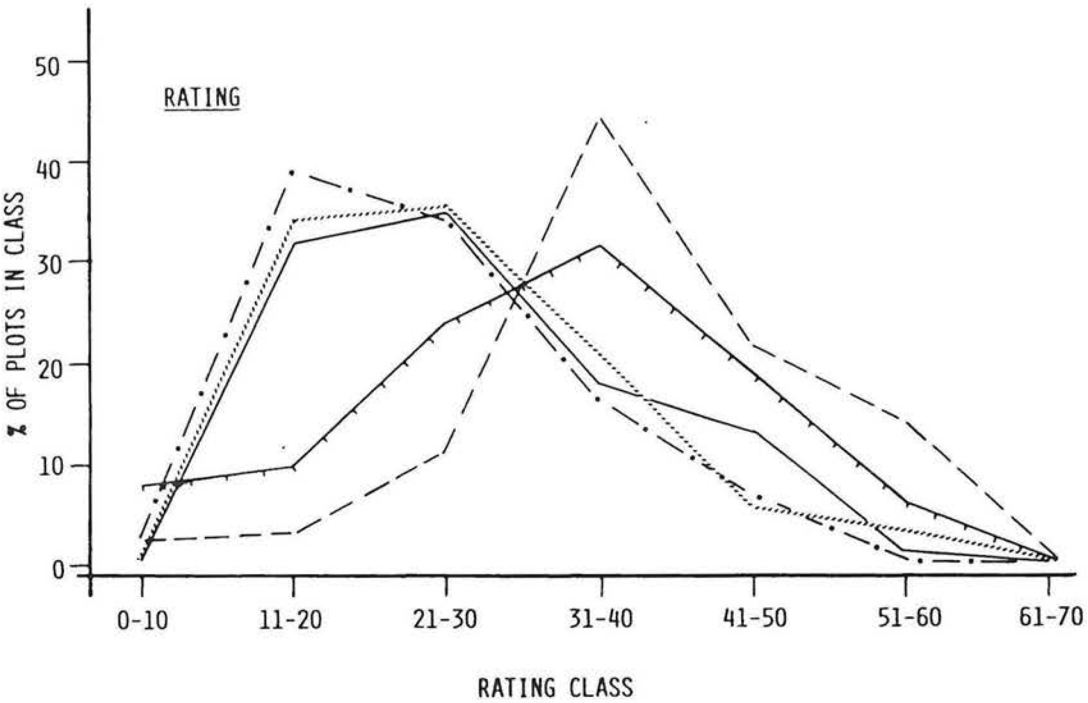
Comparing the two graphs of rating and height, it can be seen that they correspond closely, even though tree height accounted for only 25% of the input into the "Ratings". The "ratings" figures used here contain a 25% contribution from "form", and 25% from diameter, both of which would seem less likely to be correlated with site quality than height and vigour. This would indicate that rating could be further improved as an indicator of site quality by a more selective weighting of the four factors used (ht, dbh, form, vigour).

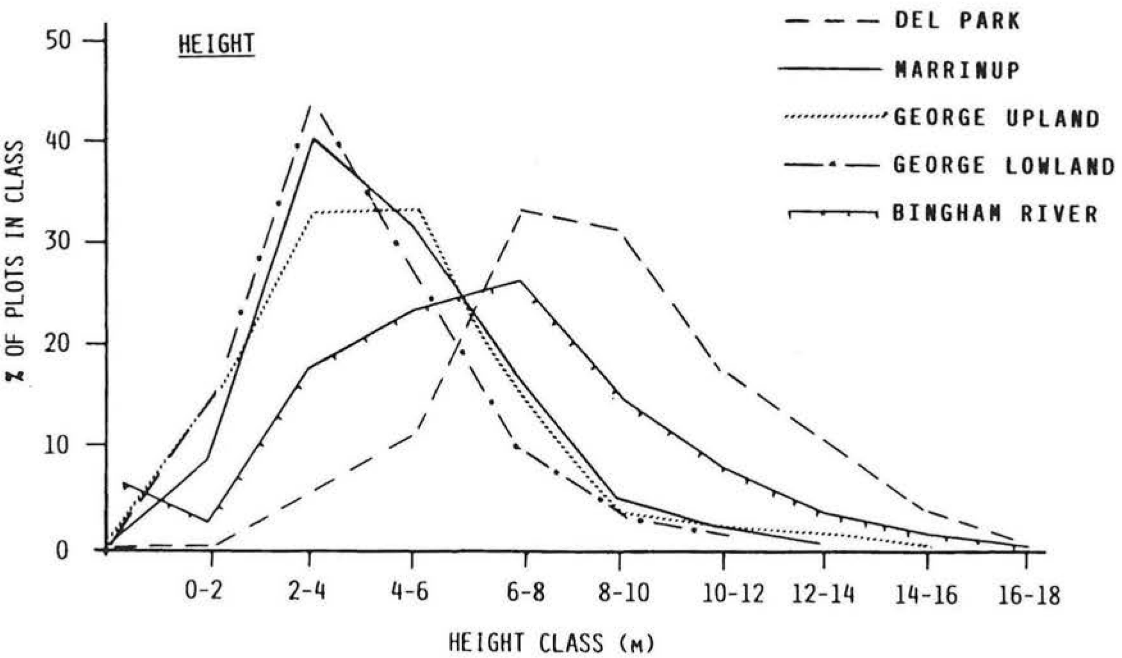
As trees grow, their height and diameter increment push them into ever higher size (and hence rating) classes. Hence, if all arboretum sites were equally amenable to tree growth, the normal frequency curve for older arboreta would simply occur to the right of curves for younger arboreta.

In the current study, Del Park and Marrinup are the two oldest arboreta, being two and one years (respectively) older than the other three. Whilst Del Park displays a frequency curve typical of an older arboretum, the curve for Marrinup corresponds very closely to those

FIGURE 6.1 CLASS FREQUENCY DISTRIBUTIONS

FOR RATINGS AND HEIGHTS





for George Upland and Lowland arboreta. This is doubly surprising since not only is Marrinup one year older than the George arboreta, but it also lies in an area of much higher rainfall. It is concluded that Marrinup's suppressed performance is indicative of a poorer site quality than that of the younger arboreta. It is suggested that the widespread presence of Phytophthora cinnamomi (dieback fungus), the shallow and outcropping caprock and the occurrence of black ironstone gravels of low fertility may have each contributed to this poor site quality at Marrinup.

Conversely, the frequency curve for Bingham River corresponds more closely with that of Del Park than George or Marrinup arboreta, despite the fact that Bingham River is an area of relatively low rainfall. This enhanced performance was attributable partly to the presence of a shallow water table, and partly to the higher level of nutrition achieved through its history of pasture improvement.

Hence, in terms of site quality, the arboreta can be ranked as follows (table 6.1):

Table 6.1 Relative Site Quality Of Arboreta

Highest site quality	1	Bingham River
↓	2 & 3	George Upland George Lowland
Lowest site quality	4	Marrinup

The site quality of Del Park arboretum cannot be compared with the above because its higher class-frequency distribution may (or may not) be entirely due to age difference.

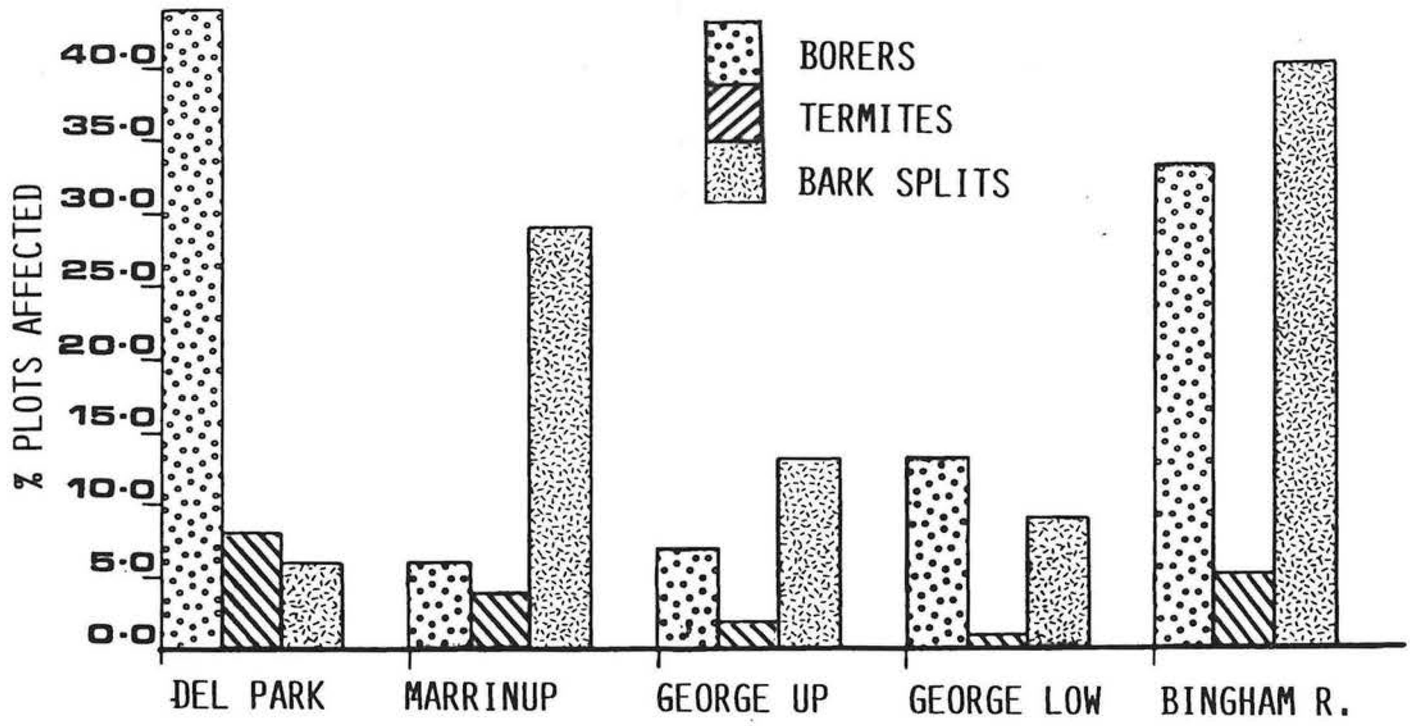
2. Stem Defect

Figure 6.2 displays the occurrence of borers, termites and cambial splits (% of plots affected) for each arboretum. At this stage, Bingham River appears to be the worst affected arboretum, the presence of borers and cambial splits being noted in a relatively large proportion of plots (33% and 40% respectively). This higher level of stem damage ~~is~~ may be due to ~~consistent~~ with the occurrence history of wildfire in this arboretum.

Also worthy of note is the high level of borers at Del Park (44% of plots) and the occurrence of cambial splits at Marrinup (29% of plots). This information is presented on a plot-by-plot basis for each arboretum in tables DP-2, MA-2, GU-2, GL-2 and BR-2 (in "Field Guide" booklets). It is also included in Appendix 2 which presents plot summaries arranged alphabetically (by species) for the combined arboreta.

FIGURE 6.2

STEM DEFECT (BY ARBORETUM)



6.2 SHATTERING CAPROCK WITH EXPLOSIVES.... ITS EFFECT ON SPECIES PERFORMANCE.

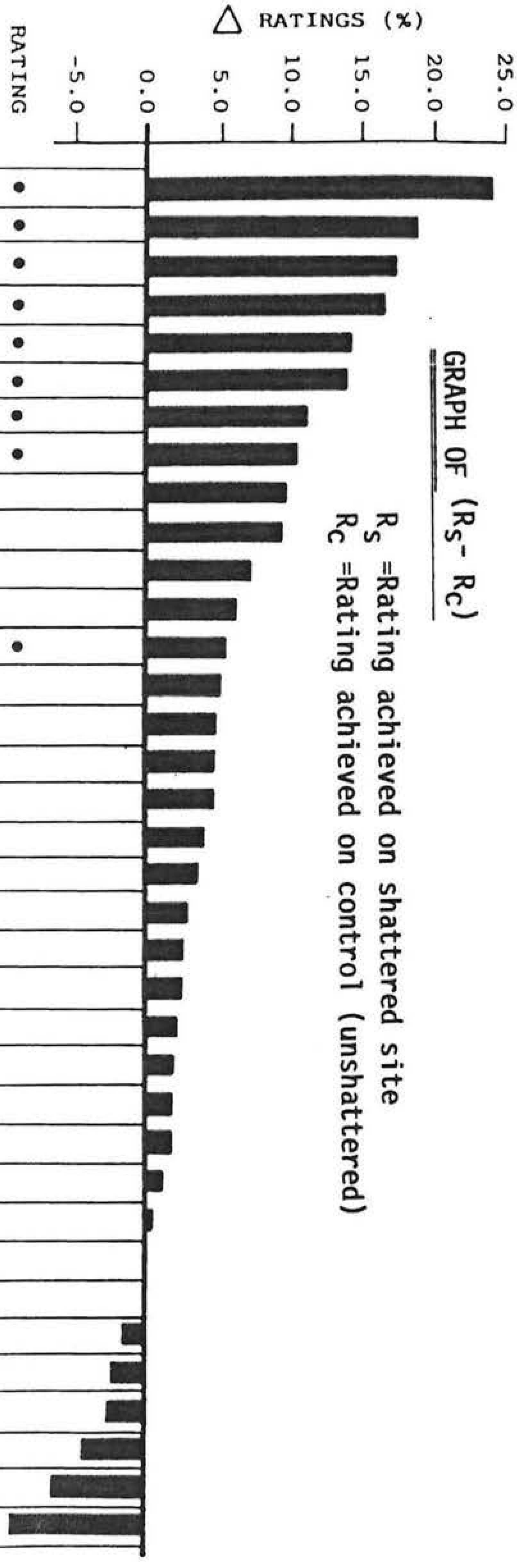
Figure 6.3 compares mean plot rating of shattered and unshattered treatments for a total of 36 paired plots in Marrinup and George arboreta. In the presence of shattering, 18 plots exhibited a statistically significant improvement in one or more of the primary measurement parameters (height, diameter, form, vigour, rating). 15 plots showed no significant change in the presence of the shattering treatment. The remaining three plots exhibited significantly poorer diameter on the shattered plots. Diameter was the only parameter to show a significant decrease in the presence of shattering.

FIGURE 6.3: THE EFFECT OF SHATTERING CAPROCK ON PERFORMANCE

GRAPH OF ($R_S - R_C$)

R_S =Rating achieved on shattered site
R_C =Rating achieved on control (unshattered)

SPECIES	S/LOT	ARBORETUM	HEIGHT	DIAMETER	FORM	VIGOUR	RATING
E.resinifera	10962	MA	•	•		•	•
E.robusta	11029	MA	•	•			•
E.leucoxylon	9602	MA	•	•	•	•	•
E.calophylla	6336	GU	•	•	•	•	•
E.sideroxylon	11844	GU	•	•	•		•
E.calophylla	6336	MA	•	•		•	•
P.pinaster	5083	GU			•		•
E.maculata	11181	GU		•	•		•
E.botryoides	7340	MA	•				
E.cladocalyx	11834	MA					
E.wandoo	6532	MA	•	•			
E.globulus	6291	GU		•			
E.laeliae	6534	MA	•	•			•
E.occidentalis	6542	GU		•			
E.kondininensis	6528	MA	•				
E.crebra	11958	MA					
E.cladocalyx	11834	GU		•			
E.melliodora	11860	MA					
E.gomphocephalla	6090	GU		•			
E.accedens	6537	MA					
P.radiata	5086/7	GU	•				
E.gardneri	6527	MA					
E.maculata	11181	MA					
E.resinifera	10962	GU					
E.falcata	6525	MA					
E.melliodora	11860	GU					
E.occidentalis	6510	MA		×			
E.astringens	4716	GU					
E.citriodora	11640	GU		×			
E.wandoo	6218	GU	•	•			
E.marginata	6471	GU					
E.camaldulensis	11910	GU					
E.gomphocephalla	6090	MA					
E.accedens	6215	GU					
E.marginata	6536	MA					
E.citriodora	11640	GU		×			



KEY:

= parameter significantly better (.05 level) on shattered site.
= parameter significantly worse (.05 level) on shattered site.

6.3 SPECIES OF INTEREST FOR REHABILITATION IN THE NORTHERN JARRAH FOREST

In terms of the current study, species of interest for rehabilitation purposes fall into three categories :-

1) Species which are currently used for rehabilitation,

2) Species which have been shown by this study to have high growth performance (and may be better for rehabilitation in the high rainfall zone than those in category 1), and

3) Species which have been found in other studies to be high water consumers (and hence contenders for rehabilitation of the intermediate and low rainfall zones).

This section analyses the performance of three examples from each of the above categories

EXAMPLE 1 : *E.maculata* (current rehab. species)

Comparison of Provenances :

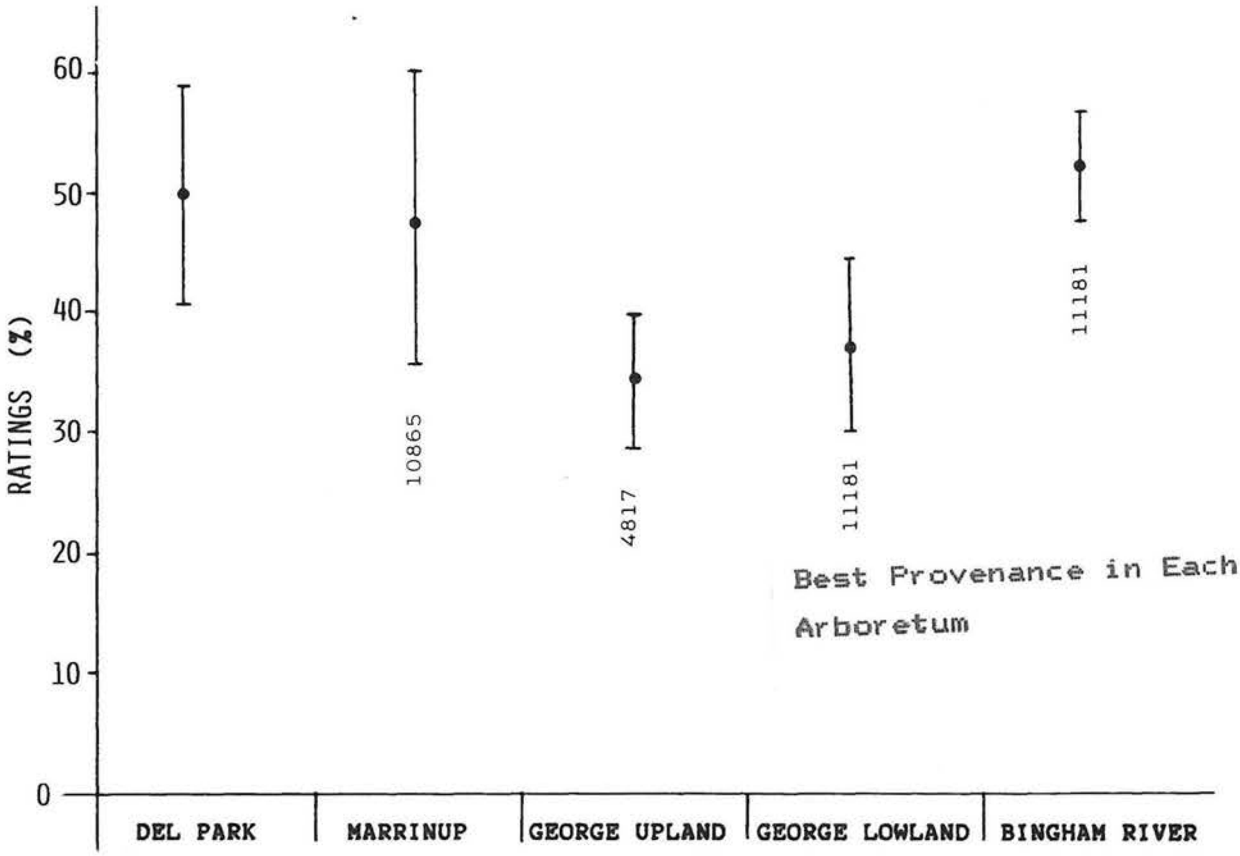
Figure 6.4 tabulates a comparison of the ratings of provenances within each arboretum. It also presents a graph of rating for the best provenance (excluding plots on explosives-shattered sites) within each arboretum.

In only two instances was statistically significant (.05 level) variation detected between the performance rating of different provenances of E.maculata:-

> In the George Upland arboretum, the rating of the Kioloa State Forest provenance (9448) was significantly lower than that of any other provenance.

<u>FIGURE 6.4</u>

<u>An Analysis Of E.maculata Performance</u>



DEL PARK		MARRINUP		GEORGE UPLAND		GEORGE LOWLAND		BINGHAM RIVER	
PROV.	**RATING**	**PROV.**	**RATING**	**PROV.**	**RATING**	**PROV.**	**RATING**	**PROV.**	**RATING**
----	49.5	10865	47.6	4817	34.1	11181	36.5	11181	51.9
		11181	45.1	11965	33.5	9448	32.1	4817	49.8
		12135	40.5	10728	33.2	4817	31.1	9448	49.8
		10846	38.5	11181	33.1	11965	28.5	10728	34.0
		11005	38.3	9448	22.1	10728	25.7	11965	30.0
		11965	36.0			10615	24.8		
		10728	34.1						
		9580	33.7						
		11240	33.0						
		9461	28.8						

] = not significantly different (.05 level)

<u>KEY TO PROVENANCES</u>

<u>SEEDLOT</u>	<u>PROVENANCE DETAILS</u>
4817	Plantation, Kirrup W.A. (origin unknown)
9448	Kioloa S.F. N.S.W.
9461	Belmore S.F. N.S.W.
9580	Kempsey N.S.W.
10615	Raymond Terrace, N.S.W.
10728	Beaufort Vic.
10846	Clouds Ck S.F. N.S.W.
10865	Barakula S.F. Qld.
11005	Gundish Qld
11181	Hunter Valley N.S.W.
11240	Richmond Range N.S.W.
11965	Coffs Harbour N.S.W.
12135	Termeil N.S.W.

FIG 6.4 MACULATA

At Bingham River, rating of the Coffs Harbour provenance (11965) was significantly lower than that than that for the Hunter Valley provenance (11181).

The Hunter Valley provenance of E.maculata (11181) displayed the most consistent performance between arboreta (figure 6.4). It had the highest mean rating in George Lowland and Bingham River arboreta and was not significantly different (.05 level) from the best provenances in Marrinup and George Upland. It also displayed the highest mean height of any provenances in all four arboreta.

Survival :

Survival of E.maculata at Bingham River was well below average for all plots except that containing the Hunter Valley provenance (figure BR-7 in Attachment 5). These and indeed all results pertaining to stem damage and survival at Bingham River must be treated with caution, as it is quite possible that these have been influenced by the wildfire which (burnt through Bingham River) in 1979.

Stem Defect :

Borers were found in the Coffs Harbour provenance (11965) of E.maculata at Bingham River. Throughout all arboreta this was the only plot of E.maculata in which borers were found (Appendix 2).Again it must be noted that the damage of stems by fire may assist the entry of borers into the tree.

No evidence of termites was found.

With the exception of four plots, all plots of E.maculata at Bingham River and Marrinup contained some degree of stem splitting. The exceptions were 10728 (Beufort, Vic. provenance) at Bingham River, the blasted caprock plot of 11181 (Hunter Valley, N.S.W. provenance) at Marrinup, and the Coffs Harbour provenance (11965) at both arboreta. No evidence of stem defect was found in E.maculata at George Upland. Only one plot of E.maculata at George Lowland suffered stem defect. This was 10615 (Raymond Terrace, N.S.W. provenance) in which some stem splitting was recorded.

General Comments On Performance :-

Like many other species in this study, E.maculata displayed significantly better performance (rating) at Bingham River than at George Upland or Lowland (figure 6.4).

EXAMPLE 2 : E.resinifera (current rehab. species)

Comparison of Provenances :

For E.resinifera, performance rating did not vary significantly between the different provenances in George Upland or Bingham River arboreta.

In both the Marrinup and George Lowland arboreta, provenance 10962 (South Helenvale Qld.) exhibited the worst performance (significant at the .05 level) (figure 6.5).

The Mendowie S.F. (N.S.W.) provenance of E.resinifera (11963) displayed the most consistant performance between arboreta.

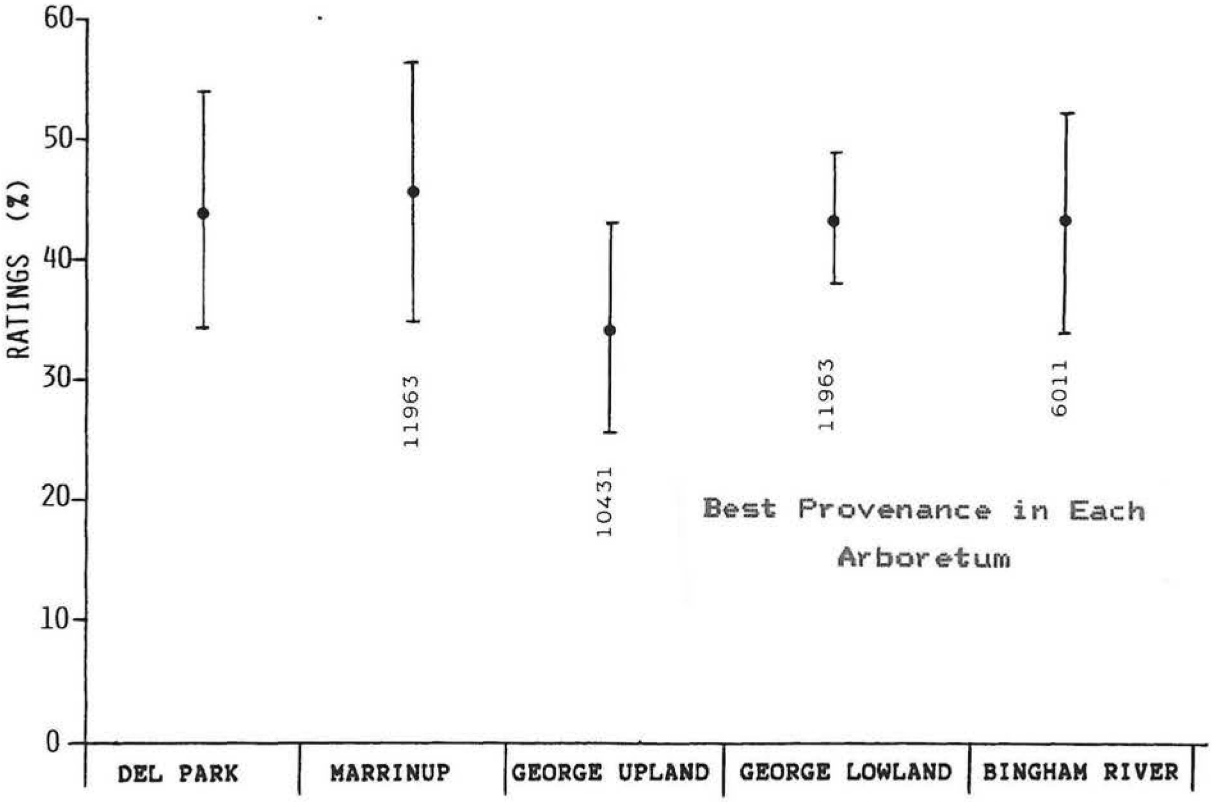
A similar separation of the provenances is obtained when height is the parameter used for comparison (figures MA-3, GU-3, GL-3 and BR-3 in attachments).

Survival :

At George Upland, 11209 (Beerwah Qld.) displayed a survival of 62% (Appendix 2). This was 18% lower than the average for all E.resinifera plots. Elsewhere survival percentages for E.resinifera were relatively high.

FIGURE 6.5

An Analysis Of E.resinifera Performance



DEL PARK PROV.	DEL PARK RATING	MARRINUP PROV.	MARRINUP RATING	GEORGE UPLAND PROV.	GEORGE UPLAND RATING	GEORGE LOWLAND PROV.	GEORGE LOWLAND RATING	BINGHAM RIVER PROV.	BINGHAM RIVER RATING
---	44.2	11963	45.7	10431	34.4	11963	42.7	6011	43.2
		11011	43.3	11963	32.4	6011	34.0	11963	34.5
		11209	37.1	6011	32.2	10431	33.1		
		10113	32.2	10962	24.6	10962	19.4		
		10431	28.3						
		10962	19.2						

] = Not significantly different (.05 level)

KEY TO PROVENANCES

SEEDLOT	PROVENANCE DETAILS
6011	Gleneagle Arboretum (origin unknown)
10113	Woolgoolga N.S.W.
10431	Woolgoolga N.S.W.
10962	South Helenvale Qld.
11011	S.W. Ingham Qld.
11209	Beerwah Qld.
11963	Medowie S.F. N.S.W.

Fig 6.5 RESINIFERA

Stem Defect :

E.resinifera suffered some of the worst incidences of borer damage of any species in this study. Details of plots suffering defect damage are as follows:-

Del Park - borers

Marrinup - borers in 11011,11209,10962; termites in 10431.

George Upland - borers in 10431,6011.

George Lowland - borers in 11963,6001,10431,10962 (ie all plots)

Bingham River - borers in 6001, borers and termites in 11963.

General Comments On Performance :

Unlike many other species in this study, E.resinifera did not exhibit enhanced performance at Bingham River. Overall growth is nevertheless quite good, with an average rating (over all plots) of 33.7%.

The high level of occurrence of borers at all locations and accross a broad range of provenances casts doubt on the suitability of this species for rehabilitation in the Northern Jarrah Forest.

EXAMPLE 3 : E.accedens (currently minor rehab species)

Comparison of Provenances :

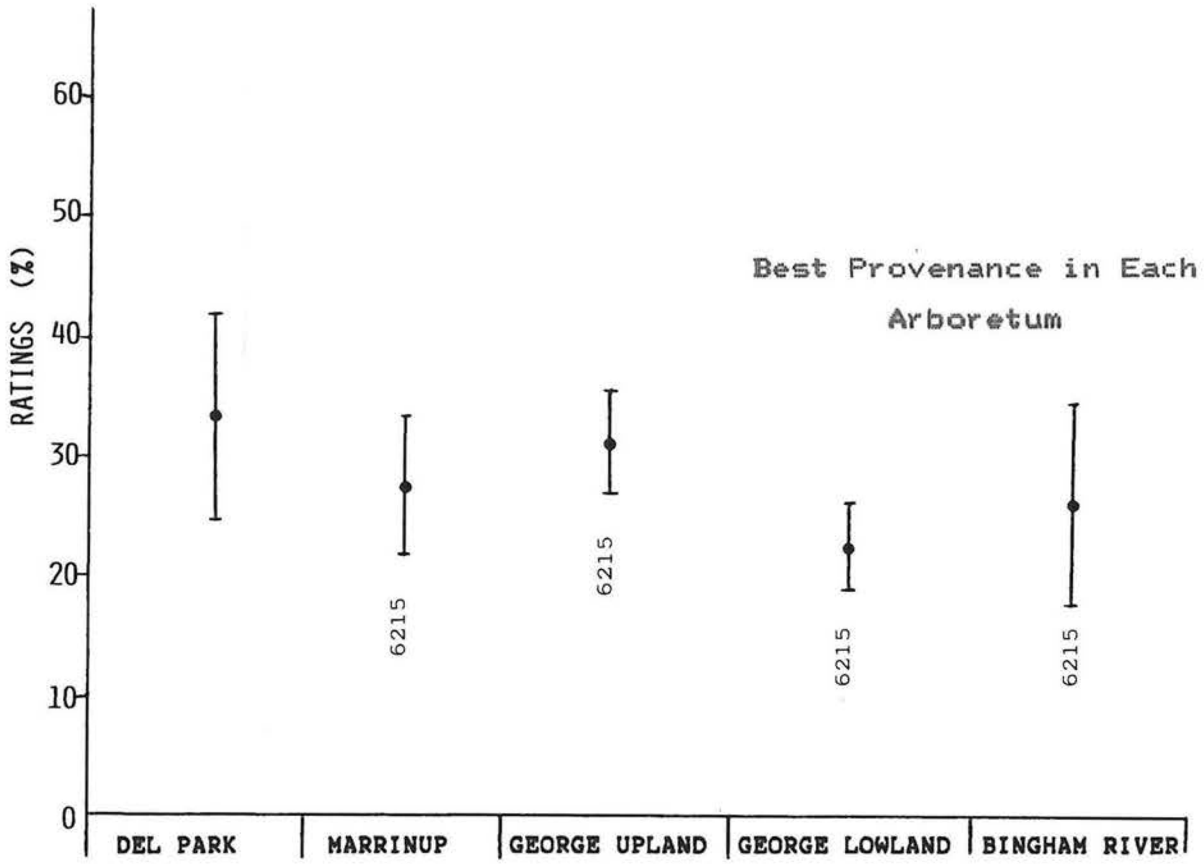
E.accedens was represented by two provenances at Marrinup arboretum and only one provenance at the other four arboreta (Figure 6.6).

Survival :

Survival of E.accedens was high (greater than 80%) in all arboreta except Bingham River where survival was 56% .

FIGURE 6.6

An Analysis Of E.accedens Performance



DEL PARK PROV.	DEL PARK RATING	MARRINUP PROV.	MARRINUP RATING	GEORGE UPLAND PROV.	GEORGE UPLAND RATING	GEORGE LOWLAND PROV.	GEORGE LOWLAND RATING	BINGHAM RIVER PROV.	BINGHAM RIVER RATING
----	32.7	6215	27.0]	6215	30.7	6215	22.0	6215	25.4
		6537	22.1]						

] = Not significantly different (.05 level)

KEY TO PROVENANCES

SEEDLOT	PROVENANCE DETAILS
6215	Narrogin W.A.
6537	Dryandra S.F. W.A.

Fig 6.6 accedens

Stem Defect :

Stem splits were found in all except Del Park arboretum. Borers were found in Del Park arboretum. Termites were found in stems in both Del Park and George Upland Arboreta.

General Comments On Performance :

In George Upland E.accedens displayed significantly better growth performance than in George Lowland. Although this was the only significant separation of arboreta, it is interesting to note that the performance in Bingham River arboretum was variable, showing twice the range of that in George Upland. This would suggest that E.accedens prefers drier, upland locations, and may be a useful species for the future rehabilitation of mined areas in the intermediate rainfall (eastern) area as well as the harsh, upland dieback-degraded areas in both High and intermediate rainfall areas which have proven so inhospitable for tree growth to date.

EXAMPLE 4 : E.globulus (good performance - current study)

Comparison of Provenances :

E.globulus was represented by only one provenance at four of the arboreta (Figure 6.7).

Survival :

Like E.accedens, E.globulus had survival greater than 80% in all arboreta except Bingham River where survival dropped to 53% for E.globulus. Stem damage by wildfire may have been to some degree responsible for this low survival.

Stem Defect :

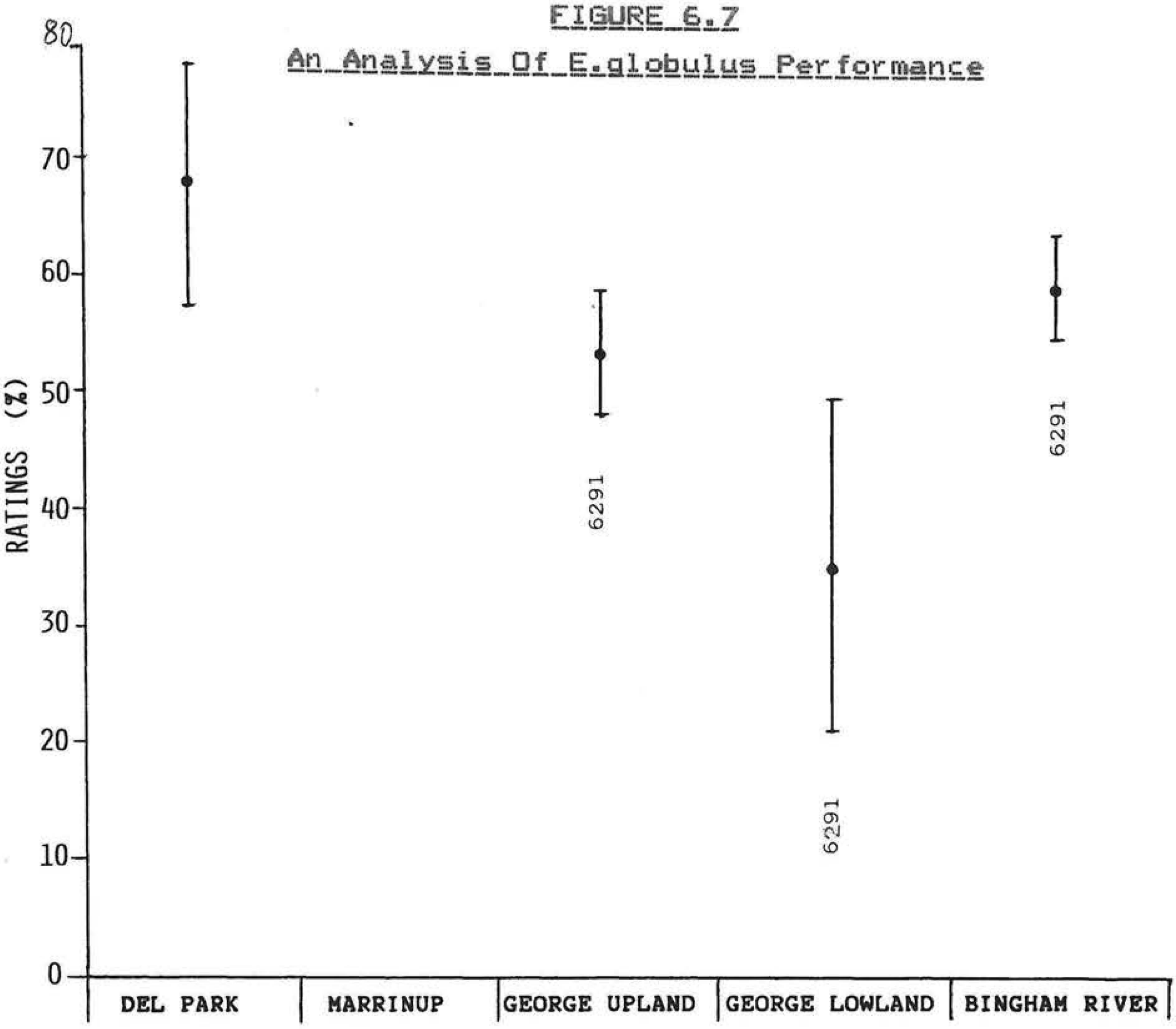
Evidence of borers was found at Del Park and Bingham River arboreta. There was also a low occurrence of stem splitting at Del Park.

General Comments On Performance :

E.globulus displayed impressive performance with one plot at Bingham River with a rating of 59% and an average over all arboreta of 49.7% (Figure 6.7). Like many species, its worst performance was at George Lowland.

FIGURE 6.7

An Analysis Of E.globulus Performance



DEL PARK		MARRINUP		GEORGE UPLAND		GEORGE LOWLAND		BINGHAM RIVER	
PROV.	**RATING**	**PROV.**	**RATING**	**PROV.**	**RATING**	**PROV.**	**RATING**	**PROV.**	**RATING**
	57.8			6291	52.8	6391	34.8	6291	59.0

KEY TO PROVENANCES

SEEDLOT	PROVENANCE DETAILS
6291	Tasmania (exact location unknown).

fig 6.7 GLOBULUS

Despite its cool,wet schlerophyl origins, this species appears to be quite adaptable. On one of the most harsh sites (George Upland) it averaged a rating of 52.8%.

EXAMPLE 5 : *E.botryoides* (good performance - current study)

Comparison of Provenances :

There was no significant difference between the ratings of provenances within each arboretum. Figure 6.8 highlights the consistancy of high performance for E.botryoides both between provenances and between arboreta.

Survival :

Survival was consistently good, ranging from 70% to 98% (Appendix 2).

Stem Defect :

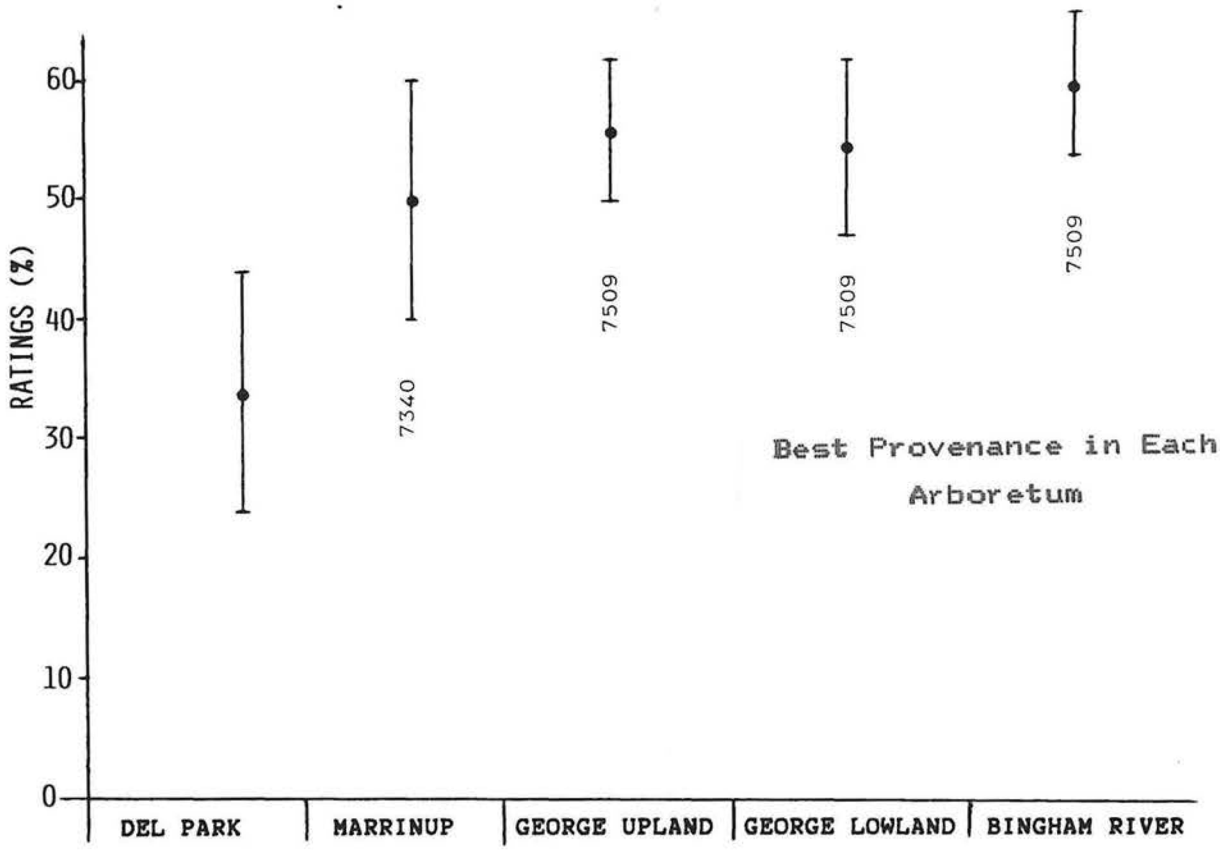
Evidence of borers was found at Del Park (in a drainage sump) and Bingham River. All plots at Bingham River had some degree of infestation, however this may have been aided to some degree by stem damage resulting from the wildfire mentioned in the introduction.. No evidence of borers,termites or stem splits was found at the other arboreta.

General Comments On Performance :

E.botryoides displayed both impressive and consistent performance. Growth performance in Marrinup, Bingham River and both George arboreta could not be separated (Figure 6.8). Unlike the majority of species (both the faster and slower growing species), E.botryoides did not suffer any depression in performance in either of the George arboreta.

FIGURE 6.8

An Analysis Of E.botryoides Performance



DEL PARK		MARRINUP		GEORGE UPLAND		GEORGE LOWLAND		BINGHAM RIVER	
PROV.	RATING	PROV.	RATING	PROV.	RATING	PROV.	RATING	PROV.	RATING
----	33.3	7340	49.5 ⌉	7509	55.3 ⌉	7509	53.8 ⌉	7509	59.5 ⌉
		12104	48.6	12134	47.1	12104	48.4	12134	48.3
		7509	48.3	12104	45.6 ⌋	12134	46.8 ⌋	12104	46.1 ⌋
		12134	47.8 ⌋						

] = Not significantly different (.05 level)

KEY TO PROVENANCES

SEEDLOT	PROVENANCE DETAILS
7340	Orbost Vic.
7509	Bodalla N.S.W.
12104	W. Orbost Vic.
12134	Meeroo Pt. N.S.W.

Fig 6·8 Botryoides

At this stage (it is still very young), E.botryoides appears to be one of the more promising species, although it would appear to be better left out of water-ponding areas to avoid problems with borers.

<u>EXAMPLE 6</u> : <u>E.viminalis</u> (good performance - current study)

<u>Comparison of Provenances</u> :

At George Lowland the overall performance ratings of two provenances, 11823 (Eildon, Vic.) and 8911 (Rocky River S.A.) were significantly higher than the corresponding ratings for 12400 (Blue Range, Vic.) and 9320 (S.W. Port Lincoln S.A.) - (Figure 6.9). At Bingham River, 11823 (Eildon,Vic.) showed significantly better performance than either provenance 9320 (Port Lincoln S.A.) or 8911 (Rocky River S.A.).There was no significant difference between provenances at George Upland. E. viminalis was not included in the Del Park or Marrinup arboreta.

Eildon (Victoria) appears to be the best provenance overall, while Blue Range (also Victoria) appears to be one of the worst.

<u>Survival</u> :

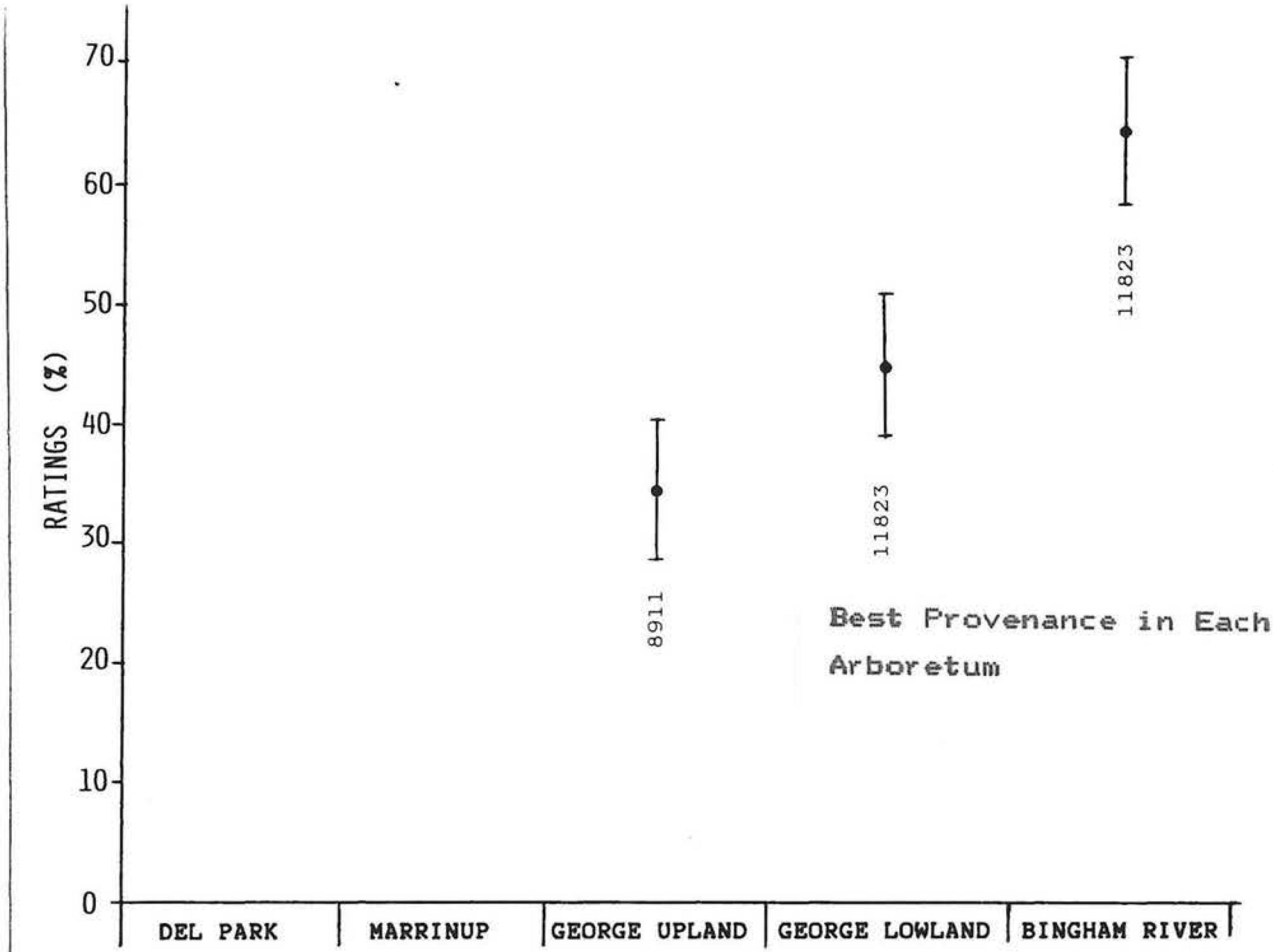
Survival was good in both George arboreta, ranging from 82 to 94% . Survival at Bingham River was variable (ranging between 63 and 92 %). This variation may have been due to the wildfire which burnt through Bingham River arboretum some years ago (see introduction).

<u>Stem Defect</u> :

Evidence of borers was found in 2 plots at Bingham River.

FIGURE 6.9

An Analysis Of E.viminalis Performance



DEL PARK PROV.	DEL PARK RATING	MARRINUP PROV.	MARRINUP RATING	GEORGE UPLAND PROV.	GEORGE UPLAND RATING	GEORGE LOWLAND PROV.	GEORGE LOWLAND RATING	BINGHAM RIVER PROV.	BINGHAM RIVER RATING
				8911	33.9	11823	44.4	11823	64.0
				11823	33.2	8911	34.3	12400	58.7
				9320	28.9	12400	32.5	9320	47.9
				12400	25.9	9320	28.1	8911	47.4

] = Not significantly different (.05 level)

KEY TO PROVENANCES

SEEDLOT	PROVENANCE DETAILS
8911	Rocky River S.A.
9320	S.W. Port Lincoln S.A.
11823	Eildon Vic.
12400	Blue Range Vic.

Fig 6.9 Viminalis

The two plots with borers (11823 and 9320) also happen to have the worst survival figures. This would indicate the possibility that stem damage by wildfire assisted the entry of borers into the tree. The other two plots at Bingham River contained bark splits.

General Comments On Performance :

While the performance of E.viminalis at George Upland is by no means poor, the distinct separation between performance in George Upland and Bingham River (Figure 6.9), and to a lesser extent George Lowland and Bingham River, would suggest that the provenances of E.viminalis studied here would tend to prefer the more fertile and moist low-lying areas.

EXAMPLE 7 : *E.microcarpa* (good hydrological qualities)

Comparison of Provenances :

Although separation of the arboreta on the basis of rating was quite distinct (Figure 6.10), provenances within each arboretum did not differ significantly for any of the parameters measured for tree performance.

Survival :

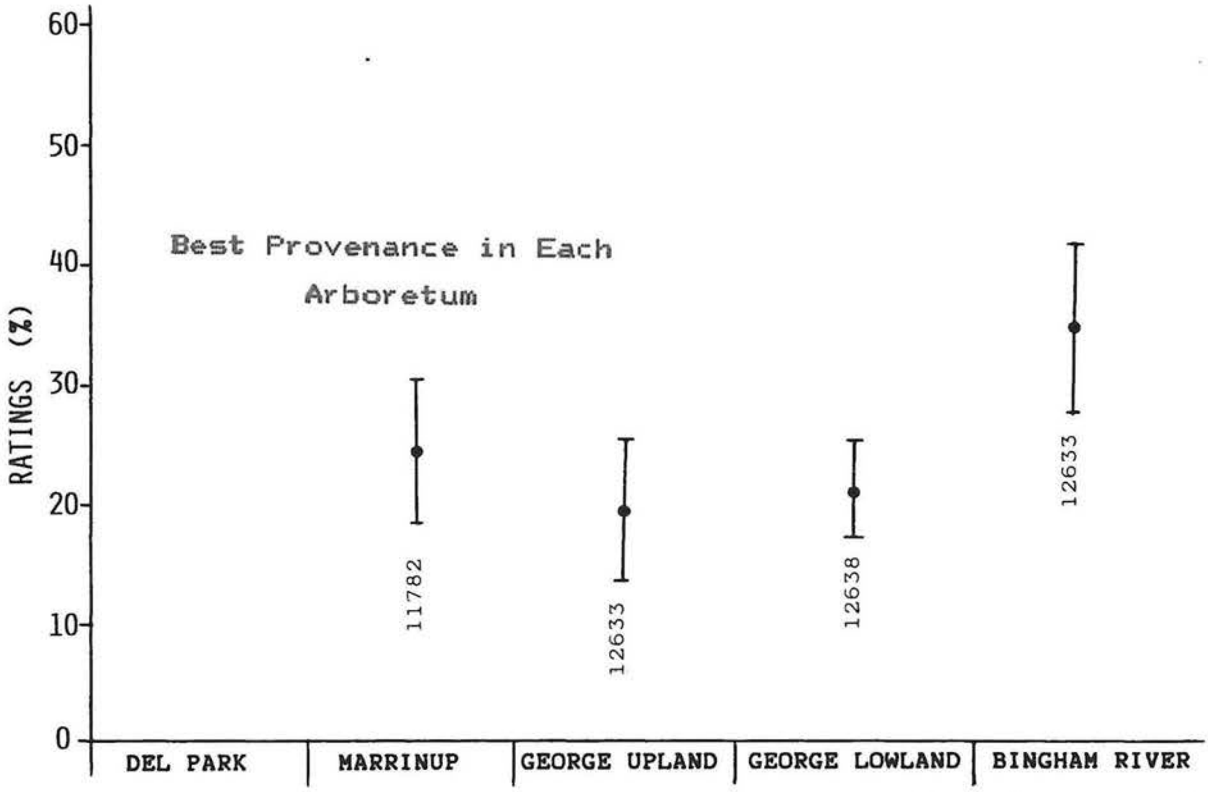
One plot at George Upland (12638 - Tooborac, Vic) had relatively poor survival (58%). All other plots of E.microcarpa throughout all arboreta showed good survival, the absolute mean survival for the species being 84% .

Stem Defect :

Evidence of borers was found in one plot (12638 - Tooborac, Vic.) in Bingham River (Appendix 2). The presence of stem splits was also noted in this plot.

FIGURE 6.10

An Analysis Of E.microcarpa Performance



DEL PARK PROV.	RATING	MARRINUP PROV.	RATING	GEORGE UPLAND PROV.	RATING	GEORGE LOWLAND PROV.	RATING	BINGHAM RIVER PROV.	RATING
		11782	23.3	12633	18.7	12638	20.1	12633	34.0
		8758	16.2	12638	16.8	12633	18.2	8758	33.7
				8758	12.4	8758	18.0	12638	31.6

] = Not significantly different (.05 level)

KEY TO PROVENANCES

SEEDLOT	PROVENANCE DETAILS
8758	Parkes N.S.W.
12633	Heathcote Vic.
12638	Tooborac Vic.

FIG 6.10 MICROCARPA.

The plot with provenance 8758 (Parkes, N.S.W.) suffered both sapwood damage by termites and stem splits.

Stem splits were also recorded in plots 11782 (Marrinup), 12638 (George Upland) and 12633 (Bingham River). The separation between performance in George Upland and Bingham River (Figure 6.10), and to a lesser extent George Lowland and Bingham River, would suggest that the provenances of E.viminalis studied here would tend to prefer the more fertile and moist low-lying areas.

General Comments On Performance :

The reputation which E.microcarpa has for transpiration and water consumption originates from studies conducted at Bingham River arboretum. Figure 6.10) shows that the growth performance of E.microcarpa in the George arboreta was substantially less than that in in the Bingham River arboretum. Transpiration studies should be repeated in the George arboreta to ensure that the transpirative ability of this species does not drop correspondingly.

EXAMPLE 8 : E.sideroxylon (good hydrological qualities)

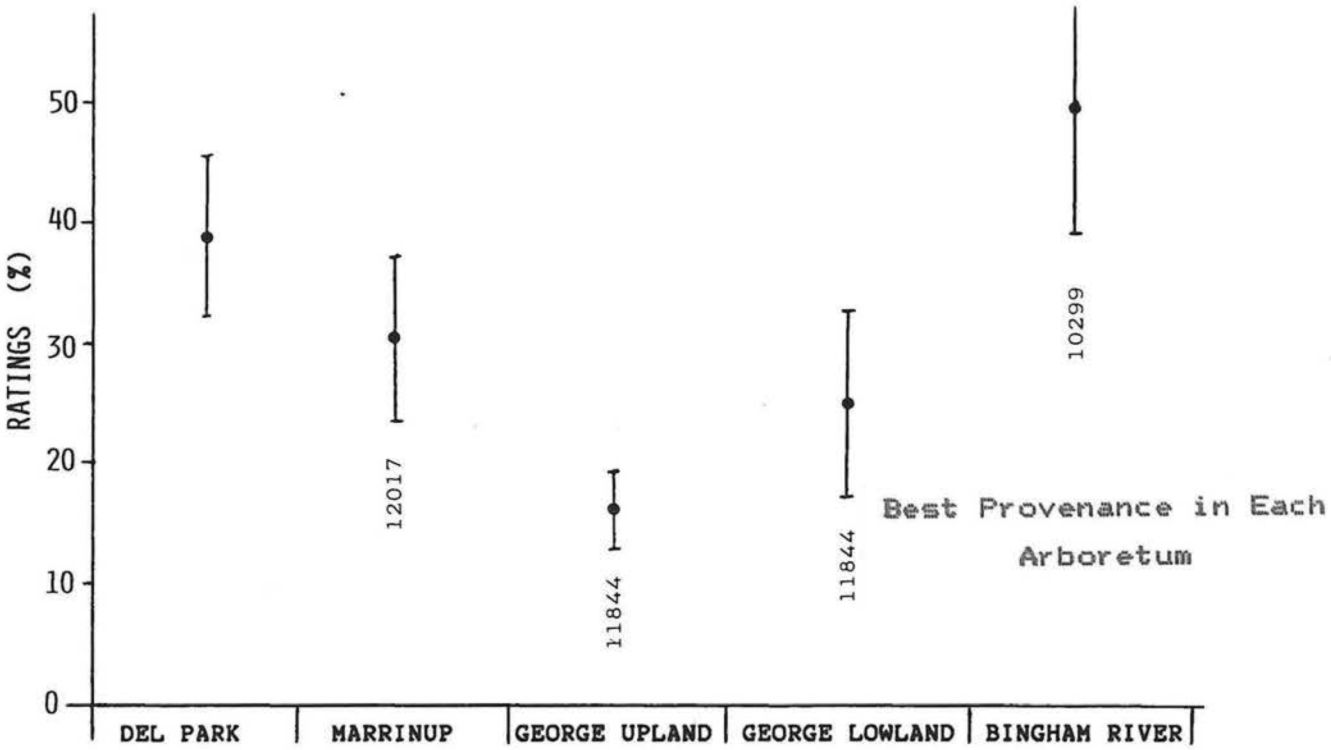
Comparison of Provenances :

The graph of best rating performance in each arboretum for E.sideroxylon (Figure 6.11) closely followed that for E.microcarpa (Figure 6.10). The performance rating for E.sideroxylon was significantly better in Bingham River than in George Upland. The performance of provenances within each arboretum did not differ significantly.

It was not possible to make any recommendations as to which subspecies (tricarpa or sideroxylon) was best.

FIGURE 6.11

An Analysis Of E.sideroxylon Performance



DEL PARK PROV.	DEL PARK RATING	MARRINUP PROV.	MARRINUP RATING	GEORGE UPLAND PROV.	GEORGE UPLAND RATING	GEORGE LOWLAND PROV.	GEORGE LOWLAND RATING	BINGHAM RIVER PROV.	BINGHAM RIVER RATING
---	38.7	12017	30.3]	11844	15.9]	11844	24.8]	10299	9.3]
		11844	28.9]	12636	15.7]	12636	18.5]	11844	39.3]
		12001	25.9]					12636	30.4]

] = Not significantly different (.05 level)

KEY TO PROVENANCES

SEEDLOT	PROVENANCE DETAILS
11844	(ssp siderox.) Gilgandra N.S.W.
12001	(ssp siderox.) Inglewood Qld.
12017	(ssp siderox.) Goonoo S.F., N.Dubbo N.S.W.
12636	(ssp tricarpa) W. Puckapunyal Vic.

Fig 6.11 Sideroxylon

Survival :

Survival was quite variable within and between arboreta and provenances (Appendix 2). For example provenance 12636 (subspecies tricarpa, Puckapunyal Vic.) had a survival rate of 64% in George Upland, 96% in George Lowland and 56% at Bingham River.

Stem Defect :

Evidence of borers was found in only one plot (10299 -subspecies tricarpa, W.Cann River, Vic.) in Bingham River. This was the only incidence of defect observed.

General Comments On Performance :

The overall performance ratings for E.sideroxylon tended to be better than for E.microcarpa, however the survival of E.sideroxylon was far more erratic. As stated for E.microcarpa, transpiration studies should be repeated in the George arboreta to ensure that the transpirative ability of this species does not decrease with poorer growth performance.

EXAMPLE 9 : E.melliodora (good hydrological qualities)

Comparison of Provenances :

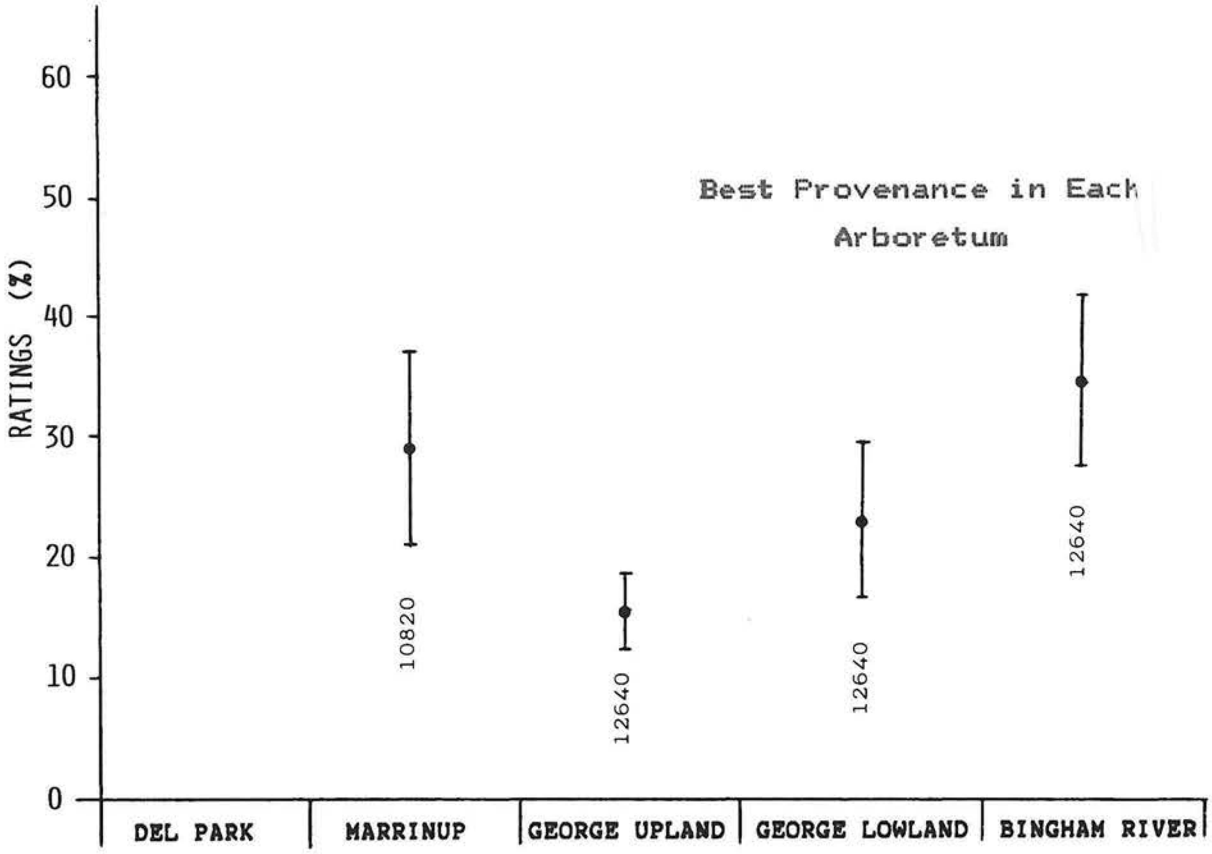
A comparison of performance ratings between arboreta for E.melliodora (figure 6.12) closely followed that for the two previous hydrologically useful species.

The only significant separation of provenances occurred at Bingham River where the E.melliodora from Beaufort, Victoria (12640) displayed significantly better performance (rating) to the provenance from Kambah, A.C.T. (11860).

Survival :

FIGURE 6.12

An Analysis Of E.melliodora Performance



DEL PARK PROV.	DEL PARK RATING	MARRINUP PROV.	MARRINUP RATING	GEORGE UPLAND PROV.	GEORGE UPLAND RATING	GEORGE LOWLAND PROV.	GEORGE LOWLAND RATING	BINGHAM RIVER PROV.	BINGHAM RIVER RATING
		10820	29.0	12640	15.6	12640	22.7	12640	34.3
		11787	25.8	11860	14.9	11827	20.2	11827	29.6
		10825	25.2	11827	11.0	11860	13.1	11860	21.3
		11827	19.0						
		11860	17.3						

] = Not significantly different (.05 level)

KEY TO PROVENANCES

SEEDLOT	PROVENANCE DETAILS
10820	E. Armidale N.S.W.
10825	Tenterfield N.S.W.
11787	Castlereagh River N.S.W.
11827	E. Trangle N.S.W.
11860	Kambah A.C.T.

Fig 6.12 melliodora

Survival figures for Marrinup, George Lowland and Bingham River were quite acceptable (Appendix 2). In George Upland however, the survival figures for 11860 (Kambah, A.C.T.) and 11827 (Trangie, N.S.W.) were 57% and 46% respectively..

Stem Defect :

Evidence of borers was found in one plot (11827 - subspecies rosea, Trangie, N.S.W.) in George Lowland. Stem splits were present in Bingham River arboretum (11860 - Kambah, A.C.T.). Stem defects were not observed in any other plots.

General Comments On Performance :

The overall growth performance of E.melliodora followed that of the previous two hydrological species closely. The poor survival figures for George Upland are disturbing and require further investigation. The matter of survival is especially important for these species which are chosen for their water consumption ability . Should a large percentage of trees die at some stage, the transpiration of that stand of trees would be vastly reduced for some time.

WE NEED SOME SORT OF CONCLUSION TO PLACE ABOVE SURVEY OF 9 SPECIES INTO SOME PERSPECTIVE.........ANY IDEAS?

BIBLIOGRAPHY

APPENDIX 1.1 EXAMPLE OF BOOKING SHEET

LINE 7

DATE 8/3/85

Site Number		Tree number	HEIGHT ESTIMATE % To Top	HEIGHT ESTIMATE % To Base	HEIGHT or dist To Tree	Diameter (cm)	Form (0-4)	Crown act. (0-2)	Vigour (0-4)	COMMENTS i.e. Borers, Splits, Leaf Damage
68	1	1	50	30	6·0	6·3	1	2	2	STEM A
		1	40	30	6·0	5·9	0	2	2	STEM B
		2	50	35	5·0	6·7	0	2	1	
		3			1·8	3·0	0	2	1	
		4			1·5	3·0	0	2	1	
		5	52	32	6·0	7·2	2	2	2	
		6			·	4·9	0	2	1	STEM A
		6			·	4·8	0	2	1	STEM B
		7	32	35	5·0	4·7	0	2	2	
		8	33	33	5·0	5·3	0	2	2	
		9	45	35	5·0	4·9	0	2	2	
		10	64	35	5·0	6·2	0	2	2	
		11			2·3	3·9	0	2	1	
		12	50	55	4·0	5·6	0	2	2	
		13			·	·				MISSING
		14			·	·				MISSING
		15			0·6	·	0	1	1	DIA. TOO SMALL (NUMEROUS STEMS)
		16			2·0	3·9	0	2	1	

3 APPENDICES
TO
COME.