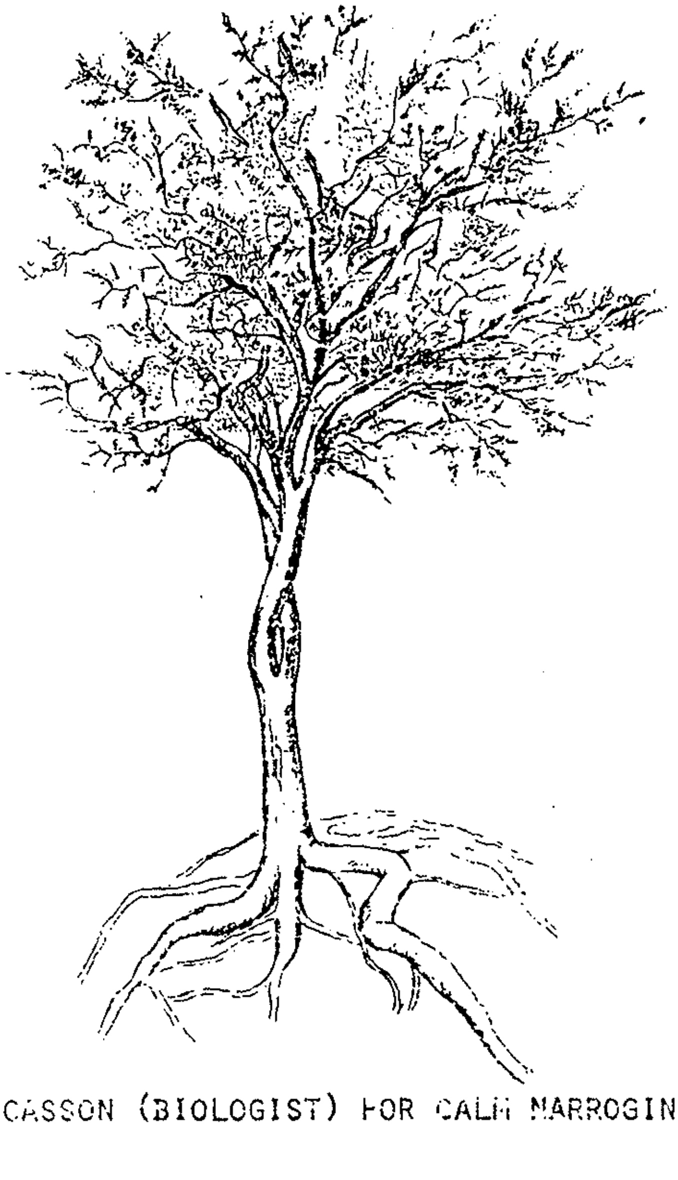
REMNANT WHEATBELT SANDALWOOD

(Santalum spicatum)



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1. INTRODUCTION

Australian sandalwood (*Santalum spicatum*) is a root hemi-parasite. That is, it is a chlorophyll containing parasite which superficially appears self-sustaining. In form it ranges from a shrub to a small tree with single or multiple stems (Herbert, 1925).

The status of Australian sandalwood has changed from a species with a wide distribution and representation, to one of restricted, "remnant" status over much of its former range (Figure 1). Such change was precipitated by commercial exploitation since European colonization (Talbot, 1990). Nowhere is this more evident than the "wheatbelt" of Western Australia (approximating the 250-500mm rainfall zone; Figure 2). Where massive clearing compounded the effect and left less than 5 % of the total indigenous plant cover in most areas. At present sandalwood can be found on a third of this area (Muir, 1978).

Current management requirements for sandalwood in the wheatbelt reflect the historical legacies left to the present. They are the endurance of a market for sandalwood oil based products, the dual needs of land reclamation and diversification on much wheatbelt farmland, and the acute reduction in population size and range of the species (Keally, 1990; WAWA, 1989). They mean that the social issues of conservation and commercialization are now combined.

Against this background the current research focussed on remnant sandalwood populations in the wheatbelt. The main objectives were to :

* elucidate which plant communities and soil types were habitat for this species

* determine whether any sub-specific groups were evident across the wheatbelt on the basis of gross morphological (phenotypic) characters.

* identify relationships between habitat and phenotype

* test germination of the populations encountered

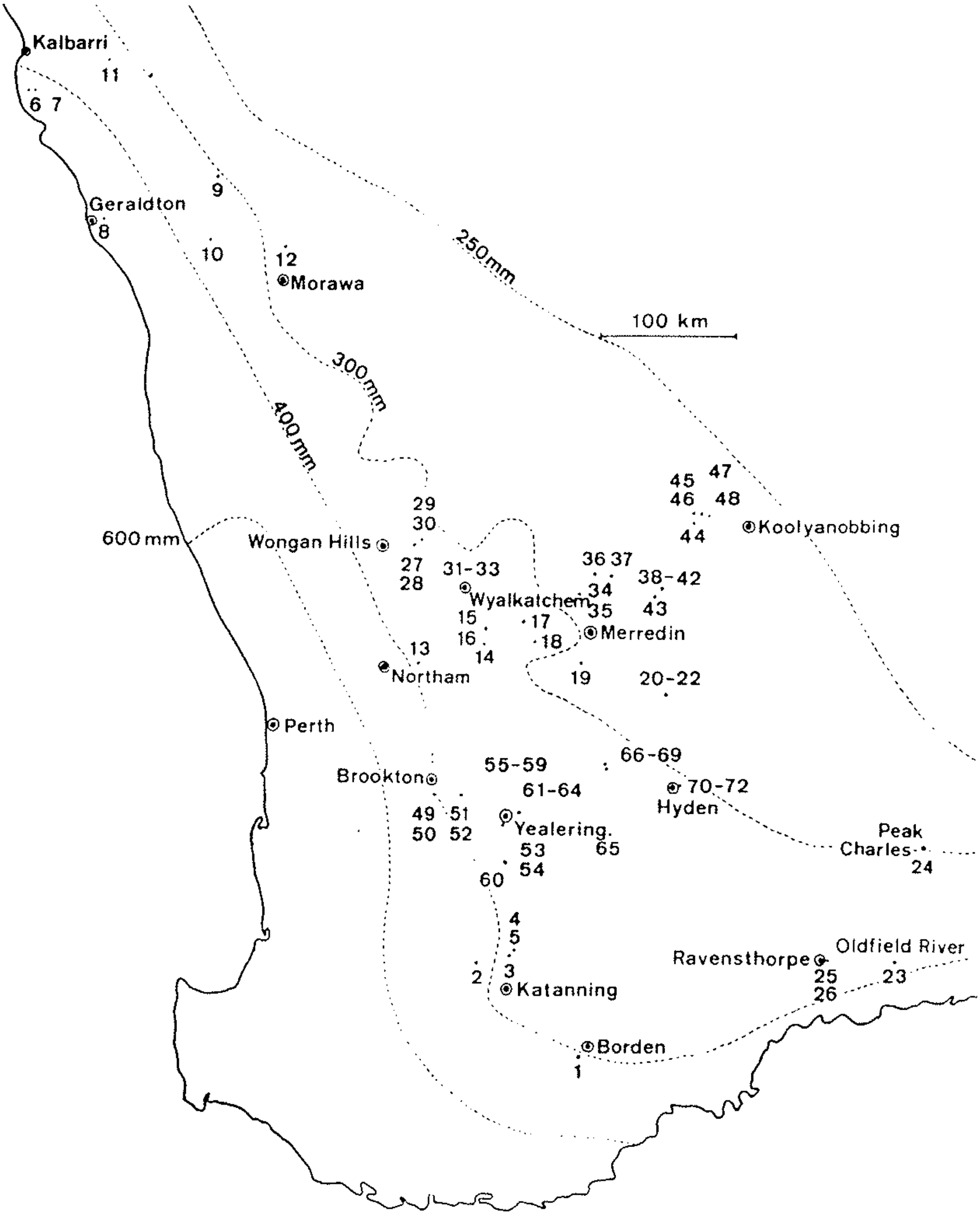


FIGURE 1 : THE LOCATION OF THE STUDY SITES FOR THE SURVEY OF REMNANT WHEATBELT SANDALWOOD

2. SELECTION AND LOCATION OF STUDY SITES

Sites which had populations of sandalwood were selected throughout the wheatbelt. They were chosen for the local populations apparent remnant or relictual status. So that a priority was placed on populations in reserves over sites on private property; except where no geographical alternatives existed such as in the extreme north and south-west of the study area.

The locations of the study sites are shown in Figure 1. Site numbers and names are listed in Appendix 10. Section 6.3 outlines major transects.

The "wheatbelt" as referred to below approximates that part of Western Australia bounded by the 400 mm isohyet and a line from the Oldfield River passing between Merredin and Koolyanobbing then continuing along the 270 mm median to the latitude of Kalbarri (Figure 1).

3. SANTALUM SPICATUM POPULATION ASSESSMENT

The aim of this section was to assess the status of the remnant populations of sandalwood which were surveyed.

METHODS

Individual plant health was coded according to :

PLANT : HEALTHY	PLANT : STRESSED
0 Intact	10 Intact
1 Few leaves dead	11 Few leaves dead
2 Tips dying	12 Tips dying
3 Whole branches dead	13 Whole branches dead
4 30% tree dead	14 30% tree dead
5 30-50% " "	15 30-50% " "
6 >50% " "	16 >50% " "

Where a "stressed" plant was considered to be chlorotic (showing yellowing) and / or wilting.

The health of the *Santalum spicatum* population and of community 'dominants' was coded according to :

0 No evidence of stress
1 Odd plant showing signs of stress
2 One or two dying plants under severe stress
3 Scattered dying and dead plants around the plot
4 Susceptible plants dying or dead
5 Graveyard death

The number of regenerating plants in the population (in 50 m2) were coded according to :

	0	1	2	3	4	5
Seedling number	none	1-3	3-5	5-30	30-50	>50
Resprout number	none	1-3	3-5	5-30	30-50	>50

Reproductive status was coded according to :

0 No buds or fruit
1 Buds
2 Initial flowers
3 Full blossom
4 Flowers withering
5 Young fruit
6 Mature fruit
7 Old fruit

To give an impression of whether *Santalum spicatum* occurred as isolated individuals or in groups the population within a habitat type was categorized according to whether they occurred individually or in clusters (defined as having touching canopies) and what number occurred in each category thus :

Score	0	1	2	3	4	5
# Individuals in the population	none	1-3	3-5	5-30	30-50	>50

Score	10	11	12	13	14	15
# Clusters in the population	none	1-3	3-5	5-30	30-50	all

At each site an estimate was made of the size categories present and then a number of individuals were selected in each category for measurement in proportion to their representation in the greater population. That is the subsample had a composition which reflected the population.

For each individual the height, crown width (average of the widest point and a diameter at 90 degrees to it), basal stem diameter (15 cm height), D.B.H., stem numbers at 15 cm and stem numbers at D.B.H. were assessed.

Transformation of proportions for regressions

All proportions (including pH) and percentages were transformed prior to use in analysis. The normalizing function used was : X(transformed) = 1/sin (square root of X).

If the regression equations quoted below are used to derive other parameters conversion will be necessary for proportions and percentages.

RESULTS AND DISCUSSION

The impact of settlement

One very important proviso when using the information in this report is to consider the impact of European settlement upon the "remnant" sandalwood which is its subject. There are several unknown factors which cannot be subjectively assessed. They are the timing and intensity of sandalwood harvesting at a location, and the stage in the "successional sequence" that communities are at after natural events such as fire and drought. Note that the fire cycle has in its turn been affected by settlement.

This means that parameters such as density and tree size may not be the same as they would have been prior to settlement, and at best may be treated as "noisy" approximations; somewhat ameliorated by covering a large number of sites.

Factors not directly subject to such interference and therefore possibly more closely linked to the ecotype/phenotype/genotype may be leaf and fruit features.

Health of individual plants and populations

Overall individual plants could be characterized as healthy, with whole branches or up to 30 % of the tree dead.

Stressed plants were evident at sites 46 and 56 (due to waterlogging?) and sites 21 and 50 (due to poor soils/limited hosts?).

Notable deaths were at Yorkrakine Rock (Site 15) and Sewell Rock (Site 64). At the later this was due to severe habitat disturbance which included seasonal waterlogging.

Otherwise most sites had healthy populations.

Santalum spicatum measurements

The averages for the parameters of gross form are presented in Table 1. These are averages of averages for smaller groups and only serve to illustrate that trees of moderate size are the average present in remnant pockets throughout the wheatbelt.

There was a definite tendency to coppice reflected by an average of 1.63 stems per plant at 15 cm. This number is doubled at breast height. At the same time there is a conservation of diameter (and it is assumed volume) between 15 cm and breast height.

In general there was at least one clumped group amongst each sample profile which represents 15 % of the populations.

TABLE 1 : SANTALUM SPICATUM MEASUREMENTS

PARAMETER	n	MEAN	SD
Height	71	3.20	1.54
Width	71	2.50	1.14
Stem # 15 CM	71	1.63	0.93
Stem # DBH	71	3.25	1.81
Diam 15 CM	71	16.47	8.86
Diam DBH	71	15.45	9.67
Proportion dead	71	0.03	0.10
Proportion Clumped	71	0.15	0.30
# Clumps	71	0.99	2.63

Interrelationships of sandalwood tree dimensions

In Table 2 it can be seen that strong correlations were:

Tree width and height.
Tree diameter at 15 cm and height.
Tree diameter at breast height and height.
Tree diameter at breast height and diameter at 15cm.

One could be derived from the other if required.

TABLE 2 : CORRELATIONS OF SANDALWOOD DIMENSIONS

PARAMETER	r	P	REGRESSION EQUATION
Width SS /Height SS	0.8833	<0.001	(Width)=0.409+ 0.653(Height)
Diam 15cm / " "	0.6046	<0.001	(Dia15)=5.336+ 3.486(Height)
Diam B.Ht./ " "	0.6206	<0.001	(DiaBH)=2.971+ 3.907(Height)
Diam B.Ht./Diam 15cm	0.7224	<0.001	(DiaBH)=2.454+ 0.789(Dia15)

Average density of sandalwood

The considerable variation in the density of *Santalum spicatum* is apparent in the magnitude of the standard deviation around the average (Table 3). This reflects the number of factors which have influenced the reserves since European arrival, including grazing, earthworks, and isolation, and also natural variability within populations and outlying individuals.

TABLE 3 : PERCENT COVER AND DENSITY MEASUREMENTS

PARAMETER	n	MEAN	SD
#/Ha S. spicatum	71	16.98	18.39
% S. spicatum	71	0.93	1.06
% Acacia	71	8.86	8.17
% Allocasuarina	71	4.72	10.29
% Eucalyptus	71	8.00	10.34
% Proteaceae	71	1.25	3.05
% Melaleuca	71	1.19	3.16
% Papillionaceae	71	0.18	0.64
% Duricrust	51	26.39	22.42

Other plant groups and sandalwood density

Density (# plants/ha) was a more discriminatory measure than percent cover for *S. spicatum* as percent cover of it was generally low.

Even so the three main correlates against other groups were weak and of low significance (transformed values). Cheifly these were a positive relationship with cover of acacias and of *Allocasuarina*s and a negative relationship with the cover of members of the Proteaceae (circa 0.1 probability; Table 4). There was a weaker positive trend for density to be related to the combined cover of acacias and eucalypts.

TABLE 4 : CORRELATIONS OF SANDALWOOD DENSITY AND PLANT COVER

PARAMETER		r	P	REGRESSION EQUATION
%SS	/Density SS	0.3110	<0.008	(%SS) =0.109+ 0.003(DenSS)
Density SS	/% Acacia	0.1898	0.113	(Dens)=13.350+1.996(%Acacia)
"	/% Allocasuarina	0.1784	0.137	(Dens)=15.302+1.253(%Allo)
"	/% Proteaceae	-0.1917	0.109	(Dens)=19.853-1.406(%Prot)
"	/%AcaciaEucalypt	0.1712	0.153	(Dens)=13.640+1.869(%AcaEuc)

SS=*Santalum spicatum*;

4 VEGETATION ASSOCIATIONS

There were two aims to this section. One was to elucidate which plant communities were habitat for sandalwood in the wheatbelt. The second was to see if any geographical groupings of communities where recognisable which might reflect sub-specific groups within the sandalwood under study.

METHODS

Vegetation association descriptions

Vegetation associations were described according to Muir (1977) with the exception that a 20 x 20 m area was censused for all strata members. While trees up to 20m from the central, subject *Santalum spicatum* plant, were considered part of the association because of the possibility of root interaction in a parasite-host relationship, and because they could share habitat type and act as indicators of abiotic factors.

Another exception to Muir (1977) was that species were assigned a percent cover of 0.1 % to indicate that they were uncommon.

Grouping by plant species

For the analysis of vegetation associations weed species were excluded.

.Sorensen Analysis

The analysis used was the Sorensen Coefficient (Mueller-Dombois and Ellenberg 1974) for presence absence data with group averaging :

$$\text{SORENSEN COEFFICIENT} = \frac{2c}{S1 + S2}$$

where :

c = the sum of a common quantitative value of a species common to sample 1 and 2.

S1 = the sum of quantitative values of species in sample 1 (S1).

S2 = the sum of quantitative values of all species in sample 2 (S2).

Cosine Theta Analysis

Percent cover was analyzed using Cosine Theta.

The Cosine Theta coefficient is the coefficient of proportional similarity.

$$\text{Cosine Theta(ip)} = \frac{\text{Sum(j) Xji Xjp}}{\text{Sq. Rt. }[(\text{Sum(j) Xji})^2 (\text{Sum(j) Xjp})^2]}$$

Here Theta(ip) is the angle between any two samples Xi and Xp about the Origin. Cosine Theta is a measure of the degree to which samples resemble each other in composition or other attributes. When Theta is 90 degrees, cos Theta = 0, and the samples have nothing in common; when Theta is 0 degrees, cos Theta = 1, and the samples are identical in composition (Imbrie and Purdy, 1962).

.Group averaging

Group averaging was used with both Sorensen and Cosine Theta analysis.

Group averaging is an agglomerative polythetic method of classification. According to Clifford and Stepehenson (1975) "Fusion is with the cluster giving the shortest mean distance." and "... gives only moderately sharp clustering, however, it has the advantages of being monotonic, little prone to misclassification, and with little group size dependence."

RESULTS AND DISCUSSION

The main plant groups associated with sandalwood

As noted above a weak positive relationship to acacias and *Allocasuarinas* and a weak negative relationship to Proteaceae (Hakeas, Grevilleas and Banksias) was apparent .

The lack of strong trends with any other dominant group may be related to the observation that at many sites *Santalum spicatum* was present at the interzone between one to several vegetation types (author - generally and A. Carmichael (sandalwood harvester Ravensthorpe / Norseman area)). Sites where the sandalwood appeared to conform to soil patchiness were 2, 4 & 5, 10, 11, 13, 17, 19, 22, 23, 25, 33, 37, 38, 39, 47, 48, 49, 62, 67, 69, 71.

The negative relationship with Proteaceae corresponded with the author's observation that *Santalum spicatum* was absent from the sandplains between Ravensthorpe and Salmon Gums. Which are dominated by members of the Proteaceae and Myrtaceae. Rather this broad range of associations was home to *Santalum acuminatum*. The latter was also common along road verges, many of which had impoverished understoreys. Also note that in the near coastal areas on sands of old stabilized dunes the 'Christmas tree' (*Nuytsia floribunda*) was the dominant parasitic tree form. Similar trends were apparent to Pat Ryan and the author for the sandplain areas in the Geraldton region and to Havel (1975) for the Perth region.

An 'average' association with sandalwood

The average percent cover for dominant plant groups at the 72 sites is presented in Table 3. The order of predominance was *Acacia* > *Eucalyptus* > *Allocasuarina* > Proteaceae > *Melaleuca* > Papillionaceae. Note that this may have been influenced by the eucalypts of the associations having larger individual percent covers. At many sites there was a significant blue-green algal or lichen based crust.

The main plant species associated with sandalwood

The species list in Appendix 3 records the number of sites at which each species occurred.

Of the most common species several groupings could be recognized. (The number of sites at which the species occurred is also shown here in brackets. Weed species were not included.)

Widespread species were *Neurachne alopecuroidea* (36), *Stipa ? flavescens* (27), *Dampiera lavandulacea* (18), *Lomandra effusa* (17), *Opercularia ? spermacocea* (13), *Stipa ? semibarbata* (12), *Danthonia caespitosa* (10), *Calytrix leschenaultii* (10), and *Olearia ? revoluta* (10).

Widespread ephemerals were *Helichrysum bracteatum* (25), *Podolepis ? capillaris* (17) and *Aristida contorta* (10).

Shallow soil indicators were *Borya sphaerocephala* (33), *Amphipogon strictus* (21) and possibly the sedges *Harperia lateriflora* (14), *Mesomelaena preissii* (10), and *Lepidosperma drummondii* (18).

One group favoured the microhabitat formed by the canopy of small trees and large shrubs and so often also occurred under the sandalwood canopies. They included *Stipa elegantissima* (57), *Dianella revoluta* (39), *Enchylaena tomentosa* (17), *Rhagodia drummondii* (13) and *R. preissii* (10).

Grevillea paniculata (10) appeared to prefer better ? soils/water harvesting situations along minor flowlines.

Candidates as major hosts were *Acacia acuminata* (50), *Allocasuarina campestris* (20), *A. huegeliana* (25) and *Eucalyptus loxophleba* (24). Less likely major hosts, though useful soil indicators - as outlined above, were *E. salmonophloia* (13) and *E. wandoo* (11).

Otherwise a spread with minor, though significant, complements from several families of plants could be recognized. They were the Poaceae (grasses), Cyperaceae and Restionaceae (sedges), Proteaceae (Hakeas, Grevilleas, etc), Mimosaceae (strongly represented with a variety of acacia species), Papillionaceae (pea forms), Sapindaceae and Rhamnaceae, Sterculeaceae and Dilleniaceae, and the Myrtaceae (Melaleaucas, Calytrixes, etc).

The status of Acacia acuminata at the study sites

Areas where *Acacia acuminata* was present but was apparently in decline were sites 1, 2, 3, 4, 5, 15, 20, 28, 31, 32, (54), 60, 61 & 68. At these sites this species required either or both of stimulation to germinate and protection from grazing.

Note that the persistence of sandalwood despite a decline in *A. acuminata* at many sites may emphasize the importance of other hosts availability to it.

Sandalwood's preferred cover regime

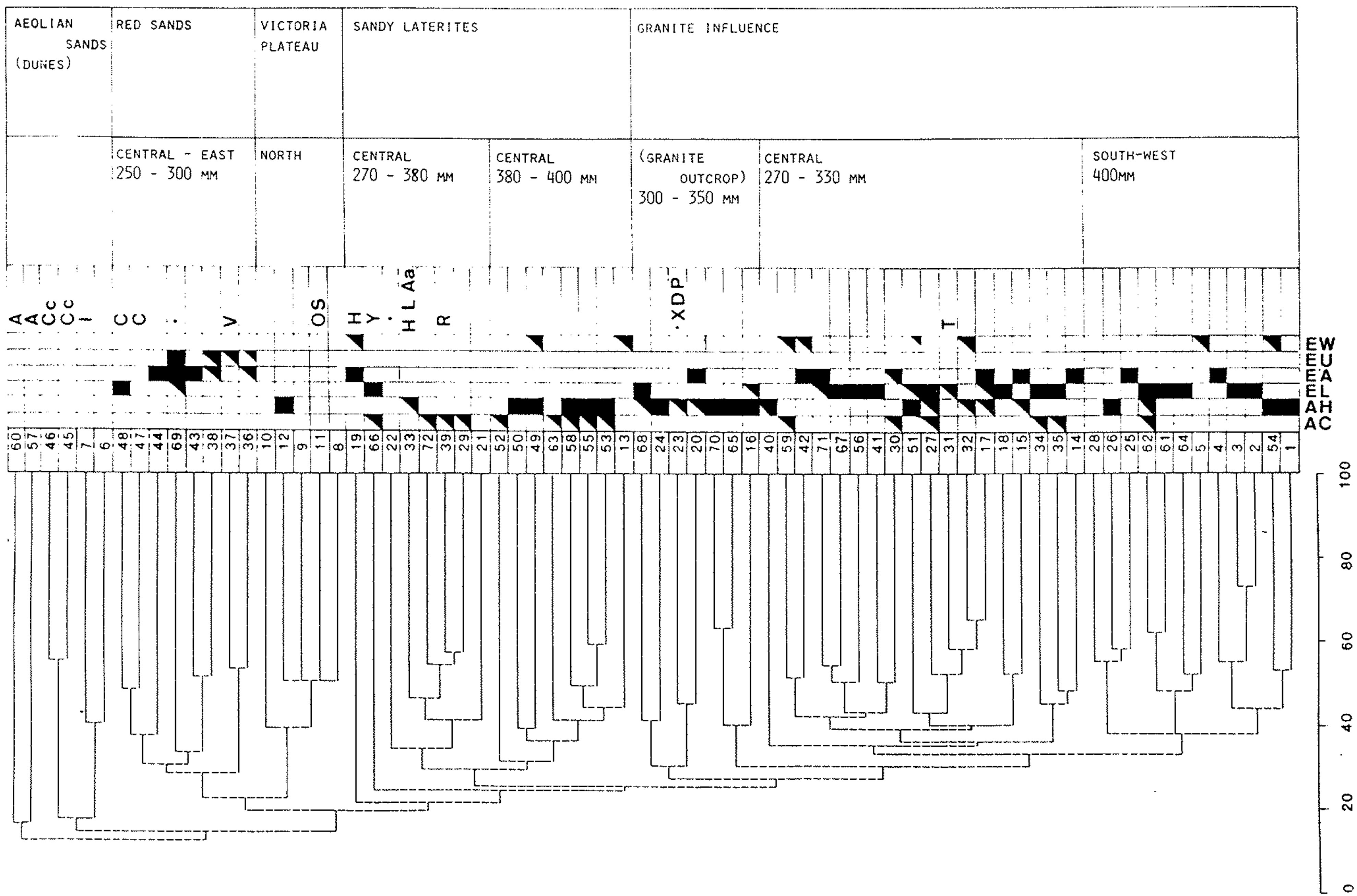
For all sites the total percent cover of all species which comprised layers 1 & 2 of the Muir description (ie all medium sized shrubs through to tree forms) was derived.

The average cover at the 71 sites censussed was 23.62 % with a standard deviation of 14.41 %. The range was from 0.9 to 60.6 % cover.

KEY :

ALLOCASUARINA	ACUTIVALVIS	Aa
"	CAMPESTRIS	AC
"	HUEGELIANA	AH
CASUARINA	OBESA	A
CALLITRIS	COLUMELLARIS	Cc
EUCALYPTUS	BIS:OCCIDENTALES	*
"	CELASTROIDES	V
"	COOLABAH	O
"	CORRUGATA	C
"	CYLINDROCARPA	D
"	CYLINDRIFLORA	Y
"	HYPOCHLAMYDEA	H
"	SP I	I
"	LEPTOPODA	L
"	LOXOPHLEBA	EL
"	PERANGUSTA	P
"	REDUNCA	R
"	SALMONOPHLOIA	EA
"	SALUBRIS	EU
"	SCYPHOCALYX	X
"	SUBANGUSTA	S
"	TRANSCONTINENTALIS	T
"	WANDOO	EW

TABLE **5** : CLASSIFICATION OF SANDALWOOD SITES BY SORENSEN ANALYSIS (PRESENCE/ABSENCE OF SPECIES WITH GROUP AVERAGING).


AEOLIAN SANDS (DUNES)
RED SANDS
CENTRAL - EAST 250 - 300 MM
VICTORIA PLATEAU
NORTH
SANDY LATERITES
CENTRAL 270 - 380 MM
CENTRAL 380 - 400 MM
GRANITE INFLUENCE
(GRANITE OUTCROP) 300 - 350 MM
CENTRAL 270 - 330 MM
SOUTH-WEST 400MM
A A Cc Cc I C C V OS H Y H L Aa R XDP T
EW EU EA EL AH AC
60 57 46 45 7 6 48 47 44 69 43 38 37 36 10 12 9 11 8 19 66 22 33 72 39 29 21 52 50 49 63 58 55 53 13 68 24 23 20 70 65 16 40 59 42 71 67 56 41 30 51 27 31 32 17 18 15 34 35 14 28 26 25 62 61 64 5 4 3 2 54 1
0 20 40 60 80 100

Sandalwood's vegetation association preference

Cosine Theta analysis

No meaningful patterns could be distinguished using Cosine Theta analysis. This was ascribed to the influence of factors such as drought and fire upon percent cover which was the basis of the form of the analysis used. Overlying this may have been the wide geographical separation of the sites.

Sorensen analysis

The results of classifying study sites on the basis of the presence and absence of plant species are shown in Table 5 and mapped in Figure 2.

In general the subgroups of Table 5 are not well defined and separate below 50 %. Such a pattern is compatible with :

i) the tendency for *Santalum spicatum* to occur in interzone situations noted above.

ii) that one species was the target; so that by definition similar site-types should contain it.

Consideration of the placement of the dominant plants in Table 5 really foreshadows the soil groups treated below; with only generalized groupings being distinguishable. *Allocasuarina campestris* was best represented on the sandy laterites within the 270 to 400 mm zone. Secondarily it occurred on granite influenced sandy laterites. *A. heugeliana* typified granite outcrops and the 380 to 400 mm (wetter, western) areas. *Eucalyptus loxophleba* reflected granite influenced soils of the central and south-western wheatbelt. As this species is endemic to the wheatbelt the northern absence probably reflects a clearing-induced effect. The placement of *E. wandoo* was similar to *E. loxophleba*, including clearing effects. *E. salubris* was a feature of central east sites of the 200 to 350 mm zone. *E. salmonophloia* occurred in central-eastern sites with red sands (granite influence) in the 250 to 330 mm zone.

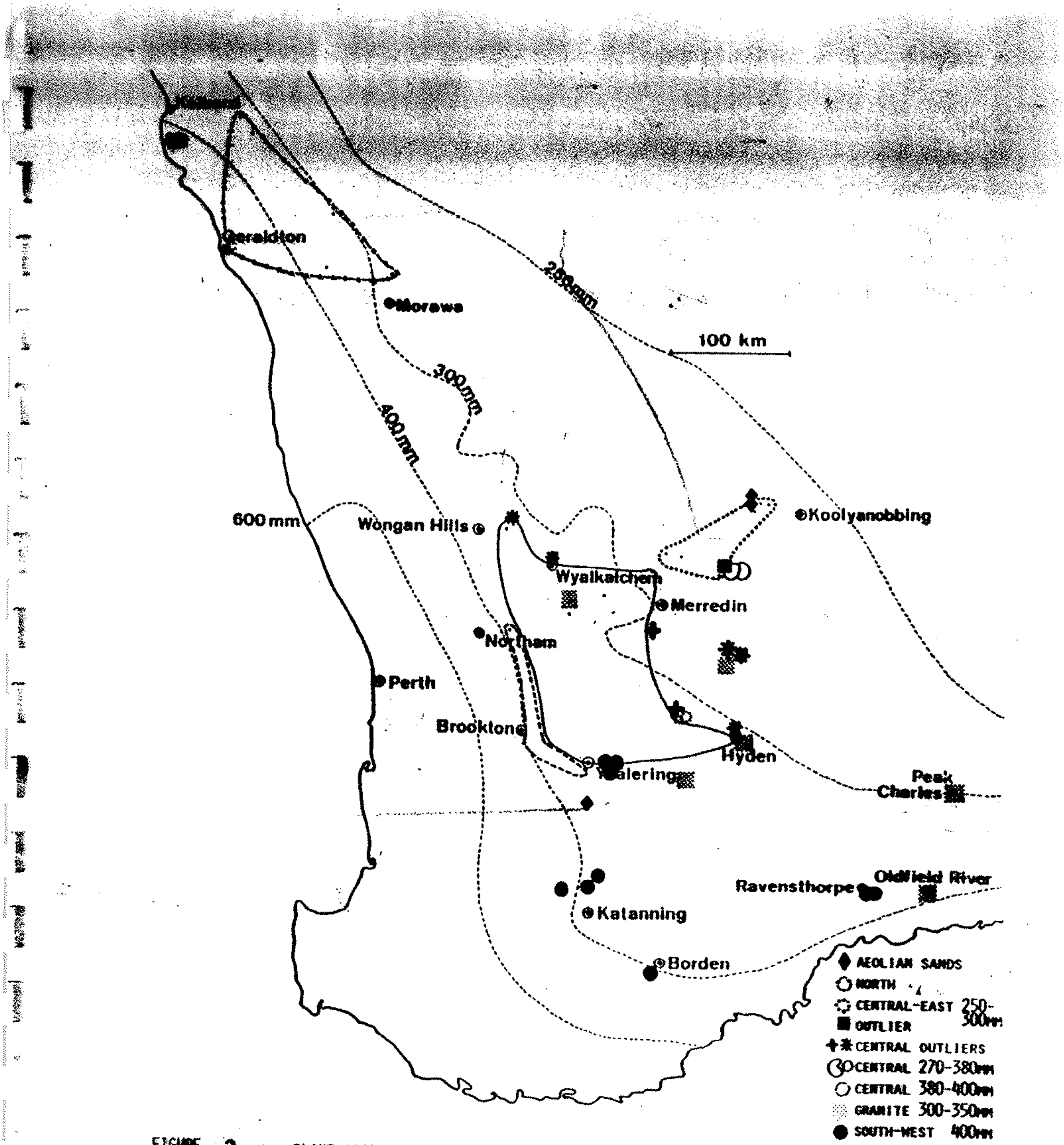


FIGURE 2 : PLANT ASSOCIATION GROUPINGS AS DETERMINED BY SORENSEN ANALYSIS (REFER TO FIGURE).

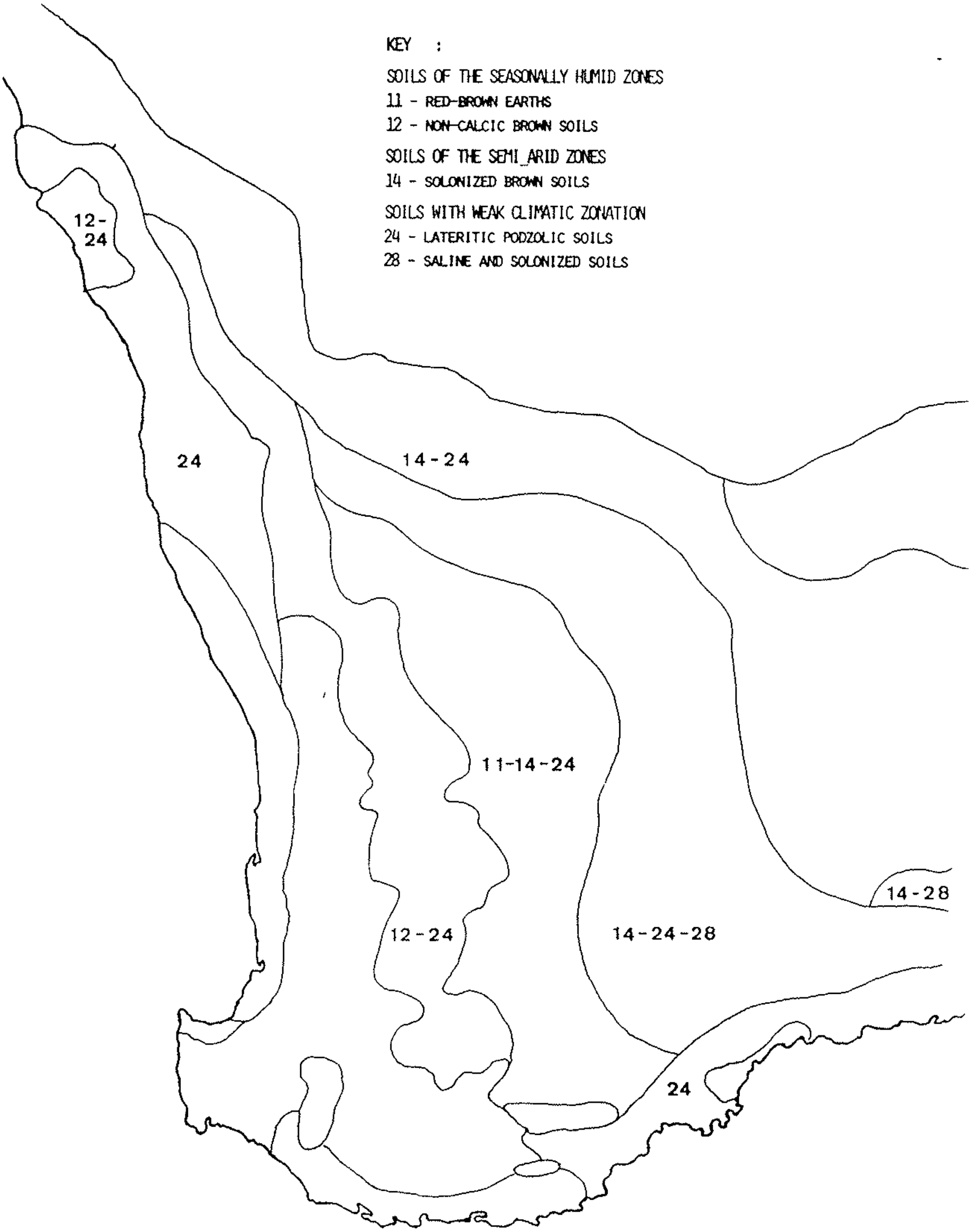


FIGURE 3 : GREAT SOIL GROUPS OF THE STUDY AREA (FROM STEPHENS, 1963)

An important point to note is that in most cases sets of sites from the same reserves have tended to be adjacent whether within or between groups regardless of the dominant species near the local. This suggests that understorey species are more important in characterizing sites preferred by *Santalum spicatum*. Also certain species may have tended to make certain sites more unique. For example, the red sand sites had *Eremophila miniata* which extends to the Great Victoria Desert. More particularly this applies to the major dominants, eucalypts, which it was noted above were only very weakly correlated with the presence of *S. spicatum*. With this in mind eucalypts were accorded significance as deep soil indicators in the rest of this work.

Three features point to the effective grouping of sites by this method. First the broad grouping of like sites; which was effective even with 'marginal' *Eucalyptus salubris* sites where the species was either extremely peripheral or of very low percentage. Second the site on bare, washed, sand featuring *Santalum acuminatum*, and the only site without *S. spicatum*, separates together at one extreme with those sites of a similar nature. Third the three species of Eucalypts in the series Occidentales were separated on a north-south basis despite being entered and treated as one species for the purpose of analysis.

Pre-clearing distribution of sandalwood habitat

Beard (1972-1981) mapped the assumed pre-clearing distribution of vegetation associations in the wheatbelt. These can be used to assess the potential area once containing sandalwood; but not the strength of the former presence.

In the Kellerberrin area, representing the central western wheatbelt, associations with *Acacia acuminata* were @ 15%, with *Eucalyptus loxophleba* were @ 40%, *Allocasuarina campestris* and *Acacia* sp scrub were @ 5% and *E. salmonophloia* @ 20%. This indicates that up to 60 to 80 percent of the area may have been suitable sandalwood habitat.

In the Southern Cross area, representing the central eastern wheatbelt, @ 10% of the area had mallee *E. loxophleba*, @ 55% had *Allocasuarina/Acacia* scrub and @ 10% had *E. salmonophloia*. Indicating that up to 75% of this area may have formed suitable habitat.

The area potentially available to sandalwood in the north and south-east of the wheatbelt is likely to have been considerably less than for the former two regions due to the predominance of deep sand heathlands and shrublands.

<u>Representativeness of the study sites</u>

A subjective spectrum of which habitat types would have had the best representation of sandalwood, based on the author's wider observations, is presented so that allowance may be made for the inherent sampling bias.

Clearly the habitat types which are not represented, and from which sandalwood is absent are of Myrtaceous and Proteaceous dominance. This excludes proteaceous heathland, melaleuca shrubland and *Eucalyptus marginata* forest.

There is a limited representation of sandalwood in mallee-eucalypt formations, where it appears to be confined to pockets and outer boundaries.

Sandalwood populations are poorly developed in *E. wandoo* and *E. salmonophloia* woodland. In the former this may be linked to the suppression zone, particularly for seedling establishment, enforced by the dominant, and the related depauperate understorey (Lamont, 1985).

The species is moderately represented in sedgelands on the sandy laterites in the central and southern wheatbelt. Though this presence can be related to contagion, or pocketing of either *Acacia acuminata*, *Allocasuarina huegeliana* or, more commonly, *A. campestris* (or *A. acutivalvis*).

Sandalwood is well represented, though locally confined, in *Allocasuarina huegeliana* woodland which is a major component of granite-influenced soils.

It is also moderately to well represented in the likely predominant shrubland of *A. campestris*, and of *Acacia* species apart from *A. acuminata*. With the latter forming suitable pockets contiguous with mallees, or amongst granite associations; while becoming dominant in the east and very north of the survey area).

It is also well represented in the *E. loxophleba/Acacia acuminata* woodlands. The soils associated with these species forming the prefered habitat throughout the central and southern wheatbelt.

In Table 6 the predominance of the association types in the study set is listed.

TABLE 6 : FREQUENCY OF MAJOR SANDALWOOD HABITAT TYPES IN THE STUDY SET

SPECIES	# OF SITES OF OCCURRENCE			
	WITH NO OVERLAP		WITH OVERLAP	
	DOMINANT SPECIES	MAJOR SPECIES	SPECIES PRESENT	MALLEE CO-OCCURS
E. salubris			4	2
E.wandoo		8	11	0.5
E. salmonophloia	12		13	0.5
A. campestris		15	20	2
E. loxophleba	15		24	2
A. huegeliana	14		25	2

Regardless of whether some sites were counted twice because of co-occurrence or overlap of the main species or only included once the distribution pattern is similar.

Clearly *A. huegeliana*, *E. loxophleba* and *A. campestris* associations are equally well represented, with only a slightly lower representation of *E. salmonophloia* and *E. wandoo*. This order conforms to the subjective list given above, with the noted exception that the *A. huegeliana* granitic soil sites are over represented. Given the fact that remnant vegetation in the wheatbelt is largely confined to the least desirable agricultural soils and landforms. It is possible that they should have ranked more with *E. wandoo* sites. In Table 5 it is clear that a bias towards granite-influenced sites exists. Such a bias is compatible with areas of outcropping rock being left unaltered by farming. It follows that there may be too many shallow-soiled, rocky sites in the study set. This is supported by the confined nature of the study site soil profiles and the association of better population structure with deeper soils (Sections 5 & 3 respectively). Finally note the even distribution of mallee sites across the major types as mainly co-occurring species.

In conclusion it appears that, with the exception of a surfeit of *A. huegeliana* sites, the study sites were representative of the mid- and south-western wheatbelt.

5 SOILS

The aim of this section was to elucidate which soil types were habitat for sandalwood.

METHODS

Percent moisture was based on the difference between the wet weight of 150 ml samples air dried for one week then re-weighed. Bulk densities were expressed as the proportion :

Air Dry Weight/150 cc

Soil depths were probed at three positions around a central tree with a steel spike. The end point was taken as the moment the spike resonated with a low pitch when struck and ceased to sink any further; indicating rock had been encountered. As such it probably represented the depth to a packstone arrangement of cobbles and boulders of country rock or in some cases a concreted aggregate. The probe was 120 cm long so that depths exceeding it's length were scored 130 cm unless dissection of the landscape allowed the thickness of layers to be better estimated.

Salinities were determined from 10 gm of soil which was air dried for one week and then agitated in distilled water for 1 hour and allowed to stand for 30 minutes before being read for conductivity in uS. A 0.005N KCl standard was used and values were converted to % Total Soluble Salts according to :

$$\% \, TSS = \{(0.00000004831) \, [(uS) \, (uS)]\} + \{(0.0002175) \, (uS) - (0.0014)\}$$

(Hatch, 1976)

where uS is the reading obtained for the sample in microsiemens per centimetre.

pH was determined in the field using pH indicator and Barium Sulphate.

Soil texture was assessed visually according to the classification :

Pebble	> 4 mm	
Gravel	2 - 4 mm	
Sand	1/16 - 2 mm	
Silt	1/256 - 1/16 mm	& by a dry silky feel between the fingers
Clay		by the ability of the wet soil to form a pliable ped and, dry, to cling to the furrows of the fingerpad

Soil colour was assessed in daylight on fresh soil according to the Munsell Color Chart.

Landform was coded according to :

1 Crest
2 Upperslope
3 Midslope
4 Lowerslope
5 Plain/Flat
6 Valley
7 Drainage Embankment
8 Flowline
9 Sump

Geological origin was coded according to :

OUTCROP	SOIL
A Diorite	H Clay
B Dolomite	I Loam
C Dolerite	J Sand
D Granite	K Silt
E Laterite	
F Limestone	

Drainage was coded according to :

DEGREE	TYPE
1 Good	7 Colluvial
2 Moderate	10 Alluvial
3 Fair/moist	
4 Poor/waterlogged	

RESULTS AND DISCUSSION

Soil groups description

The dominant great soil groups for the study region are shown in Figure 3. Their correspondence to the current day isohyets and the close fit with the vegetation groupings from Sorensen analysis are evident by reference to Figure 2. However at such a broad scale they do not provide information relevant to each site. More specific information, which linked vegetation associations with soils, was derived from Beard (1973 to 1980) and Newbey (1984). The former provided district information on geology and soils and the structure along the catena. While in elucidating the soil groups outlined in Table 7 dominants and Eucalypts in general were used as indicators of soil type to corroborate the information gathered from the current shallow sampling (Newbey, 1984).

Five major groupings of soils are presented in Table 7. The table presents the topographic and soil origin information in the order determined by vegetation analysis. The corresponding 'meaningful' shallow soil parameters are shown in Appendix 4.

First are the sand dominated sites. Notable in this group were the saline *Casuarina obesa* lake site at Yealering Town Reserve (site 57; which was a minor mound rather than a dune) and the tertiary coastal dune site at Kalbarri National Park (site 6).

TABLE 7 : STUDY SITES MAJOR SOIL GROUPS AS DETERMINED BY PRESENCE/ABSENCE COMPARISON OF ALL PLANT SPECIES ACROSS ALL SITES.

GEOLOGICAL SURFACE	LANDFORM ELEMENT	POSITION	SOIL	VEGETATION	SITE	SITE
DUNES	LAKES	Crest	Aeolian Sand (U) (grey)	Casuarina obesa/Eucalyptus rudis woodland	60	60
		Lowerslope	Fringing poorly drained saline soils (V) (grey)	" " " " "	57	57
		Crest	" " " ± " " (U) (red)	Samphire complex	46	46
		Lowerslope	Aeolian Sand (U) (red)	Callitris columellaris open woodland	45	45
	COASTAL - TERTIARY	Crest	" " over aeolianite (U) (grey)	Eucalyptus sp 1 mallee	7	7
	- SECONDARY	"	" " " limestone " "	Acacia rostellifera/ Melaleuca shrubland	6	6
SANDPLAIN	OLD PENEPLAIN	Undulating	Well-drained calcareous sandy loam (D or G)	Eucalyptus loxophleba/ Eucalyptus corrugata	48	48
		"	" " " " " "	Callitris columellaris/ Eucalyptus corrugata	47	47
		"	" " sandy loam (D or G)	Eucalyptus salmonophloia	44	44
		"	Variable drained ?colluvium of minor depression (D)	" " /Eucalyptus sp F/E. loxophleba	69	69
		"	Well-drained clay loam (G or U)/ Deep calcareous earths	" " /Eucalyptus salubris	43	43
		"	" " sandy loam (D or G)/ " " "	" " " "	38	38
	EMBANKMENT	Midslope	" " " " " " " "	(Eucalyptus salubris)	37	37
		"	" " " " " " " "	(Eucalyptus salubris)	36	36
VICTORIA PLATEAU	STONY BREAKAWAYS	Crest	Sandy laterite over granite ± $CaCO_3$ nodules (G or D)	Acacia species/ Hakea recurva/ Eucalyptus loxophleba	10	10
-	LINEAR IRON RIDGES	Midslope	Ferruginous, skeletal, young soils (U)	Allocasuarina huegeliana/ Acacia acuminata woodland	12	12
	EROSIONAL PLAIN	"	Red sandy loam, young granitic soils (G or D)	Acacia ramulosa/ Acacia tetragonophylla/ Hakea preissii	9	9
	RIVER EMBANKMENT	"	Red loam ± $CaCO_3$ concretions at depth (G or D)	Acacia species/ Hakea species/ Eucalyptus subangusta	11	11
	FLAT-TOPPED MESA	Crest	Sandy laterite over sedimentary and igneous rocks (G or D)	Acacia species/ Hakea species		8
SANDPLAIN	OLD PENEPLAIN	Mid-upperslope	Well-drained gravelly sand (D or G) (	Eucalyptus hypochlamydea		19
		Breakaway	" " " " (U) (	Eucalyptus cylindriflora/ Melaleuca/ Mixed species shrubland		66
		" /crest	" " cracking clay loam (G or U) (	Eucalyptus sargentii low woodland/ forest		22
		Crest	" " gravelly sand (D or G) Ecdeiocolea(	Eucalyptus hypochlamydea/ Eucalyptus leptopoda		33
		"	" " " " " sedgeland (	Lateritic mixed species shrubland		72
	OLD SLOPE	Midslope	" " sandy loam (D) (	Eucalyptus redunca mallee		32
	OLD PENEPLAIN	"	" " gravelly sand (D) (	Lateritic mixed species shrubland		29
		"	" " " " " (	Lateritic mixed species shrubland		21
		Mid-upperslope	" " " " "	Lateritic mixed species/ Allocasuraina campestris shrubland		52
		" "	" " " " "	" " " " " "		50
		" "	" " " " "	" " " " " "		49
		" "	" " " " "	" " " " " "		63
		" "	" " " " "	" " " " " "		58
		" "	" " " " "	" " " " " "		55
		" "	" " " " "	" " " " " "		53
		" "	" " " " "	" " " " " "		13

TABLE 7 : CONTINUED

GRANITE EXPOSURE	OUTER APRON	Midslope	Granitic moderately-drained sandy loam (U or G)	Eucalyptus loxophleba low woodland	68
		Lowerslope	" " " " " "	Allocasuarina huegeliana low woodland	24
	RIVER EMBANKMENT	Midslope	Mosaic : young soils over granite/gneiss (D)(± clay/Ca)	Eucalyptus macrandra/ E. cylindrocarpa/ E. perangusta mallee	23
	OUTER APRON	Lowerslope	Granitic well/moderately drained loams/sandy loams (U or G	Eucalyptus salmonophloia/ Allocasuarina huegeliana woodland	20
	SKELETAL SOIL	Crest	Granitic sand (U or G)	Allocasuarina huegeliana (Eucalyptus loxophleba) low woodland	70
	SHEETS/INNER APRON	"	" " "	/ Granite complex	65
		'Upperslope'	" " "		16
	OUTER APRON	Lowerslopes	Granitic moderately-drained sandy loam (U or G)	Allocasuarina huegeliana low woodland	40
	SHALLOW SOIL	"	Well-drained sandy loams (D)	Allocasuarina campestris shrubland	59
	OUTER APRON	"	Granitic well-drained loams (D)	Eucalyptus salmonophloia woodland	42
		"	" " " " "	" " / Eucalyptus loxophleba woodland	71
	(EMBANKMENT)	"	Granitic moderately-drained sandy loam (U or G)	Allocasuarina huegeliana low woodland	67
		"	Granitic soil (U or G)	Eucalyptus loxophleba woodland	56
		"	" " "	" " "	41
		"	± shallow well-drained sandy loams (D)	Allocasuarina campestris/ Eucalyptus salmonophloia	30
	SWALE/OUTER APRON	A range	Granitic moderately-drained sandy loam (U to G)	Allocasuarina huegeliana/ (Eucalyptus loxophleba)	51
		"	" " " " " " (± gl/sd)	Allocasuarina huegeliana/ (Eucalyptus loxophleba)/ (A. campestris)	27
		"	Well-drained sandy loam (D) over deep calcareous earth	Eucalyptus transcontinentalis/ (Eucalyptus loxophleba)	31
		"	Granitic moderately-drained sandy loam (U to G)	Eucalyptus loxophleba/ Eucalyptus salmonophloia	32
		"	" " " " " "	(Eucalyptus loxophleba/ Allocasuarina huegeliana)	17
	OUTER APRON	Midslope	" " " " " "	Eucalyptus loxophleba/ Eucalyptus salmonophloia/ A. huegeliana	18
		"	" " " " " "	Eucalyptus loxophleba/ Eucalyptus salmonophloia/ A. huegeliana	15
		Upperslope	SHALLOW, granitic, well-drained sandy loams (D)	Allocasuarina campestris/ Eucalyptus loxophleba	34
		"	" " " " " "	" " " "	35
		"	Well-drained loam (D)	Eucalyptus salmonophloia woodlland	14
		Midslope	Well-drained sandy loams (D)	(Eucalyptus loxophleba)	28
	EMBANKMENT	Lowerslope	Greenstone, moisture retentative loams; sandy surface	(Eucalyptus loxophleba)	26
		"	" " " " ; deep clay loam	Eucalyptus salmonophloia	25
	OUTER APRON	A range	Granitic soils	± Allocasuarina huegeliana/ E. loxophleba/ E. salmonophloia	62
		"	" "	" " " "	61
		"	" "	" " " "	64
		"	" "	" " " "	5
		"	" "	" " " "	4
		"	" "	" " " "	3
		"	" "	" " " "	2
		"	" "	" " " "	54
		"	" "	" " " "	1

Second are the sandplain sites with the red earths of the interior. The presence of deep calcareous earths was indicated by *Eucalyptus corrugata* and by *E. salubris*. This was confirmed by the high pH and salinity of the shallow soil samples at Westonia and Sandford Rocks (Appendix 4). A clay content was a feature of four of these soils at shallow depths.

Third are the ferruginous to lateritic red earths of the Victoria Plateau near Geraldton. These are tightly grouped in the Sorensen analysis and are also tightly grouped compared with the other soils sampled by their relatively high bulk denities and silt contents (Appendix 4). Coalseam 'National Park' which separates by Sorensen from the others was the only soil with a high clay content. These soils were acidic.

Fourth are the sandy laterites which have the next highest sand contents after the dunes with low to moderate bulk densities and moisture contents twice those of other soils. These soils split on the predominance of *Ecdeiocolea* or *Allocasuarina campestris*. These soils were acidic.

Fifth are the granitic soils; forming a large, loose, grouping. In a general sense these can be considered 'outer apron' granitic soils which are influenced, or confined, by nearby granite.

> The first subgroup are 'middle slope soils' with low soil moistures, moderate to high bulk densities and moderate silt contents as distinguishing features.
>
> Next is a subgroup of 'inner apron' soils which are situated on the protruding granite outcrops and have low soil moistures and very low bulk densities; indicating that they are poorly developed soils. Salinity at one of the sites may indicate mineralization from the base rock or a perched watertable in which rain-borne salt has accumulated. Soil depths were variable in this group depending upon whether the plants were situated over crevices or shallow pans in the rock.

The lowerslope soils have moderate soil moistures, depths and bulk densities which reflect a moderate degree of weathering from their progress downslope. Some of these soils are mildly 'saline'and one is basic indicating that their low position may place them in contact with travertine calcareous accretions.

The last subgroup with some granite a are the swales. These sites are at various levels in the topography and probably reflect some irregularity/discontinuity in the underlying geological strata. As such they are similar to the lowerslopes in that they are points were moderately processed soils accumulate. Thus they have the same moderate soil moistures, depths and bulk densities as the lowerslope soils. But they do not have the saline/basic features indicative of lower-lying soils which characterize the redeposition of calcium weathered from the rock higher in the profile.

The last loose group are generally 'outer apron'soils.

One major trend that should be noted is for the non-dune sites to typify gradational and mostly duplex soils. This points to some confining layer (whether clay or rock) at depth being associated with *Santalum spicatum* at the surveyed sites.

<u>The influence of soil types on sandalwood</u>

TABLE 8A: SOIL CORRELATES OF SANDALWOOD HEIGHT AND RANGE IN HEIGHT

PARAMETER		r	P	REGRESSION EQUATION
HeightSS	/pH 10cm	-0.2174	0.068	(HtSS)=5.214- 1.772(pH10cm)
HeightSS	/pH 30cm	-0.2593	<0.033	(HtSS)=5.757- 2.186(pH30cm)
HeightSD	/pH 10cm	-0.2203	0.065	(HtSD)=2.001- 0.979(pH10cm)
HeightSD	/Soil depth	0.3542	0.002	(HtSD)=0.349+ 0.008(Depth)
HeightSD	/Colour 10cm	-0.3151	0.007	(HtSD)=2.025- 0.020(Col10cm)
HeightSD	/Colour 30cm	-0.3515	0.003	(HtSD)=2.518- 0.026(Col30cm)

TABLE 8B: SOIL CORRELATES OF COVER OF EUCALYPTS AND ACACIAS

PARAMETER		r	P	REGRESSION EQUATION
%Eucalypts/pH 10cm		0.2988	0.011	(%Euc)=2.862(pH)-1.861
%Acacias	/Silt 10cm	0.4682	<0.001	(%Aca)=0.533+ 2.650(Silt10cm)
"	/Silt 30cm	0.4624	<0.001	(%Aca)=0.629+ 2.960(Silt30cm)
"	/Bulkdens 10cm	0.4564	<0.001	(%Aca)=21.388(BD10cm)-3.473
"	/Bulkdens 30cm	0.3454	0.004	(%Aca)=14.289(BD30cm)-1.928
"	/Moisture 10cm	-0.3052	0.01	(%Aca)=2.259- 1.274(Mois10cm)
"	/Moisture 30cm	-0.3747	0.002	(%Aca)=2.350- 1.298(Mois30cm)
"	/Sand 10cm	-0.2491	0.036	(%Aca)=2.110- 0.878(Sand10cm)

Height of *Santalum spicatum* was weakly, negatively, correlated with pH (Table 8A). Similarly variation in height (as expressed by the standard deviation) was weakly, negatively, correlated with pH. These facts indicate that the species prefers neutral to acidic soils

Variation in height was also most strongly, and positively, correlated with soil depth (Table 8A). Indicating that deeper soils had a range of individual heights and not one uniform age-class.

Negative correlations of height variation on soil colour essentially indicate poor range of population structure on the red earths of the Victoria Plateau and, to a lesser extent, the Koolyanobbing/Lake Deborah area, which had high colour scores on scaling, (Table 8A). Both are probably attributable to grazing, with the former group suffering more intensive grazing.

The influence of soil types on other plant groups

Percent cover of eucalypts weakly correlated with shallow pH of soil (Table 8B). Indicating a preference for alkaline soils.

Percent cover of acacias was strongly correlated with the proportion of silt in the soil and with soil bulk density (Table 8B). It was less strongly, negatively, correlated with percent soil moisture and with the proportion of sand. This indicates that the acacias prefer the heavier (more silty/loamy) soils of the series encountered.

Topography

There was no real trend in aspect preference; which suggested other factors such as soil, other plant species and cover were more important (Appendix 4).

Similarly position ranged from low-lying to crest (Appendix 4).

Drainage was generally good with the main type of drainage being colluvial with limited alluvial influence. This was supported by the limited slope at most sites (Appendix 4). The most common case being ± 1 degree. It is open to conjecture whether alluvial drainage was not important to *Santalum spicatum* in the wheatbelt, or was the most cleared and/or harvested habitat type. Though the seeming preference of *Santalum spicatum* for an interzone situation suggests it may have been important.

Sandalwood's preferred soil regime

Due regard must be given to the fact that the parameters collected during this work were from shallow soil samples only penetrating to 30 cm so that the uniformity of the C horizons of these soils at depth was not indicated by the sampling.

For those parameters which required measurement at 10 and 30 cm there was a high, significant, correlation between the two depths (Table 9). This is reflected in the averages listed in Table 10.

Percent soil moisture was low and therefore in keeping with the generally good drainage.

Soil depth was on average moderate, though it ranged from quite shallow to in excess of 2 meters.

The averages for the soil horizons are shown in Table 10; in general a weak humic A horizon could be distinguished from a B horizon which contained the bulk of the fibrous roots present and was weakly distinguished from the C horizon which appeared to continue beyond the 30cm depth.

The bulk densities recorded were less than 2 gm/cc indicating considerable weathering and development of void spaces, and also limited impedance to roots.

This is consistent with the textural description of the soils as generally gravelly sands with a silt component. (Note that on casual observation they might be considered sands because of the generally small size of what is technically gravel).

Soil pH was on average neutral to slightly acidic (Table 10). This conformed to the mode though the range was from 4.5 to 9.5 (only seven sites were basic).

Soil salinity (% Total Soluble Salts) was on average low being circa 2 %. Notable exceptions were at Yealering (sites 56 & 57), Kalbarri National Park (site 7) and two sites in the Westonia area (sites 38 & 43).

TABLE 9 : CORRELATIONS BETWEEN SOIL PARAMETERS AT 10CM AND 30CM

PARAMETER		r	P	REGRESSION EQUATION
Conductivity (uS)		0.9619	<0.001	(10cm)=0.006+0.472(30cm)
pH		0.8768	<0.001	(10cm)=0.081+0.909(30cm)
Soil colour		0.7863	<0.001	(10cm)=3.548+0.865(30cm)
Bulk density	(proportion)	0.7123	<0.001	(10cm)=0.078+0.630(30cm)
Moisture	(%)	0.5532	<0.001	(10cm)=0.399+0.415(30cm)
Pebbles	(proportion)	0.7761	<0.001	(10cm)=0.649(30cm)-0.009
Gravel	(proportion)	0.8299	<0.001	(10cm)=0.065+0.828(30cm)
Sand	(proportion)	0.8074	<0.001	(10cm)=0.192+0.810(30cm)
Silt	(proportion)	0.8422	<0.001	(10cm)=0.054+0.961(30cm)
Clay	(proportion)	0.9409	<0.001	(10cm)=0.002+0.892(30cm)

Grouping of sites by soil physical properties

Those physical and chemical properties which were measured for study site soils only separated the sites weakly (Appendix 12). The close similarities indices between the soils and the scattering of geographically close sites throughout the hierarchies of the appendix suggest great similarities between soil properties over all sites. A result which might be expected given that one species was targeted. It may also indicate that deep soil factors (such as confining layers, hydrology) and other physical factors which were not measured (such as soil nutrients) are more important to the species. This would account for the better separation on the basis of the plant species above; as the plants are influenced by such factors.

TABLE 10 : LANDFORM AND SOIL AVERAGES AT SANTALUM SPICTUM SITES

PARAMETER	n	MEAN	SD
Slope	72	1.93	1.27
Drainage	72	1.93	0.91
Soil moisture 10cm	72	3.75	2.11
" " 30cm	72	3.66	2.57
Soil depth	72	68.78	37.89
Soil horizon A	68	6.93	5.65
" " B	42	24.98	5.16
Bulk density 10cm	72	1.31	0.19
" " 30cm	67	1.38	0.21
Texture 10cm :			
Pebble	72	0.54	1.43
Gravel	72	2.71	2.13
Sand	72	4.54	2.58
Silt	72	1.91	1.57
Clay	72	0.31	0.95
Texture 30cm :			
Pebble	68	0.89	1.72
Gravel	68	2.66	2.10
Sand	68	4.43	2.57
Silt	68	1.68	1.40
Clay	68	0.30	0.97
pH 10cm	72	6.53	1.07
" 30cm	69	6.66	1.05
Conductivity 10cm	72	0.01	0.02
" 30cm	69	0.02	0.05

Extreme soil types with sandalwood

Apart from more sandy or clayey soils noted above a few sites were of high salinity and/or waterlogged.

A saline site was Yealering Town Reserve site 57 where the persistence of one *S. spicatum* tree in the littoral zone of a flowline with *Casuarina obesa* meant it was subjected to high salinity (and, with site 56, possibly also periodic waterlogging). Some trees along the embankment were mildly chlorotic. In this situation the 'salt' was more likely to be soluble salt such as NaCl.

The other saline sites were probably of CaCO3 origin. The most obvious being Kalbarri (site 7) here the high pH and presence of shallow limestone made this clear. Similar, though less uniform patterns were apparent for the *Eucalyptus salubris* soils near Westonia.

Waterlogging was most obvious at Lake Deborah, where site 46 had a shallow watertable and stunted, chlorotic, *S. spicatum* trees in the littoral zone of a minor lake. Where they grew with samphires and low myrtaceous shrubs.

Evidence on soils from other research

Dominant plant species preferred soil types

According to Havel (1975) there are two groups of dominant plant species that occur in the study region.

One group is widespread geographically but has a narrow edaphic range. This is typified by *Nuytsia floribunda* which is more strongly controlled by the presence of leached sandy soil than by the climate. Similarly *Banksia prionotes* prefers sandy soils; though it prefers the drier easterly conditions.

The other group has a marked bias towards the drier conditions of the east; with the centre of distribution in the agricultural region. Mainly they are associated with soils that have some impedance to root penetration in the subsoil, such as impervious clay or massive rock. *Allocasuarina huegeliana* prefers sandy loams and loams around granite outcrops. *E. wandoo* prefers the heavier textured soils, underlain by clay, which tend to have inadequate soil moisture storage. *Acacia acuminata* occurs on moderately fertile, shallow loams. The soil preference of *Santalum acuminatum* was not well typified as it occurred on only one aberrant soil type in the northern Jarrah forest. This was on heavy-textured kaolinitic clays, occurring on the surface near granite outcrops.

Observation from the current work placed *S. acuminatum* on both the sandy laterites to sandy loams with confined horizons and the deep sands of the region. Thus overlapping mainly with *N. floribunda* and occasionally with sandalwood.

In the arid interior the main habitat of sandalwood is red loam with mulga (*Acacia aneura*) while that of quandong is sand or loam, in spinifex-shrub steppe or near creeks (Jessop, 1981). This corroborates the results for this study for sandalwood as does the observation for *A. acuminata* above. Namely sandalwood prefers intermediate soils of a sandy, silty, loamy nature.

<u>Soil nutrient contents</u>

Soil nutrients were not cencussed in the current work, however two sources provide some reference points on the broad soil types encountered. (Note that the elements N, P and K are the main focus of what follows).

First the three major soil groups of the Merredin region, as defined by Bettenay and Hingston (1961), may be used to broadly categorise the current study sites of the central wheatbelt (but not those of the Ravensthorpe or Geraldton regions). The only site truly representing aeolian lake parna soils was site 46. Site 45 may also have fitted the category on the basis of *Callitris* sp dominance. The sites most readily categorised as lateritic (sandy laterites) were sites 19, 66, 22, 33, 72, 39, 29, 21, 52, 50, 49, 63, 58, 55, 53, and 13. The remaining majority of sites encompass the alluvial and colluvial soils from country rock.

Consideration of the nutrient section of Table 11 shows that it is the lateritic soils that have the lowest nutrient contents.

Second the work of Havel (1975) in the northern Jarrah forest may be used to provide finer scale comparison and contrast based on the presence of dominant and or indicator species. Though it must be noted that the sample of sites used in that work had only a few representative of eastern plant associations.

Even with such a proviso a clear trend emerges in the context of the current emphasis on *Santalum spicatum* (Table 12). The species most commonly associated with *S. spicatum*, *Acacia acuminata*, occurred at site types with comparatively high soil nutrient content. This was echoed by *Allocasuarina huegeliana* and by *Eucalyptus wandoo* site type preferences. *Santalum acuminatum* had a very restricted representation in Havel's study areas; not representative of the sandy to sandy-laterite areas it was observed in by the author. Even so it occurred in a soil type of lower nutrient content than those species which accompany *S. spicatum* already mentioned. At the extreme of the spectrum were the nutrient impoverished sites which were habitat to *Banksia prionotes* and *Nuytsia floribunda*.

All were acidic soils of pH 5.52 to 6.23.

TABLE **11** : THE MAJOR SOIL GROUPS OF THE MERREDIN REGION (FROM BETTENAY AND HINGSTON (1961))

SOIL GROUP	AEOLIAN LAKE PARNAS	ALLUVIAL & COLLUVIAL SOILS FROM COUNTRY ROCK	LATERITIC SOILS
POSITION OF SOILS	LAKE FRINGES	LOWERSLOPE/DEPOSITIONAL	UPPERSLOPE/DEPOSITIONAL
TEXTURE	LOAMY SAND TO CLAY LOAM IN THE SURFACE, BECOMING FINER TEXTURED WITH DEPTH. N.C.F. 0.06-0.12 mm	CLAYEY SAND TO SANDY CLAY LOAM IN THE SURFACE, SILT DECLINES CLAY INCREASES WITH DEPTH. N.C.F. 0.11-0.31	COARSE CLAYEY SAND TO COARSE SANDY LOAM N.C.F. $\geq$ 0.31mm
WATER PENETRATION	LOW	LOW TO MODERATE	GOOD
WATER AVAILABILITY	DRY YEARS - WATER IS LIMITING WET YEARS - SUPPORTS GOOD GROWTH; ADEQUATE NUTRIENT SUPPLY	? INTERMEDIATE WATER AVAILABILITY	LOW WILTING POINT GOOD WATER AVAILABILITY
pH	ALKALINE THROUGHOUT 0-3 cm 7.5 23-45 cm 9.9	NEUTRAL IN THE SURFACE ALKALINE WITH DEPTH 0-3 cm 7.4 23-30 cm 9.4	SLIGHTLY ACIDIC 0-3 cm 5.3 15-36 cm 6.8
NUTRIENTS	P 0.013% K 0.64 % (A.S.) HIGH K 0.9-2.0 meq/100g (A.) Ca FREE LIME / HIGH N 0.1 % (RELATED TO P) T.E. WELL SUPPLIED	P 0.011% K 0.17 % (A.S.) MOD. K 0.6-2.0meq/100g (A.) Ca 1.8-7.7 meq/100g MOD N 0.07 % T.E. WELL SUPPLIED	P 0.006% K 0.04 % (A.S.) LOW K 0.01-0.6 meq/100g* (A.) Ca 1.1-2.2 meq/100g LOW N 0.04 % T.E. Cu, Mn, Zn limited
SALINITY	HIGH HIGH EXCHANGEABLE Na EXTREME IN AUTUMN AND SUMMER	NOT INHERENTLY SALINE SIGNIFICANTLY LEACHED	NOT INHERENTLY SALINE SIGNIFICANTLY LEACHED
VEGETATION	HALOPHYTIC FORMATION CHENOPODS, CASUARINAS, CALLITRIS SP, SOME EUCALYPT MORRELS	SCLEROPHYLLOUS WOODLAND EUCALYPTUS SP, CALLITRIS SP ON BREAK-AWAYS	HEATH FORMATION SCLEROPHYLLOUS SHRUBS, ACACIAS, CASUARINAS, SOME MALLEES/PROTEACEAE

*NCF = Non Clay Fraction; * deficiencies occur below 0.2 Meq/100g; A.S. = Acid Soluble; A = Available*

T.E. = Trace Elements

TABLE 12 : Soil nutrients of site types associated with wheatbelt plant species (From Havel, 1975).

Site Type	Nppm	Pppm	K me*	Ca me*	Mg me*	CECme*	% Satn.	Species
F	200	19	15	15	36	52	40	NF
J	300	10	10	12	50	62	31	NF/BP
Z	1000	55	24	49	138	119	56	(AH)
R	1900	80	40	73	284	185	60	(SA)
M	1600	126	75	74	182	128	75	EW/AH
L	3100	199	93	134	384	231	79	EW/AA /(AH)
Y	1200	56	60	39	171	107	60	EW/(AH) /(NF)

AA = Acacia acuminata; AH = Allocasuarina huegeliana; BP = Banksia prionotes; ; EW = E. wandoo; NF = Nuytsia floribunda; SA = Santalum acuminatum; XX = strong presence; (XX) = limited presence; * = x100

Sandalwood self-mulching and nutrient conservation

The implication of self-mulching and some degree of nutrient recycling is supported by several pieces of evidence.

Hobbs and Atkins (1991) found significantly higher levels of N and P in the soil under sandalwood tree canopies compared to the adjacent woodland surrounds. The majority of mass in a square meter under the canopy was sandalwood litter (8040±370gm) with a small biomass component of other species (287.6±90.7gm) while the adjacent area had only @30gm of other species.

The nutrient concentrations of the soils found by the above authors are compared in Table 13 with those of Barrett et al (1985) for leaves from mature trees of 52 years age, and old, senescing, leaves from 4 year old trees. They form a natural progression, despite the vegetative material/soil contrast, that suggests very strongly that some leaf-litter based enrichment of the soil may be occurring. This may aid and abet the withdrawal of N and K which apparently occurs in older leaves, and could play a major role in recycling P, which may be less readily mobilized (Barrett et al 1985).

TABLE 13 : The nutrient content of attached leaves, and leaf litter of Santalum spicatum and of soil from under the canopy and from adjacent to the canopy (ppm).

	LEAVES		SOIL	
	4 Y.O. TREES	52 Y.O. TREES	CANOPY	ADJACENT
TOTAL N	15250	13800 ±3100	2788 ±467	625 ±132
TOTAL P	750	450 ± 90	115 ± 14	50 ± 8
TOTAL K	1330	1442 ± 139	747 ±139	553 ±122

(4 Year Old trees were the broad leaf-form from Jam Paddock;
52 Year Old trees were on Acacia acuminata hosts in Dryandra State Forest and ranged from 2.9 to 6.2 m; n=3; Barrett et al (1985)).
(Soils were at Durokoppin Nature Reserve, under trees of 3-4 m in height and with 4-6 m canopy diameters; n=5; Hobbs and Atkins (1991)).

In line with such a senario is the apparent ability of unattached (up to 9 months old) sandalwood seedlings to benefit from nitrogen fixation in the soil around them (Barrett and Fox, 1989).

From the point of view of survival there would also be some advantage to a seedling to have secondary nutrient sinks available when the seed reserves deplete at 2 years (Barrett et al 1985).

6 ASSESSMENT OF SANDALWOOD SUBSPECIFIC VARIATION

This section centred on individual tree features which were less likely to be affected by historical intervention and short-term climatic fluctuations. These features were considered to be leaf morphology, leaf colour, and fruit features.

6.1 LEAF MORPHOLOGY

The objective of this section was to compare leaf dimensions of sandalwood populations across the wheatbelt to determine whether any demographic patterns were evident.

METHODS

From 10 to 20 leaves were taken from each tree of the population. These were taken from terminal branchlets selected at random around the tree and from varying heights. These branchlets were generally marked by young, somewhat succulent, growth and little woodiness.

Proceeding from the apex, one leaf of the second non-juvenile, pair of opposite leaves was selected. Similarly one leaf from the basal pair on the same branchlet was selected (Figure 4). This meant 2 leaves were harvested per branchlet.

This approach was adopted to account for the inherent variability of leaves on the same plant. Generally basal leaves were short, almost obcordate, while leaves closer to the tip were lanceolate.

Each leaf's width at the widest point and length from the tip to the base of the blade was measured.

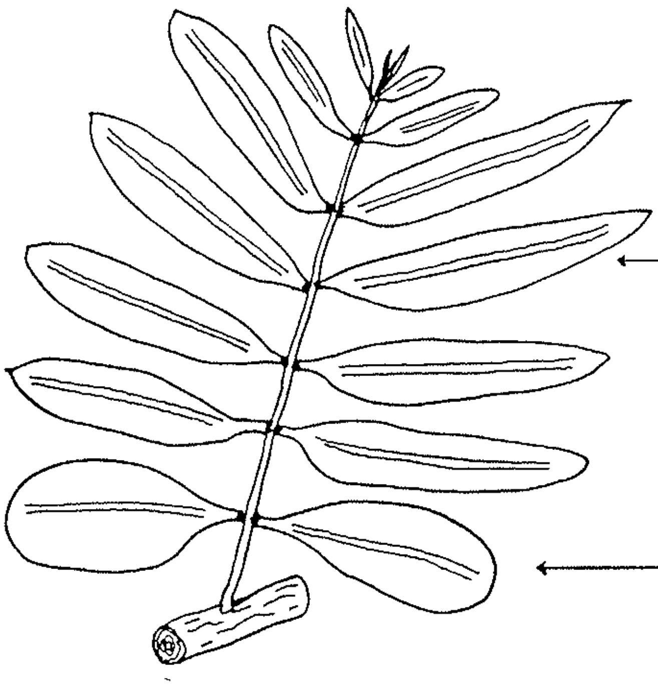


FIGURE 4 : THE POSITION OF THE TWO LEAVES COLLECTED FROM EACH BRANCHLET.

Leaf thickness was not censused for two reasons. One was because at one location thin and thick leaves were present in close proximity. The thick leaves were on stunted trees growing close to the watertable on a lake's edge, while the thin leaves were on trees higher up the topography. Examination showed the same number of cells per blade from abaxial to adaxial surface on trees of either leaf thickness. That is the thickness increase was achieved by cell hypertrophy and not an increase in cell number. This indicates that the response was a physiological response rather than a genetic (ecotypic) one. Such a pattern conforms to the observation that leaves are thicker in the south-west wheatbelt than the Goldfields (I. Carmichael, Ravensthorpe sandalwood harvester), thus reflecting the regional rainfall difference.

The averages for the widths and lengths of the populations were included for Principal Components Analysis (see the following section).

RESULTS

No separation of populations on the basis of leaf length or width was apparent (Appendix 5).

DISCUSSION

The readily observable variation in leaf morphology appeared to have obscured any underlying demographic trends within the 1 area. This is despite leaf width apparently being a heritable character in sandalwood (Brand, 1991).

It is possible that the approach adopted may have helped to obscure any trends. An alternative may have been to compare only the dimensions of the basal leaves, or only those of middle position, of a branchlet; instead of combining them.

Otherwise sampling may not have been geographically spread enough to distinguish differences.

External evidence that the wheatbelt is a subspecific group

When comparing the wheatbelt with the wider range of sandalwood the former may represent a recognisable sub-group of the latter.

It was the opinion of Ian Carmichael (local sandalwood harvester) of Ravensthorpe that inland trees from the goldfields had finer leaves than those of the coastal area. In 1990 he had trees germinated from inland seeds growing near Ravensthorpe that had maintained a fine leaf form in contrast to local seedlings. Similar trends were recognized for arid-inland (Kalgoorlie) and wheatbelt (Narrogin) stock grown from seed by Barrett et al (1985). Further they found the broad leaf form had lower mineral concentrations than the narrow leaf form for all elements tested. They could not separate this difference as a volume effect or as an inherent physiological effect. Such observations were also matched by Brand (1991) who recognized thin leaves in the arid zone (Mt. Keith) compared with north-west coast (Shark Bay).

Paralleling this woodgrain and oil content differ between coastal and inland areas (sections 8.6 & 8.7).

Genetically there is little genetic distance between the middle wheatbelt (Dryandra) and the peripheral eastern wheatbelt/semiarid zone (Marvel Loch); but a large genetic distance between these and arid inland sites and a still larger distance between the former two and populations on the north-west coast (Shark Bay) (Brand, 1991). Although they support the other observations such findings are limited by the number of sites involved, the wide scale of sampling and the large amount of historical intervention at Dryandra.

6.2 LEAF COLOUR

The objective of this section was to compare leaf colour of sandalwood populations across the wheatbelt to determine whether any demographic patterns were evident.

METHODS

Two forms of colour were recognized for sandalwood leaves. The first was for the, apparently wax-based, glaucescent coat which imparts the dull sheen to the leaf. This colour was best observed with reflected light on the leaves and with the leaves on mass. The second was the underlying green of the chlorophyll in the leaf tissue. This was observed on several single leaves after they had been rubbed at least thirty times with the skin of the finger to remove the sheen.

One tree per population was carefully assessed and the result was checked less rigorously against other trees to assure that it was representative.

Colour was standardized using a British Paints interior colour chart of 200 tiles. All sandalwood leaf colour comparisons were made in daylight on the basis of reflected light on the adaxial surface.

At site 21 the colour of 15 quandong (*Santalum acuminatum*) leaves was assessed as above. In addition the transmitted light colour, that which passed through the leaf when it was held to the sky, was assessed for both sandalwood and accompanying quandong.

From site 21 (ie sites 21 to 72) a note was made if an obvious tone which resembled that of the quandong was present in the sandalwood leaves. It was subjectively classified as "dominant" (the prevailing tone), "underlying" (apparent underneath the prevailing tone on close inspection) and none.

Leaf colour per population was assessed by plotting it geographically and by forming contingency tables comparing it with the dominant genera, with very low ($\leq$ 1 %) and higher (> 1 %) cover of acacias, and with soils of lateritic and non-lateritic origin.

Similarly the presence of the yellow tone was assessed by forming contingency tables as explained in section 8.2. Divisions not explained in that section were the lighter (bronze olive) and darker (dark fig, and rich olive) green colours.

RESULTS

Leaf sheen colour

The two major leaf sheen colours adopted to describe the populations were 1360 (whisp green) and 1426 (been sprout). They were distributed as follows :

COLOUR	1360	1360/1426	1426
SITE #	1 2 3 4 5	22 32 33 54 56	34 35 37 38 39
	6 7 8 9 10	58 59 65 70	41 42 43 44 45
	11 12 13 14 15		46 47 48 49 50
	16 17 18 19 20		52 53 55 57 61
	21 23 24 25 26		63 64 66 67 72
	27 28 29 30 31		
	40 51 62 68 69		
	71		

At sites 37 and 39 there was a slight tendency for young trees to have a sheen of 1629.

At site 22 the leaves appeared 1360 in the sun and 1426 under cloud cover.

Sheen was significantly associated with the underlying leaf colour (Table 14; Fisher's Exact Test; 2, 0.05).

TABLE 14 : COMPARISON OF LEAF SHEEN AND LEAF COLOUR FREQUENCY IN FOUR COMBINATIONS.

LEAF COLOUR	LEAF SHEEN 1360	LEAF SHEEN 1426
bronze olive	11	21
dark fig/rich olive	25	4

Leaf colour with sheen removed

Three main colours could be used to describe the sandalwood populations' leaves. These were, in order of ascending depth of colour, bronze olive (3111), dark fig (3112) and rich olive (4014).

Quandong versus sandalwood leaf colour

Wider observation indicated the yellow shade was characteristic of *S. acuminatum*. In only a few instances was it evident as a sandalwood leaf colour.

On the basis of reflected light the colours of non-glaucous quandong leaves at site 21, a lateritic sedgeland, were rich olive in the centre and lime yellow (3122) as undertone at the edge. By comparison accompanying sandalwood was dark fig at the centre with lime yellow as an undertone at the edge.

On the basis of transmitted light, the transparent colour, quandong leaves were lime yellow while sandalwood was quince green (3124).

Similarly sandalwood site 49 had a tendency for the bronze olive to tint with lime yellow on the verge of *Calothamnus* sp heath. At the contiguous, quandong dominant, site 50, a large single sandalwood was bronze olive over lime yellow on the north and bronze olive on the south. Likewise a single tree noted near a stand of *Banksia prionotes* was tinged with lime yellow.

Shade and leaf colour

A trend for shade to influence the intensity of green was noted. For example at site 44 the sun side of a tree was bronze olive and the shade side dark fig. At site 39 the predominant colour of mature trees was bronze olive while sheltered, low, young trees were a deep tone of rich olive.

Shading also appeared to influence colour on the small scale, inspection at sites 58, 61 and 65, showed the adaxial upper leaf surface to be lighter (bronze olive) than the abaxial lower leaf surface (dark fig).

Recently fallen leaf colour

It was noticed that recently fallen leaves had a uniform purple colouration, which was similar to the colour of nut flesh at maturity as it began to dry out. As the fallen leaves aged they tended to turn jet black which marked them in contrast to other community litter.

Geographic pattern for sandalwood leaf colour

The colours representative of each population were arrayed geographically (Figure 5). Clear patterns were not evident. However two localized effects were noted. One was the deeper leaf colour in the near coastal regions (and higher rainfall zones) of the north and south coasts (Kalbarri/Geraldton and Ravensthorpe/Oldfield R. respectively). A slight exception being site 6 near Kalbarri. The other the lighter leaf colour in the central wheatbelt. In particular the eastern "upper mid-west" and the "lower mid-west" transects (as defined under nut diameters; this section).

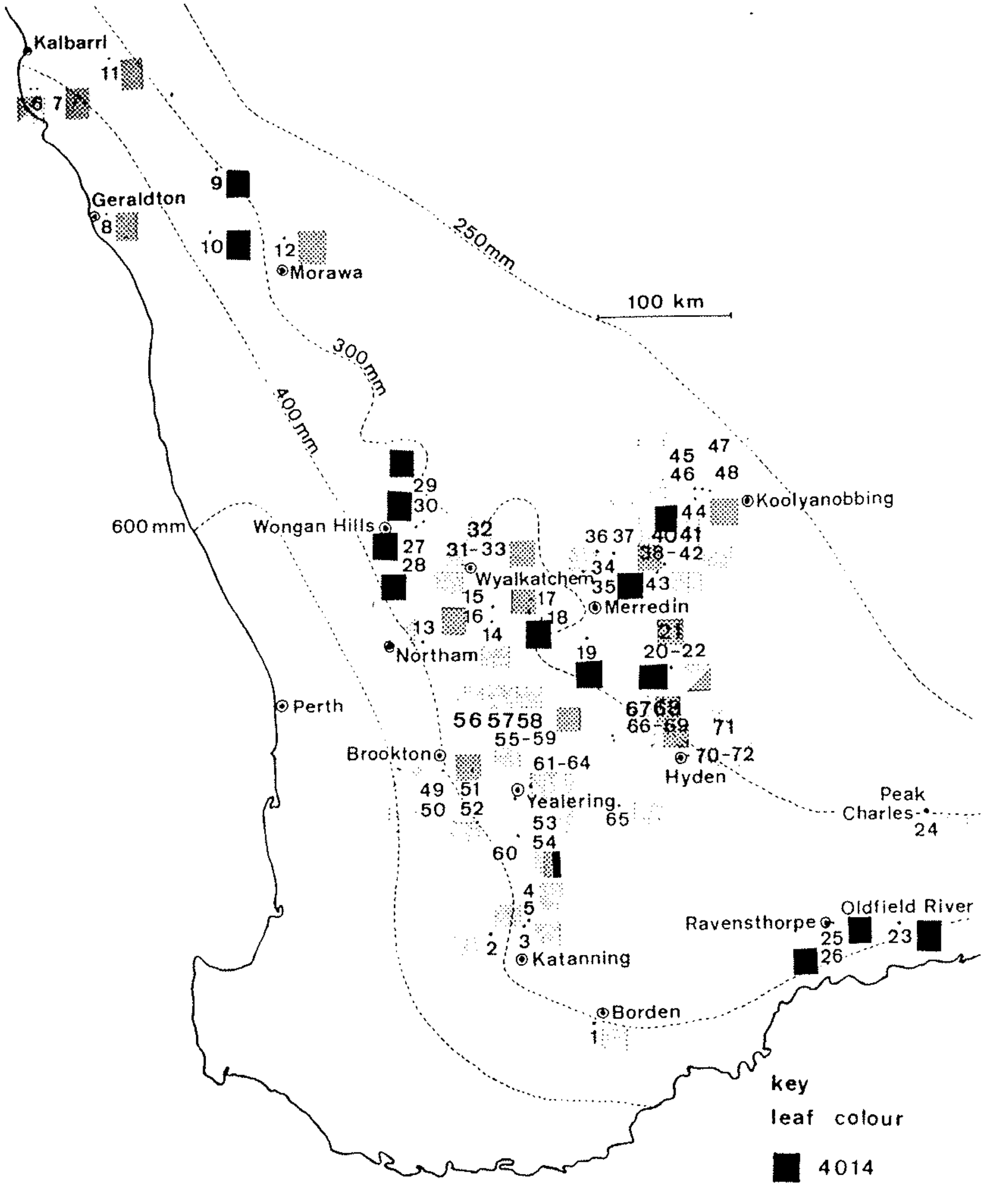


FIGURE 5 :

CHIEF LEAF COLOUR OF SANDALWOOD AT STUDY SITES

Community dominants & soils, & sandalwood leaf colour

Community dominants and lateritic soils did not show any significant association with leaf colour, whereas the percent cover of acacias did (Table 15A; Fisher's Exact Test; 2, 0.05)

Similarly there was association of the presence of yellow with acacia cover (Table 15B; Chi-squared; 2, 0.05).

On a non-statistical basis this was matched by a distinct difference when the intensity of the yellow was considered. At the low acacia cover sites the most common population intensity of yellow was "dominant" (11 of 12 sites), with each population at least having individuals of "underlying" intensity. While at the high cover acacia sites the mode was "underlying" (8 of 8 sites; at site 45 this was very weak). In both cases there were populations where individuals with no yellow co-existed with those with yellow.

Lateritic soils were also significantly associated with yellow leaf colour (Table 15B; Fisher's Exact Test; 2, 0.05).

Note that at two sites recording a plant as rich olive was a possible coverall for bronze olive with underlying lime yellow. This would have the effect of moving sites 22 and 29 from no yellow to yellow in the laterite category. Also note that sites 56 and 57 were laterite influenced, really forming a series with 55 and 58, and could have been placed in the yellow/laterite compartment. Neither of the two preceding would alter the significance.

There was a significant association of intensity of leaf green colour with the presence of yellow (Table 15B; Fisher's Exact Test; 2, 0.05).

The association of leaf colour with the localized water regime is treated in section 8.3; no association was found.

TABLE **15a**: COMPARISON OF THE FREQUENCY OF SITES WITH LIGHTER AND DARKER LEAF COLOURATION.

	LEAF COLOUR LIGHTER (3111)	DARKER (3112, 4014)
ALLOCASUARINA DOM. SITES	12	6
EUCALYPTUS DOMINATED SITES	14	11

EUCALYPT & ALLOCAS. SITES	26	17
MALLEE SITES	5	4

ACACIA SP COVER $\leq 1\%$	15	4
ACACIA SP COVER $\geq 1\%$	23	26

SOILS OF LATERITIC ORIGIN	12	4
OTHER SOIL TYPES	26	26

TABLE **15b**: COMPARISON OF THE FREQUENCY OF SITES WITH AND WITHOUT YELLOW LEAF COLOURATION.

	YELLOW	NON-YELLOW
ACACIA SP COVER ≤ 1 %	12	6
ACACIA SP COVER > 1 %	8	23

	YELLOW	NON-YELLOW
SOILS OF LATERITIC ORIGIN	10	4
OTHER SOIL TYPES	11	24

	YELLOW	NON-YELLOW
LEAF COLOUR 3111	18	13
LEAF COLOUR 3112/4016	2	16

DISCUSSION

Leaf sheen colour

The clear association of each of the two sheen colours with the two categories of leaf green colour may indicate two things. One is that the underlying colour had a strong influence on how the sheen was perceived. The second that there is a physiological link between sheen and leaf green colour.

In either case the linkage of the two forms of colour tends to render persuing the sheen as a definitive phenotypic expression redundant.

Leaf colour with the sheen removed

With the preceding in mind it is the apparent colour of the bulk of the leaf photosynthetic/green tissue that is treated below.

Quandong versus sandalwood leaf colour

Clearly sandalwood shared pigmentation with its congeneric partner the quandong.

The presence of the yellow colour appears to be a diagnostic feature. For the closer inspection mentioned above indicates that the transmitted light passing through the quandong leaves on mass imparts the very characteristic yellow tone to the plant; whereas sandalwood is a sheen affected shade of olive.

Along with this characteristic colour the quandong also has a regular leaf arrangement with the leaves held vertically. This is in marked contrast to the less regular and lax arrangement on sandalwood.

An account of a plant where the features are : less branching, secondary shoots and leaves are held in a vertical position, leaves tend to turn yellow, trees flower poorly and fruits are strongly coloured; closely approximates the quandong. Yet these are the general symptoms of nitrogen deficiency (Davidescu, D. and Davidescu, V., 1982). Note that a couple of listed features do not apply to Santalum species, but rather to deciduous, non-mast-fruiting, fruit trees of the genus Prunus. The features were earlier leaf loss and smaller fruit.

These features are paralleled by sulphur deficiency. Which is characterized by slow stem diameter increase, yellow-green colouration of the leaf blade without tissue death, secondary shoots and leaves in a vertical position, and strongly coloured fruits (Davidescu, D. and Davidescu, V., 1982).

These observations also match those of Barrett and Fox (1989) who found seedling sandalwoods with hosts were green shades while those without showed yellowing.

Other evidence also points to nitrogen being a key, potentially limiting, requirement for sandalwood seedlings. Crossland (1982) found that nitrogen promoted shoot growth and an increase in leaf numbers. Whereas the addition of surplus phosphorus was inhibitory.

Shade and leaf colour

Cursory investigation suggested that shading increased the depth of green on the small scale. The converse being that exposure to the sun reduced it. Potential sun induced yellowing was noticed at only one site on a large old tree (site 26).

Recently fallen leaf colour

The strong darkening of the fallen leaves and the fruit flesh may also reflect the nutritional status of those organs at abscission and maturity respectively. Phosphorus deficiency is manifested as dark blue-green growing leaf colour (or purple shades in Cruciferae); while dried leaves have a dark, almost black colour (Davidescu, D. and Davidescu, V., 1982). This clearly indicates that little phosphorus would be expected in abscised leaves and in mature fruit flesh of sandalwood.

Several observations support the contention that there is a significant P source in the leaves; which may be withdrawn prior to abscission. For intact leaves on the tree are predated (throughout the distribution) by leaf cutter bees and scale-like insects (author's observations). They are also readily grazed by sheep, cattle and rabbits. The foliage is desirable because it contains about 17% crude protein (Mitchell and Wilcox, 1988).

Geographic pattern for sandalwood leaf colour

Soil factors appear to underly the deeper leaf colour at the northern (sites 8 - 12) and southern (sites 23, 25 and 26) wheatbelt compared to those in the central south-west. The soils in the north are those of the Victoria Plateau and those of the south are of greenstone origin. These two groups are distinct from the central southwest.

These trends appear significant given that the vagaries of shading (noted in results), rainfall, stage of serral succession and tree age may influence colour.

Community dominants & soils, & sandalwood leaf colour

The association of strength of leaf greenness and yellow with acacia cover and of yellowing with lateritic sands strongly suggests a nutritional basis to the strength of leaf colouration. In line with the other observations above the main candidate nutrient is nitrogen; given that acacias fix nitrogen and that the sandy laterites tended to have a poor representation of acacias.

6.3 FRUIT

The nut of sandalwood is a distinctive, persistent, feature which is readily collected and measured. With both old and recent nuts available the aims of this section were to use nut features to determine whether nut size varied with time for each tree and whether geographical trends in nut features could be distinguished for populations.

METHODS

Terminology

The term fruit was used to embrace the outer flesh (epicarp), the inner shell (endocarp) and the kernel (embryo and endosperm). Figure 6 outlines the relationship of these components.

So for comparison with other work :
a nut = shell (endocarp) + kernel (endosperm & embryo)

Collection and measurement

Previous seasons' shells

These were collected from under each tree at random. They were sorted into four categories :

Old - fragmenting, fragile/brittle, grey Medium - hard, grey
Newer - hard, shades of white, with or without flesh
Recent - hard, (fairly clean) yellow, with or without purple coats (these last were 1989/1990 products)

Numbers in each category varied with the tree sampled.

The diameters of individual shells were measured.

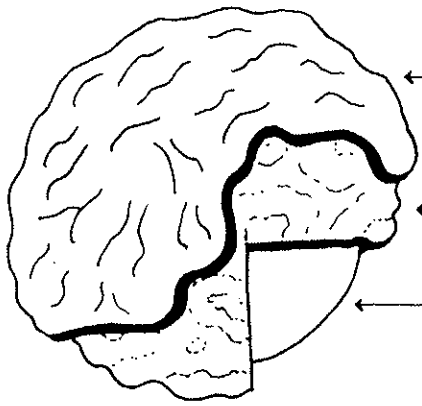


FIGURE 6 : TERMINOLOGY APPLIED TO THE FRUIT OF SANTALUM SPICATUM.

. 1990/1991 season's fruit

The fruit were collected as described under "fruit production".

Individual fruit were measured. Where possible 35 per tree were assessed for diameter, weight and dry flesh weight, and an extra 5 were removed from their shells and the diameters and weights of the kernels were taken.

Analysis

Previous seasons' shells

The average diameters per tree per category were calculated and incorporated into a one-way ANOVA with the tree as the independent variable.

1990/1991 season's fruit

Principal components analysis

The measurements of shell weight, shell diameter, kernel width, kernel weight and flesh weight were averaged per population and subjected to principal components analysis.

Principal-components analysis is one of a variety of procedures developed for the purpose of analyzing the intercorrelations within a set of variables.

. If the task is begun with two variables the aim is to produce a composite score measuring what these variables have in common and producing a maximum variance among individuals. Between the two variables is an axis (or "component") which defines the factor (or basic dimension) that the variables are measuring in common. It is not a regression line, which describes interrelationships, but rather a basis for discrimination, a starting point from which to emphasize differences. It is equivalent to the x or y axis but more "important". Maximum variance is accomplished by projecting all points by the minimum perpendicular distance onto the principal axis (of an ellipse).

A third variable can be introduced and the test-space becomes three-dimensional (the ellipse becomes an ellipsoid).

As more and more variables are included, additional significant components may appear, indicating that the domain is not unidimensional and more dimensions are required to define it.

In short principal-components analysis defines a unique set of reference axes for a given combination of m variables using maximum variance criterion.

However, for interpretation two further things are required. Firstly, a new set of axes is formed by rotating the principal-component axes mentioned above. This renders a multidimensional space intelligible on a 2-dimensional surface such as a figure. Secondly the ecological meaning of the axes must be determined and applied to this representation.

Non-parametric testing

Major transects were designated as :

Northern (sites 6 - 12)

Upper mid-west 1 (sites 27 - 48)

Upper mid-west 2 (sites 13 - 22)

Lower mid-west (sites 49 - 72)

Southern (sites 2, 3, 4, 5, 1, 25, 26, 23 & 24)

Comparison of shell diameters between latitudes

The Mann-Whitney rank test was applied to the diameters of the shells of individual trees for comparisons between northern, midwestern and southern sites.

Comparison of shell diameters from east to west

At each major latitudinal transect sites were designated as either east or west of a geographic midpoint. The average shell diameter for each tree was then given a 1 if it was under the median diameter for that transect or a 2 if it was over the median size. The total "east" and "west" scores were tallied for each transect to determine whether, on mass, the east or west had the greater total rank score.

RESULTS

Previous seasons shells

Analysis of variance for nut diameter :

Source of variation	Degrees of freedom	Sum of squares	Mean squares
Between ages (all trees)	3	0.1005	0.0335
Within trees	359	15.9986	0.0446
Total	362	16.0992	0.0781

Summary statistics :

Category	n (trees)	Average	S.D.
Old	115	1.80	0.20
Medium	107	1.84	0.21
Newer	83	1.82	0.21
New	58	1.82	0.24

There was no significant difference in diameter between the ages (f ratio).

1990/1991 season's fruits

Principal Components Analysis

Principal factor analysis of fruit parts indicated that 2 factors explained 95% of the variance. Factor 1 equated to nut size (ie nut weight, nut diameter, kernel diameter and kernel weight) and gave better separation of the data than factor 2, flesh weight.

The scaled rotated values for each site are shown in Figure 7 and the grouping and interpretation in Figure 8. In the case of the latter the only "sensible" groupings that could be recognized were on a geographical basis as represented and not on other features such as community type. For the factor 2 ("nut flesh") axis the north-south separation was marked. However along axis 1 ("nut size") the succession from left to right approximates mid-west sites, southern sites, and northern sites. The latitudinal groupings used are explained in the preceding methods under non-parametric analysis.

Diagonally there were weak to moderate east-west trends for the southern and lower mid-west sites respectively.

The outlying position of site 62 is clear.

Non-parametric testing

Mann-Whitney test

Table 16 outlines the east-west arrangement of nut size along the major sampling transects or latitudes.

The main significant separation on the basis of old nut diameter was of lower mid-west sites as opposed to northern and upper mid-west sites (Table 17).

Rank totals

Table 18 shows that the general trend was for nut diameter to increase from the east to the west. The exceptions were the sites of the upper mid-west and north.

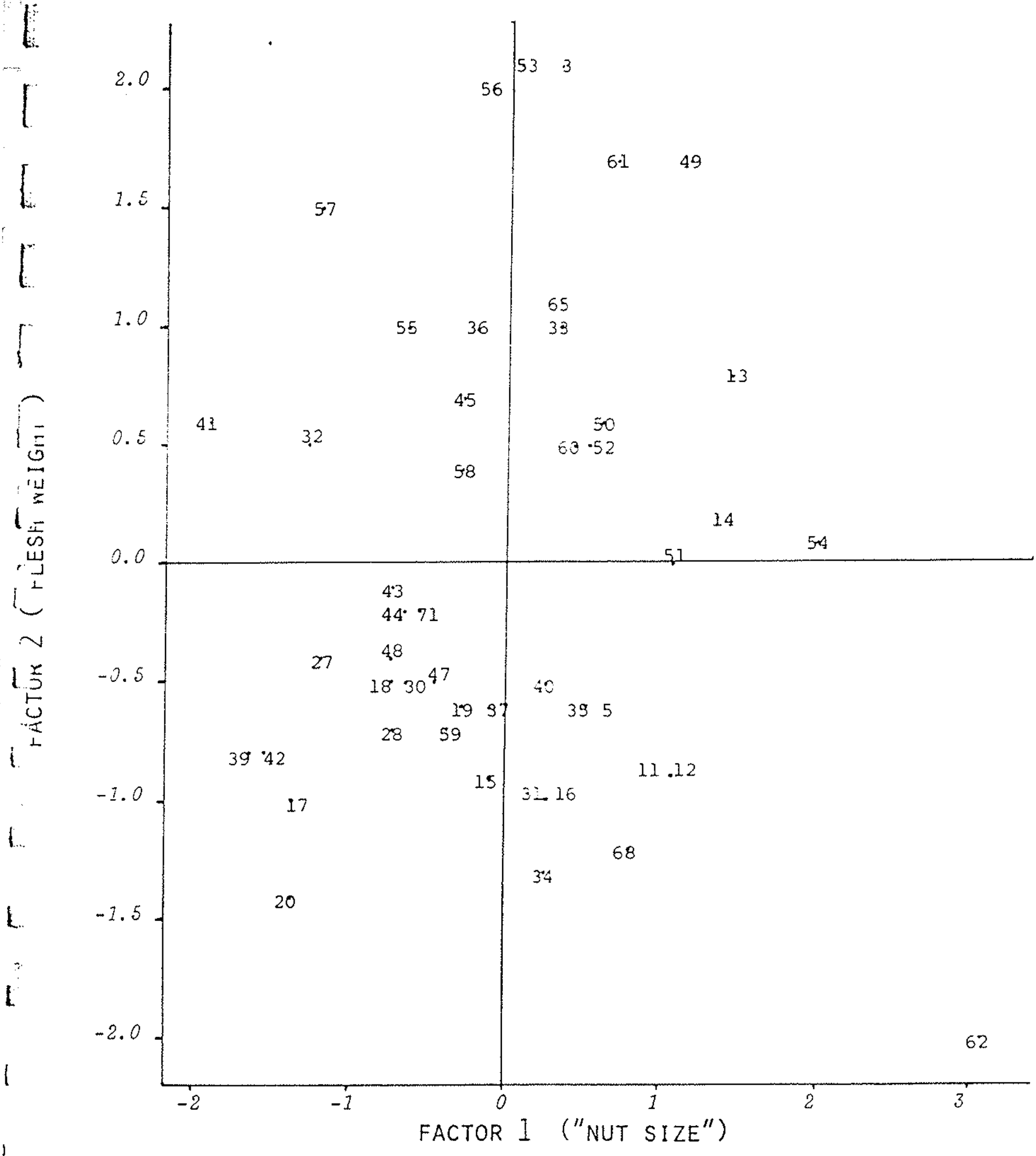


FIGURE 7

P.C.A. OF SANDALWOOD NUT FACTORS FROM 48 SITES AT WHICH TREES PRODUCED NUTS DURING SUMMER 1990 / 1991.

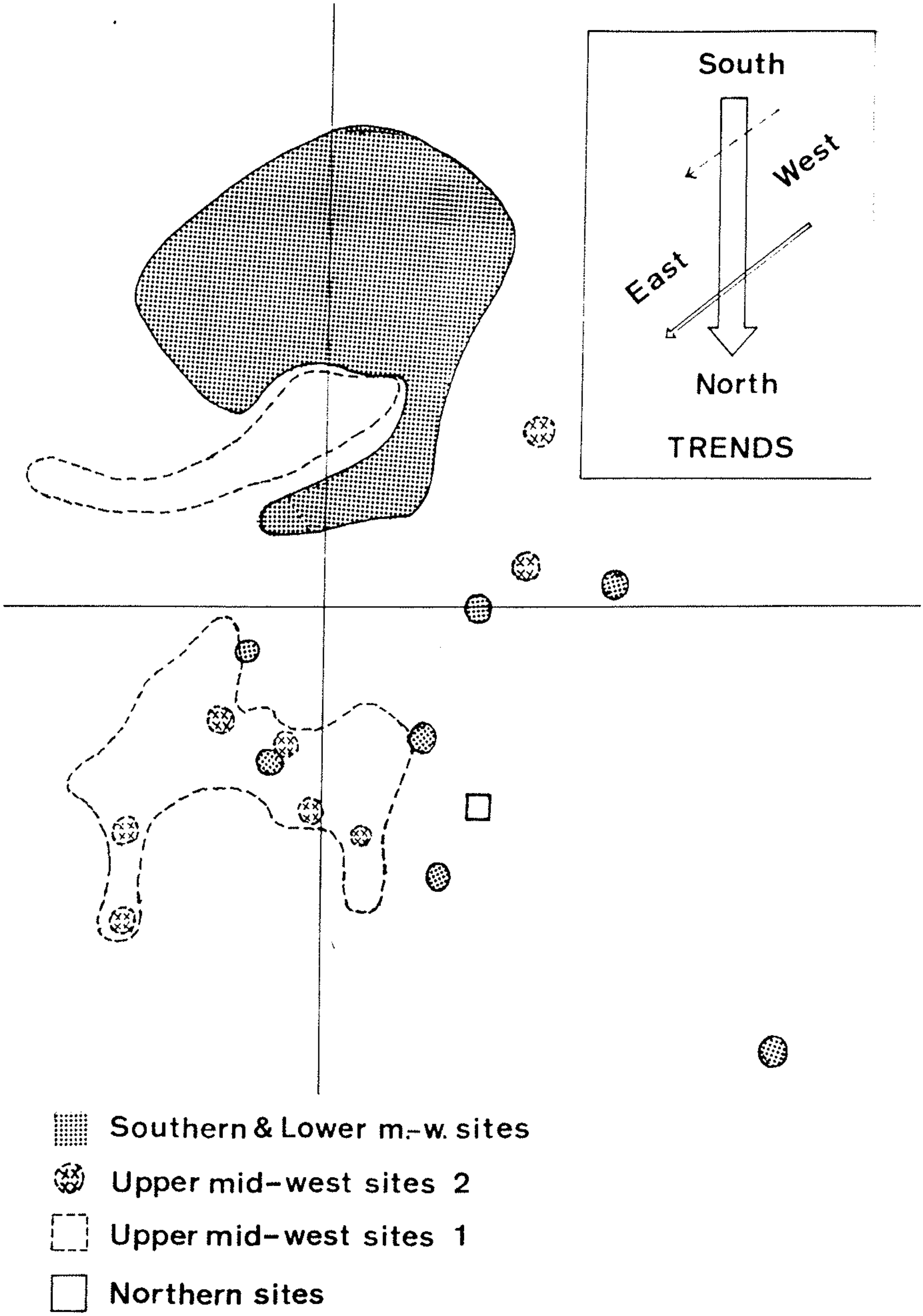


FIGURE 8 : INTERPRETATION FOR FIGURE 7

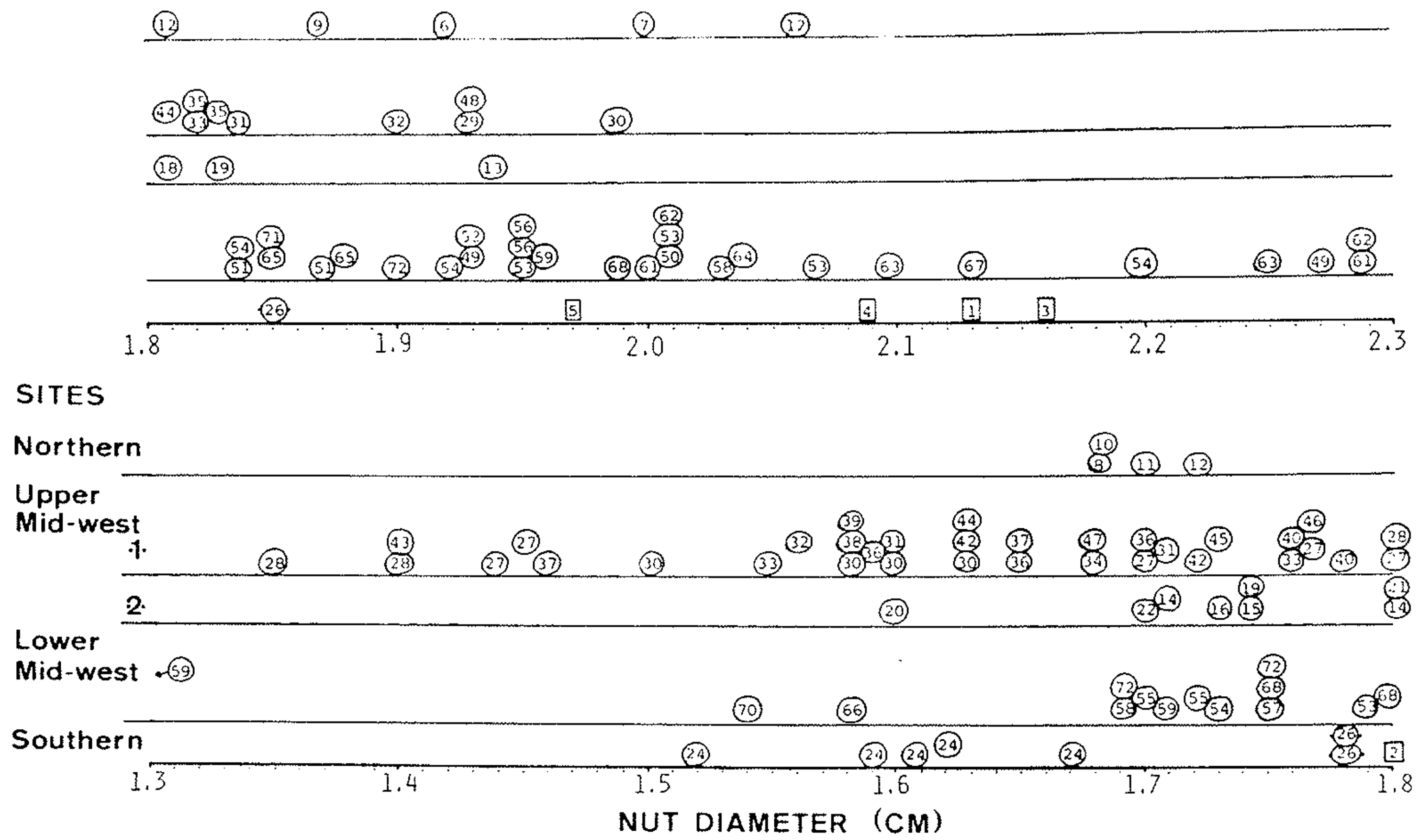


TABLE **16** : DIAMETERS OF OLD SANTALUM SPICATUM NUTS ARRANGED IN LINEAR ORDER (X AXIS) AND GROUPED BY RELATIVE LATITUDE (Y AXIS). (EACH CIRCLED SITE NUMBER IS THE AVERAGE FOR ONE TREE FROM THE POPULATION; FOR THE SOUTHERN SITES ○ IS PEAK CHARLES, ◇ IS REVENSTHORPE, □ IS KATANNING/BORDEN).

TABLE **17** : COMPARISON OF *SANTALUM SPICATUM* POPULATIONS AT DIFFERENT LATITUDES ON THE BASIS OF THE DIAMETERS OF OLD NUTS. (REFER TO PRECEDING TABLE. SIGNIFICANCE LEVELS ARE FROM THE MANN-WHITNEY RANK-SUM PROCEDURE.)

<table>
<tr><th>RELATIVE LATITUDE</th><th>NORTHERN</th><th>UPPER 1 MID-WEST</th><th>UPPER 2 MID-WEST</th><th>LOWER MID-WEST</th><th>SOUTHERN</th></tr>
<tr><td>NORTHERN</td><td>—</td><td></td><td></td><td></td><td></td></tr>
<tr><td>UPPER 1 MID-WEST</td><td>NS</td><td>—</td><td></td><td></td><td></td></tr>
<tr><td>UPPER 2 MID-WEST</td><td>—</td><td>—</td><td>—</td><td></td><td></td></tr>
<tr><td>LOWER MID-WEST</td><td>***</td><td colspan="2">***</td><td>—</td><td></td></tr>
<tr><td>SOUTHERN</td><td>NS′</td><td>NS′</td><td>—</td><td>NS′</td><td>—</td></tr>
</table>

KEY : NS - NOT SIGNIFICANT; ′ - ± PEAK CHARLES; *** ≤ 0.01

TABLE **18** : LONGITUDINAL GRADIENTS OF DIAMETERS OF OLD NUTS AT DIFFERENT LATITUDES FOR *SANTALUM SPICATUM*. (DIRECTION OF ASCENDING DIAMETER INDICATED ON THE BASIS OF LOW TO HIGH RANK TOTALS EACH SIDE OF THE MEDIAN).

RELATIVE LATITUDE	NUT SIZE SMALLER	LARGER
NORTHERN	EQUAL	EQUAL
UPPER 1 MID-WEST	WEST	EAST
UPPER 2 MID-WEST	EAST	WEST
LOWER MID-WEST	EAST	WEST
SOUTHERN	EAST	WEST

DISCUSSION

The absence of variation in shell diameter with time suggested that this feature was fixed for a tree and formed a valid basis for attempting to array or compare the populations.

The principal components analysis and the non-parametric procedures both confirm the same trends. On the basis of nut size, and shell diameter in particular, there was clearly a tendency for midwest sites to be grouped together and for northern and southern sites to be grouped together. In terms of longitude both analyses indicate an east-west gradient. An exception was the first upper mid-west transect with a reversed trend (west:smaller - east:larger). This could have been an artifact of the fruiting pattern (extremely limited production between Nungarin and Westonia) and deep sands near the water table at Lake Deborah in the east. Another exception was the geographically narrow "transect" in the north with a limited number of sites. Similarly, in terms of latitude, the failure of the nonparametric test to distinguish southern and upper mid-west sites, could be attributed to the same cause.

The longitudinal east-west gradient is intuitively clear as a pattern related to rainfall where a diminution of size from west to east would be expected (see Figure 1).

However the latitudinal grouping of southern and northern sites is not so clear. In Figure 1 it can be seen that the upper mid-west sites extend beyond the 300 mm isohyet for at least half the total number of sites. This is not the case for the southern or northern sites which can effectively be considered more "coastal" as opposed to the others central location. Again this is a pattern related to rainfall.

This finding is corroborated by the difference in nut size found between wheatbelt and Kalgoorlie provenances in Narrogin during 1978, where the former were larger (Loneragan, 1990). Also similar trends were noted between small nuts in the arid inland and large nuts in the central wheatbelt and at the north-west coast (Brand, 1991). Again the latter appears to be a pattern related to water, generally rainfall, though more likely an ameliorated, maritime-influenced environment on the coast at Shark Bay (author's observation).

Flesh weights on the PCA differ slightly from this pattern in that they appear to separate northern versus southern populations so that it appears that latitude has more of a direct effect on flesh weight. This matches the strong negative correlation of flesh weight on days at or above 30 oC per annum discussed below. However the mid-west sites still grouped together which corroborates the nut diameter findings.

The dichotomy in clarity between nut-size features and flesh; with the former being less clearly separated on the PCA may reflect the degree to which they are genetically controlled. First they are assigned different axes by the analysis; an indication of inherent differences. Second the contrast is between the clear separation on the basis of flesh and the less clear, smudgy, separation on the basis of "nut-size" features. This is despite flesh being climate and density dependent (section 7.3) and shell diameter being nearly fixed per tree and affected only by climate. The nut size pattern may be affected by the mixing of weights and diameters for shells and kernels. It may also be that there is some conformation of the latter being connected to the genetics of the tree. For the "smudging" along the nut-size axis conforms to a genetically controlled feature for sandalwood. Where most variation is within populations (Brand, 1991). So that limited and "smudgy" separation might be expected between populations for a genetically controlled character.

7 FACTORS INFLUENCING FRUIT COMPONENT FEATURES

7.1 THE RELATIONSHIP OF SHELL WIDTH TO OTHER FRUIT FEATURES

The aim of this section was to determine whether shell diameter was a feature determined by other fruit features.

METHODS

The separation of component fruit parts was described under fruit production. Fruit component averages per site were correlated with each other.

RESULTS

The average weights and diameters of fruit components over all the sites are listed in Table 19. Nut component interrelationships were highly significant (Table 20). In order of the strength of the correlation coefficients the trends were : 1) kernel width and kernel weight; 2) kernel weight and shell diameter; 3) shell diameter and kernel diameter; 4) shell weight and shell diameter; 5) shell weight and kernel diameter; and 6) shell weight and kernel weight. The interrelationships are illustrated in Figure 9.

TABLE **19**: AVERAGES OF FRUIT FEATURES

FRUIT FEATURE	N	AVERAGE	S.D.	RANGE
KERNEL WEIGHT	51	1.16 GM	0.14	0.94 - 1.46
SHELL WEIGHT	49	1.55 GM	0.66	0.43 - 3.63
FLESH WEIGHT	51	1.05 GM	0.32	0.52 - 1.75
KERNEL DIAMETER	51	0.96 GM	0.29	0.42 - 1.60
SHELL DIAMETER	54	1.76 CM	0.18	1.38 - 2.16
WHOLE NUT WEIGHT	54	2.60 GM	0.65	1.39 - 4.12

TABLE **20** : CROSS-CORRELATES OF FRUIT FEATURES

FRUIT FEATURE .A	FRUIT FEATURE .B	R	P	REGRESSION
KERNEL DIAMETER				
	KERNEL WEIGHT	0.9506	<0.001	K.D. = -1.413 + 1.995 (K.W.)
	SHELL DIAMETER	0.8272	<0.001	K.D. = -1.368 + 1.317 (S.D.)
	SHELL WEIGHT	0.7293	<0.001	K.D. = 0.458 + 0.319 (S.W.)
KERNEL WEIGHT				
	SHELL DIAMETER	0.8530	<0.001	K.W. = 0.059 + 0.637 (S.D.)
	SHELL WEIGHT	0.6931	<0.001	K.W. = 0.962 + 0.142 (S.W.)
SHELL DIAMETER				
	SHELL WEIGHT	0.8154	<0.001	S.D. = 1.416 + 0.224 (S.W.)
FLESH WEIGHT				
	SHELL WEIGHT	0.6282	<0.001	F.W. = 0.580 + 0.304 (S.W.)
	SHELL DIAMETER	0.5823	<0.001	F.W. = -0.826 + 1.064 (S.D.)
	KERNEL DIAMETER	0.5772	<0.001	F.W. = 0.440 + 0.641 (K.D.)
	KERNEL WEIGHT	0.5417	<0.001	F.W. = -0.456 + 1.277 (K.W.)

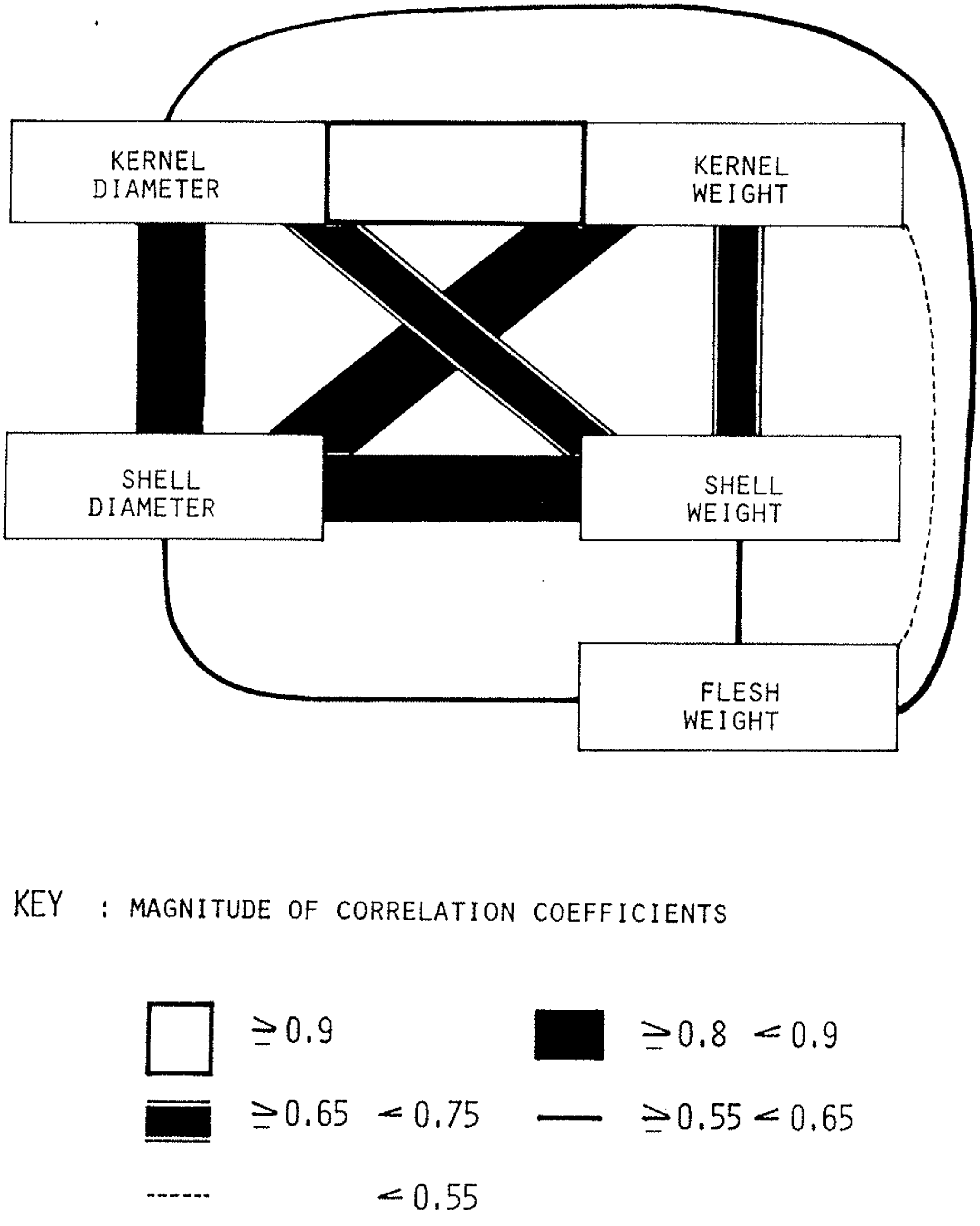


FIGURE **9** : DIAGRAMMATIC REPRESENTATION OF THE INTERRELATIONS OF FRUIT FEATURES

DISCUSSION

Several things tend to indicate that shell diameter my be a key determinant for the other fruit features, and not a dependent variable. Shell diameter correlates with kernel diameter, kernel weight and shell weight equally. Similarly flesh weight is more strongly correlated with shell weight and diameter than kernel features. Ecophysiologiclly this is not surprising as a woody structure is primarily carbon and therefore cheaper (in terms of energy and chemical resources) to invest in than a kernel composed of lipid, carbohydrate and protein (Levin, 1974). As such it may be a simpler matter for a parent tree to provide the shell than to fill the kernel. This matter may be made even simpler if it is the final diameter and not the density that is more important; ie a similar structural size may be achieved with a lighter weave. In this regard note that it is only shell weight and not diameter that is influenced by percent cover of acacias (section 7.3). That the kernel of *Santalum spicatum* is expensive to invest in is supported by the finding of Barrett et al (1989) that the kernels are similar to other nut producing species with 60.7 % fat, 17.7 % protein, and 16.4 % carbohydrate.

Such a finding is compatible with the demonstrated relationship of *average rainfall* with shell diameter. If shell diameter were plastic it would be expected to reflect the quantity of annual rainfall more strongly than it would the average rainfall.

7.2 CLIMATE AND ALL FRUIT FEATURES

The aim of this section was to test for climatic correlates of fruit features.

METHODS

Weather data from towns in closest proximity to all sites was provided by the Western Australian Bureau of Meteorology.

The nut components from the current year's crop were correlated with sandalwood density, percent cover of acacias, casuarinas and eucalypts, the total preceding summer and winter rainfall, average rainfall, and number of days per annum with temperatures at or above 30 oC and 35 oC, and with the number of days per annum at or under 5 oC and 2 oC.

The "old" class of nuts average diameter per tree was regressed against average rainfall and tree diameter at 15 cm. Average rainfall was used because it negated questions of the actual age of "old" nuts and therefore the need for synchronous rainfall data.

RESULTS

For the diameter of recent nuts there were significant regressions on average rainfall and on days equal to or exceeding 30 oC per annum. The rainfall bearing the stronger correlation. Similarly for the diameters of "old" nuts there was a correlation with average rainfall.

The following results are in approximate order of magnitude (Table 21).

For flesh weight and shell diameter, average rainfall was the most strong correlate. Secondarily both were negatively affected by days at or above 30oC.

For shell weight the relationships were similar, but with winter & summer rain bearing a stronger correlation coefficient than days at or above 30oC. Also days at or less than 5oC were important; though the correlation was the most weak.

TABLE **21** : CLIMATIC CORRELATES OF FRUIT FEATURES

FRUIT FEATURE	CLIMATIC FEATURE	R	P	REGRESSION
FLESH WEIGHT				
	AVERAGE RAINFALL	0.5206	<0.001	F.W. = -0.092 + 0.003 (A.R.)
	DAYS/YEAR ≥ 30°C	-0.4967	<0.001	F.W. = 2.009 - 0.010 (30°C)
SHELL DIAMETER				
	AVERAGE RAINFALL	0.5157	<0.001	S.D. = 1.128 + 0.002 (A.R.)
	DAYS/YEAR ≥ 30°C	-0.4459	<0.001	S.D. = 2.205 - 0.005 (30°C)
SHELL WEIGHT				
	AVERAGE RAINFALL	0.4954	<0.001	S.W. = -0.644 + 0.006 (A.R.)
	WINTER & SUMMER RAINFALL	0.4486	<0.001	S.W. = -0.046 + 0.004 (W.S.)
	DAYS/YEAR ≥ 30°C	-0.4226	0.002	S.W. = 3.084 - 0.016 (30°C)
	DAYS/YEAR ≤ 5 °C	0.3754	0.008	S.W. = 0.374 + 0.016 (5 °C)
KERNEL DIAMETER				
	WINTER RAINFALL	0.4314	0.002	K.D. = 0.264 + 0.002 (W.R.)
	WINTER & SUMMER RAINFALL	0.4290	0.002	K.D. = 0.283 + 0.002 (W.S.)
	AVERAGE RAINFALL	0.3698	0.008	K.D. = 0.256 + 0.002 (A.R.)
	DAYS/YEAR < 5 °C	0.2770	0.049	K.D. = 0.611 + 0.005 (5 °C)
	DAYS/YEAR ≥ 35°C	-0.2724	0.053	K.D. = 1.218 - 0.006 (35°C)
KERNEL WEIGHT				
	WINTER & SUMMER RAINFALL	0.4542	<0.001	K.W. = 0.848 + 0.001 (W.S.)
	WINTER RAINFALL	0.4305	0.002	K.W. = 0.858 + 0.001 (W.R.)
	AVERAGE RAINFALL	0.4235	0.002	K.W. = 0.806 + 0.001 (A.R.)
	DAYS/YEAR ≥ 30°C	-0.3522	0.011	K.W. = 1.442 - 0.003 (30°C)

Kernel diameter was most strongly correlated with the preceding winter rainfall. This was similar to winter & summer and stronger than the relationship for average rain. Next weakest correlates for kernel diameter were days at or below 5oC and days at or above 35oC.

The pattern was similar for kernel weight with the exception of no correlation with days at or under 5oC.

Old shell diameters on an individual tree basis (n=117) produced a very similar regression to that for recent nuts on a population basis.

DISCUSSION

The apparent rainfall gradient underlying the geographical pattern of shell diamter-cum-size was confirmed statistically for both current seasons and much older nuts on a population and individual basis respectively.

For the other nut features there was a dichotomy in the results.

Average rainfall has a stronger relationship with shell weight (and shell diameter) and with flesh weight. Again this indicates fidelity of parent trees to fruit dimensions enforced by their long-standing position in the rainfall gradient. It has already been shown that the shell diameter is stable with time for individual trees. The above indicates that the same may be true of shell weight and flesh weight. On the other hand kernel diameter and weight were more closely correlated with the immediately preceding seasonal rainfall which indicates that these features would vary according to the amount of that rainfall in each productive year.

For kernel diameter and weight three factors indicate that the winter is important to final dimensions. They are the conjunction of winter rainfall, and days per year at or below 5oC, as correlates, and the relatively weaker correlations with days per year at or above 30oC. (Note that the more extreme case of days per year at or above 35oC is only weakly correlated with kernel diameter.)

7.3 SANDALWOOD DENSITY & OTHER SPECIES COVER VS FRUIT FEATURES

The aim of this section was to test for fruit feature correlates amongst variables representing the community dominants.

METHODS

Sandalwood density and the percent cover of acacias, casuarinas and eucalypts were correlated with individual fruit features.

RESULTS

Shell weight was correlated with the percent cover of acacias. Flesh weight was correlated with acacia cover and negatively correlated with sandalwood density (Table 22).

DISCUSSION

The correlation of shell weight only with percent acacias tends to indicate that it is more of a key feature than flesh weight which, although similarly correlated with acacias, is adversely affected by density of sandalwood plants. In other words a sandalwood tree appears to have some dependency upon percent cover of acacias for the weight of both shell and flesh, but under increasing competition for the "resource" represented by the acacias it is flesh weight that is adversely affected. That is, shell weight is more "important" to a sandalwood tree than flesh weight and is held constant preferentially.

TABLE **22** : PLANT COVER CORRELATES OF FRUIT FEATURES

FRUIT FEATURE	PLANT COVER	R	P	REGRESSION
SHELL WEIGHT				
	% ACACIAS	0.3533	0.015	S.W. = 1.323 + 0.033 (%.A.)
FLESH WEIGHT				
	% ACACIAS	0.3327	0.020	F.W. = 0.940 + 0.013 (S.D.)
	SANDALWOOD DENSITY	-0.2812	0.048	F.W. = 1.134 + 0.004 (S.D.)

8 HABITAT INFLUENCE ON SANDALWOOD POPULATIONS

8.1 HABITAT FACTORS VERSUS FRUIT PRODUCTION

The aim of this section was to determine which of individual tree, percent cover of dominant species, sandalwood density and climate factors, control total fruit production.

METHODS

Fruit were collected during March 1991 by which time the majority had fallen to the ground and were clearly mature. They represented the 1990/1991 seasons crop for each tree which bore fruit. The total fruit production of each tree was collected and weighed. Then it was divided into incompletely-formed and fully-formed nuts. The character used was whether the nut had a fully-formed flesh which could be separated from the nut. On investigation a separable flesh proved to correspond to a fully formed kernel, whereas fused or undeveloped flesh corresponded to an undeveloped kernel. Nuts which had lost their flesh were taken as being fully developed. Weights and numbers in the categories were measured.

Not all the nuts still had their flesh, so that the subsample per tree's production that had flesh was used to derive the proportion of weight accounted for by flesh, and this proportion was applied to the remaining weight to give a "total" flesh weight per tree.

Regressions were tested against rainfall for 1989, 1990, and 1990 winter and summer (to march 1991) , average rainfall, the number of days per year at or above 30oC and 35oC, the number of days per year at or below 5oC and 2oC, the percent cover of acacias, casuarinas and eucalypts respectively (arcsine transformation for proportions), sandalwood density (#/ha) and stem diameter at 15cm. The values per tree were of weight of total fruit production, weight of flesh, weight of fully developed nut shells and kernels respectively, of underdeveloped nuts, and of numbers of fully developed and of underdeveloped fruit, and of their scaled counterparts (total amounts divided by the diameter at 15 cm) respectively. (Note that in an attempt to remove the effect of tree size upon production a scaled set of values represented by total fruit weight, total shell weight and total kernel weight, each respectively divided by the diameter of the parent plant was also included in the correlation matrix).

RESULTS

The significant results for those trees that did produce fruit are shown in Table 23.

No production features were related to the cover of dominants or sandalwood density.

Only the weight of underdeveloped nuts was sufficiently explained by multiple regression. These were functions of diameter at 15cm and rainfall, or of the former and the number of days per year at or above 30 oC. In both cases the combined correlation coefficients were stronger than for either rainfall or days at or above 30 oC alone with the weight of incompletely-formed fruit. A combined equation with the three variables was not significant.

The correlations with the preceding year's rainfall, the winter and summer rainfall of the year of production or the combination of the two produced similar correlation coefficients and attached significances. These were only slightly stronger than the correlation with average rainfall.

TABLE 23 : CORRELATES OF FRUIT PRODUCTION

CORRELATES OF TREE DIAMETER AT 15 CM

PRODUCTION FEATURE	TREE FEATURE	R	P	REGRESSION
TOTAL FRUIT WEIGHT	DIAM AT 15 CM	0.3180	-0.001	T.F.W. = 296.34 + 32.80 (DIAM)
TOTAL I.F.F. WEIGHT	"	0.2894	-0.001	T.I.W. = 34.41 + 9.04 (DIAM)
TOTAL FLESH WEIGHT	"	0.2389	0.002	T.F.W. = 108.58 + 9.62 (DIAM)
TOTAL KERNEL WEIGHT	"	0.2556	0.007	T.K.W. = 82.27 + 5.38 (DIAM)
TOTAL SHELL WEIGHT	"	0.2415	0.011	T.S.W. = 171.73 + 8.58 (DIAM)
# OF POTENTIAL FRUIT	"	0.1871	0.027	#.P.F. = 173.77 + 8.00 (DIAM)
# OF F.F.F.	"	0.1924	0.022	#.F.F. = 101.02 + 5.79 (DIAM)

CORRELATES OF RAINFALL

PRODUCTION FEATURE	RAINFALL	R	P	REGRESSION
TOTAL I.F.F. WEIGHT	1989+w/s1990	0.2205	0.013	T.I.W. =-346.83 + 0.71 (8990)
TOTAL I.F.F. WEIGHT	AVERAGE RAINFALL	0.1903	0.025	T.I.W. =-284.12 + 1.31 (A.R.)

CORRELATES OF TREE DIAMETER AT 15 CM & RAINFALL

PRODUCTION FEATURE		R	P	REGRESSION
TOTAL I.F.F. WEIGHT	DIAM AT 15 CM &		0.007	T.I.W. =-375.01 + 0.57 (WS90)
	1989+w/s1990	0.3200	0.042	+ 7.41 (DIAM)
TOTAL I.F.F. WEIGHT	DIAM AT 15 CM &		0.002	T.I.W. =-325.87 + 1.03 (A.R.)
	AVERAGE RAINFALL	0.3249	0.072	+ 7.96 (DIAM)

CORRELATES OF DAYS PER YEAR AT OR ABOVE 30°C

PRODUCTION FEATURE		R	P	REGRESSION
TOTAL I.F.F. WEIGHT	#DAYS/YEAR $\leq$ 30°C	-0.1819	0.033	T.I.W. = 596.99 - 4.07 (#.D.)

* I.F.F. = INCOMPLETELY-FORMED FRUIT; F.F.F. = FULLY-FORMED FRUIT;
# OF POTENTIAL FRUIT = # I.F.F. + # F.F.F.; W/S1990 = WINTER & SUMMER RAINFALL 1990

This was not the case for the number of underdeveloped nuts which were not linked to tree diameter at 15cm or climatic features.

Otherwise total fruit production, weight and number of developed fruit, their shells and kernels, and developed nut flesh weight were significant functions of diameter. The respective investment proportions in fully developed nuts and their flesh were strongly correlated.

No total production features were correlated to habitat features when they were scaled by tree size.

DISCUSSION

The large number of trees available for analysis (maximum n=114) should have contributed to trends becoming obvious despite localized or individual effects. So that although particular individual trees may be genetically predisposed to low fruit production (Barrett, Fox and Sarti, 1989) the trends distinguished below are the predominant ones.

Total fruit production is a function of tree size. Witness the correlation of total fruit weight, total shell weight, total kernel weight, and total fully formed fruit number and total flesh weight as functions of tree diameter at 15cm.

It was the incompletely formed fruit (i.f.f.) that diverged from this relationship. Their weight mainly related to tree diameter, but was also influenced conjointly by rainfall (average or current) and independently, and negatively, by days per year at or above 30 oC. Of the three, tree size was the strongest with a slight adjusting influence from rainfall. (Note this means that although i.f.f. weight variation in response to rainfall should influence the relationship between total fruit production and tree size the effect will be minimal. Because rainfall was a minor influence on i.f.f. weight and the i.f.f. weight itself was a minor subset of the total weight of fruit produced.) The lesser influence is that of days at or above 30 oC (which is affected by latitiude and longitude (Appendix 11). (Again the influence of this on the overall tree size/total production relationship is diminished by i.f.f. being a minority component of bulk.)

More starkly the numbers of incompletely formed fruit did not correlate with any other features. This is possibly because they reflect the genetic consequences of the pollination of the flowers.

Considering the interrelationships between total production and incompletely formed fruit it appears that a sandalwood tree can only invest a certain amount of (unknown) resource in fully formed fruit. Hence the correlation of tree size with the number of fully formed fruit. Outside this limit a tree has an ability to invest in incompletely formed fruit in response to rainfall. Such a dichotomy would be compatible with a limited store of "nutrients" which could be donated to fruit which is a function of tree size. The trees still respond to rainfall that allows extra growth and investment (probably by supplying carbon and water based material); but they do not dilute the quality of the investment in the size-related fully developed fruit quotient (ie major nutrient sources such as protein are not diluted evenly over all potential fruit). In other words there is a limitation on the number of fully formed fruit that can be formed other than rainfall. This other limiting resource could be nutrients.

Density of sandalwood did not correlate with total production features. This indicates that either or both of the factors that could be affected by density, cross-pollination and resource acquisition, were adequate for production at most sites.

Scaling the production components by tree size did not result in any significant correlations. As all correlations were on absolute amounts this indicates that no habitat features effected an increase in production on a per unit tree size basis. Only total amounts per tree were affected by the significant factors.

Where fruit are to be cropped the results indicate sandalwood density must be optimised. For, although there is individual variation and some trees may inherently produce more than others (a function of the genetics of the individual tree), ultimately fruit production is a function of tree size (which may indicate that it is a feature of the genetics of the species). The consequnce of which is that it is the number of trees rather than the amount per tree that can be manipulated.

8.2 COMMUNITY TYPE VERSUS SANDALWOOD DENSITY, SIZE, AND FRUIT PRODUCTION

The aim of this section was to ascertain whether any of the broad groups of community types were superior in terms of sandalwood density, size and total fruit production.

The null hypothesis was that the occurrence of characteristics was independent of community type.

METHODS

Contingency analysis was adopted because it permitted categorization, is unaffected by the uneven numbers across categories and is standardised for presentation. All testing took the form of a two-tailed test, with a Ho = no association between non-sandalwood feature and sandalwood feature, the alternative being the presence of an association. Statistical analysis was by Chi-squared test unless the expected frequency was less than 5 in one of the cells of the table. In which case Fisher's Exact Test was substituted (Zar, 1974).

Four ways of grouping the sites were used so as to construct 2 x 2 contingency tables (Table 24).

The first was to divide the sites on the basis of percent cover of acacias. Only two categories were used $\leq$ 1 % and > 1 % acacia cover. As acacias were present at virtually all sites these tables had the largest number of sites.

The second was to divide the sites on the basis of whether the main dominants were Allocasuarinas (*A. campestris* and *A. huegeliana*) or tree-form Eucalypts (*E. loxophleba* and *E. salmonophloia*).

Allocasuarina sites were #'s 1, 12, 14b, 16, 23, 24, 26, *29, 40, 49, 51, *52, 53, 54, 55, 58, *63, 65, 70, *72. (* = A. campestris)

Eucalypt tree-form sites were #'s 2, 3, *4, *15, *17, 18, *19, *20, *25, 27, *30, 31, 34, 35, *36, 41, *42, *43, *44, 48, 56, 60, 61, 62, 64, 67, 68. (* = E. salmonophloia)

Thirdly, the only coherent minor grouping of sites excluded by this second process was that covering sites dominated by mallee-form eucalypts. So these sites were grouped and made the second row of tables against the combined tree-form Eucalypt and *Allocasuarina* groups outlined above.

Mallee sites were #'s 7, 14a, 22, 23, 38, 39, 66, 69, & 71.

The fourth division was lateritic soils versus non-lateritic soil sites. Lateritic sites were #'s 13, 19, 21, 22, 29, 33, 39, 49, 50 52, 53, 55, 58, 63, 66, & 72. This division for soils was chosen on the basis of sandy-lateritic soils being the most impoverished soil types (section 5 : soil nutrient content).

For all sets of sites low and high ranges were then set for sandalwood parameters. For density (0-30 & 31-60 sandalwood trees / ha), mean tree diameter at 15cm (0-16.67 & $\geq$ 16.68) and fruit production (0-85.00 & 85.01-170.00 scaled as total fruit weight in grams divided by the stem diameter at 15cm in cm; note that scaling was used as total production was shown to be a function of tree size (section 8.1)). For the proportion of trees fruiting in each population the categoriy divisions were 0 - 0.49 and 0.50 - 1.0. The centre points were the medians. See the Appendices for relevant measurements.

RESULTS

The comunity type comparisons are presented in table 24.

The only significant subtable was 24 I (Fisher's Exact Test; 2, 0.05). This indicates that in a comparison of mallee and other community types tree diameters were associated with community type. Observation suggests the mallee had the lower diameters.

None of the other sandalwood parameters was linked to lateritic soils (Table 24 k to m).

DISCUSSION

There was no tendency for eucalypt tree-form dominated communities or *Allocasuarin* densities, size or fruit production per unit diameter of or by sandalwood.

However in a comparison of the teamed former communities with those dominated by mallee-form eucalypts there was an associaiton with sandalwood basal diameter. (In addition, although no significance is attached to the observations, there was a complete absence of high densities or high fruit production at the mallee sites).

This finding is compatible with the earlier finding that sandalwood appears to prefer sites with a low percent cover of dominant species. This is because mallee sites tended to be more densely populated by the dominant. Observation suggests that this situation favours the regular, upright and penetrating habit of the quandong (*Santalum acuminatum*) over the irregular, spreading habit of sandalwood. Another factor which may be involved is the monotypic nature of the stands. At its extreme this may mean the presence of only the mallee form to the exclusion of other species.

Leaf colour relationship with habitat type is considered under section 6.2.

TABLE **24** : COMPARISON OF THE FREQUENCY OF SITES IN HIGH AND LOW CATEGORIES FOR SANDALWOOD DENSITY, SIZE AND TOTAL FRUIT PRODUCTION.

a

	DENSITY (# TREES / HA)	
	0 - 30	31 - 60
ALLOCASUARINA DOM. SITES	15	4
EUCALYPTUS DOMINATED SITES	20	7

b

	0 - 30	31 - 60
ACACIA SP COVER ≤ 1 %	15	4
ACACIA SP COVER > 1 %	45	8

c

	MEAN TREE DIAMETER AT 15 CM	
	0 - 16.67	≥ 16.68
ALLOCASUARINA DOM. SITES	10	9
EUCALYPTUS DOMINATED SITES	17	10

d

	0 - 16.67	≥ 16.68
E. SALMONOPHLOIA SITES	9	2
OTHER EUC. & ALLOCAS. SITES	18	17

e

	0 - 16.67	≥ 16.68
ACACIA SP COVER ≤ 1 %	12	7
ACACIA SP COVER > 1 %	31	22

f

	FRUIT (GM) / DIAMETER (CM)	
	0 - 85.00	85.01 - 170.00
ALLOCASUARINA DOM. SITES	8	5
EUCALYPTUS DOMINATED SITES	15	6

g

	0 - 85.00	85.01 - 170.00
ACACIA SP COVER ≤ 1 %	10	3
ACACIA SP COVER > 1 %	39	10

ALLOCASUARINA SITES = A. HUEGELIANA + A. CAMPESTRIS
EUCALYPTUS SITES = E. LOXOPHLEBA + E. SALMONOPHLOIA

TABLE 24 CONT'D : COMPARISON OF THE FREQUENCY OF SITES IN HIGH AND LOW CATEGORIES FOR SANDALWOOD DENSITY, SIZE AND TOTAL FRUIT PRODUCTION.

h

	DENSITY (# TREES / HA)	
	0 - 30	31 - 60
EUCALYPT & ALLOCAS. SITES	35	11
MALLEE SITES	9	-

i

	MEAN TREE DIAMETER AT 15 CM	
	0 - 16.67	≥ 16.68
EUCALYPT & ALLOCAS. SITES	27	19
MALLEE SITES	9	-

j

	FRUIT (GM) / DIAMETER (CM)	
	0 - 85.00	85.01 - 170.00
EUCALYPT & ALLOCAS. SITES	23	11
MALLEE SITES	2	-

EUCALYPT. & ALLOCASUARINA SITES = E. LOXOPHLEBA + E. SALMONOPHLOIA + A. HUEGELIANA + A. CAMPESTRIS

MALLEE SITES = OTHER EUCALYPTS OF MALLEE FORM

TABLE 24 CONT'D : COMPARISON OF THE FREQUENCY OF SITES IN HIGH AND LOW CATEGORIES FOR SANDALWOOD DENSITY, SIZE AND TOTAL FRUIT PRODUCTION.

k

	DENSITY (# TREES / HA)	
	0 - 30	31 - 60
LATERITIC SOILS	15	1
NON-LATERITIC SOILS	44	12

l

	MEAN TREE DIAMETER AT 15 CM	
	0 - 16.67	≥ 16.68
LATERITIC SOILS	9	7
NON-LATERITIC SOILS	34	22

m

	FRUIT (GM) / DIAMETER (CM)	
	0 - 85.00	85.01 - 170.00
LATERITIC SOILS	9	2
NON-LATERITIC SOILS	31	11

n

	PROPORTION OF TREES WITH FRUIT	
	0 - 0.49	0.50 - 1.0
LATERITIC SOILS	4	7
NON-LATERITIC SOILS	14	27

TABLE 24 : CONT'D COMPARISON OF THE FREQUENCY OF SITES IN HIGH AND LOW CATEGORIES FOR SANDALWOOD DENSITY, SIZE AND TOTAL FRUIT PRODUCTION.

o

	PROPORTION OF TREES WITH FRUIT	
	0 - 0.49	0.50 - 1.0
ALLOCASUARINA DOM. SITES	5	8
EUCALYPTUS DOMINATED SITES	9	12

p

	0 - 0.49	0.50 - 1.0
EUCALYPT & ALLOCAS. SITES	14	20
MALLEE SITES	2	2

q

	0 - 0.49	0.50 - 1.0
ACACIA SP COVER $\underline{-}$ 1 %	5	8
ACACIA SP COVER - 1 %	13	26

8.3 LOCAL WATER REGIME AND SANDALWOOD DENSITY, SIZE, LEAF COLOUR AND FRUIT PRODUCTION

The aim of this section was to determine whether factors which influenced the localized water regime affected sandalwood density, size, production and leaf colour.

METHODS

Two-way contingency tables were formed. With each of the sandalwood features of density, tree diameter, fruit production and leaf colour being divided into two categories as defined in the previous section. Only those populations which bore fruit were included in the production contingency tables. Localized influences on soil water were delineated as the common divisions for Tables 25, 26, and 27. Soil moisture and bulk density were assigned median points of 3% and 1.43 respectively and Appendix 4 was used to assign sites to each of the categories. Water-gaining tendency was assigned to a site if it had two or more or the following features : it was in a drainage embankment, flowline or sump; its drainage was fair or poor; and/or it was in an alluvial situation (see Appendix 4).

RESULTS

There was no association of any of the measures which may have reflected the localized water regime with any sandalwood population feature on the basis of a two-tailed test (Tables 25, 26 & 27; see contingency analysis, methods, previous section).

However a one-tailed Fisher's Exact Test showed high density to be deficient for low soil moisture sites ($p = 0.0506$).

TABLE 25 : COMPARISON OF THE FREQUENCY OF SITES WITH LOW AND HIGH SOIL MOISTURE.

	SOIL MOISTURE AT 10 CM	
	LOW	HIGH
	$<3\%$	$\geq 3\%$
LOW SANDALWOOD DENSITY	32	28
HIGH SANDALWOOD DENSITY	2	8
LOW DIAMETER AT 15 CM	19	24
HIGH DIAMETER AT 15 CM	15	14
LOW PROPORTION TREES+FRUIT	5	14
HIGH PROPORTION " "	18	17
LOW FRUIT PRODUCTION/TREE	16	26
HIGH FRUIT PRODUCTION/TREE	4	7
LIGHT LEAF COLOUR (3111)	16	23
DARK LEAF COLOUR (31124014)	15	14

TABLE 26 : COMPARISON OF THE FREQUENCY OF SITES WITH LOW AND HIGH SOIL BULK DENSITIES.

	BULK DENSITY AT 10 CM	
	HIGH	LOW
	1.92 – >1.43	≤1.43 – 0.93
LOW SANDALWOOD DENSITY	44	14
HIGH SANDALWOOD DENSITY	11	1
LOW DIAMETER AT 15 CM	4	40
HIGH DIAMETER AT 15 CM	11	17
LOW PROPORTION TREES+FRUIT	5	14
HIGH PROPORTION " "	5	30
LOW FRUIT PRODUCTION/TREE	6	35
HIGH FRUIT PRODUCTION/TREE	1	11
LIGHT LEAF COLOUR (3111)	8	31
DARK LEAF COLOUR (31124014)	6	23

TABLE 27 : COMPARISON OF THE FREQUENCY OF SITES WITH LOW AND HIGH WATER-GAINING CHARACTERISTICS.

	WATER-GAINING TENDENCY LOW	WATER-GAINING TENDENCY HIGH
LOW SANDALWOOD DENSITY	41	18
HIGH SANDALWOOD DENSITY	5	6
LOW DIAMETER AT 15 CM	33	10
HIGH DIAMETER AT 15 CM	15	14
LOW PROPORTION TREES+FRUIT	16	3
HIGH PROPORTION " "	22	13
LOW FRUIT PRODUCTION/TREE	25	16
HIGH FRUIT PRODUCTION/TREE	10	2
LIGHT LEAF COLOUR (3111)	30	10
DARK LEAF COLOUR (31124014)	15	13

DISCUSSION

The localized water regime, as expressed by the three separate features, did not appear to be a cheif determinant of sandalwood density, size, fruit production or leaf colour.

Such a finding may indicate that all trees, regardless of their situation, are adequately supplied in terms of water by their hosts. The only indication of any limitation was of soil moisture on high density. Such a link could be enforced by a direct link of sandalwood or of its hosts to soil moisture.

8.4 UNDER-CANOPY SANDALWOOD LITTER

The aim of this section was to determine if there was any link between habitat and the litter produced by the sandalwood study populations.

METHODS

The modal cover, depth and composition(the proportion of leaves, nuts and weed species) of litter under the canopies of sandalwood trees was described for each population.

RESULTS

Most trees in all the populations had an obvious litter component under the canopy.

The depth and percent cover of the litter is summarized in Table 28.

TABLE 28 : LITTER DEPTH AND PERCENT COVER UNDER THE CANOPIES OF SANTALUM SPICATUM TREES OF WHEATBELT STUDY SITES.

		------------ PROPORTION ------------ (% COVER BASIS)		
DEPTH	% COVER	SANDALWOOD LEAF	: SANDALWOOD NUT	: WEED SPECIES
mode	mode	average	average	average
1cm	80%	7.24	1.22	1.39
range	range	SD	SD	SD
0.5-5.0cm	3-100%	2.55	1.61	2.35

The majority of the under-canopy ground was covered by litter; with the majority of populations exceeding the mode in Table 23. Leaf litter was the main constituent of the total under-canopy litter. Weed species were mainly exotic species such as *Avena fatua*, *Erhartia calycina*, *Hypocheris glabra*, and *Romulea rosea*. They could form thick mats which obscured the lower litter layer, this was particularly so on the verge of reserves and generally the wetter areas (more south and west). The native species which utilized the under-canopy space included the climbing grass *Stipa elegantissima*, *Dianella revoluta*, and some species of the Chenopodiaceae such as *Enchylaena tomentosa* (in the eastern regions) and *Rhagodia* spp, representatives of other families made occasional appearances.

No pattern which matched those of fruit-size or leaf colour was evident in litter.

DISCUSSION

A significant litter cover under the sandalwood canopy was a feature of most populations.

This was frequently capitalized by weed species. In line with what was noted in the soil section the litter appeared to be a resource on which they thrived. This was particularly so in the water gaining areas.

This provision of a nutrient-rich nucleus presents a reserve management problem. At its simplest the removal of the litter should remove the weeds. However it also removes mulching for seedlings and established trees, and also removes protective cover for seedlings.

8.5 THE RELATIVE INFLUENCES OF WATER & NUTRIENTS ON SANDALWOOD

In practice it is difficult to separate the influences of water and nutrients on sandalwood. In the Australian arid environment water availability may limit nutrient availability. Such an effect was noted at Durokoppin reserve in the wheatbelt. Where annuals only developed 3 years after fertilization of an area after sufficient rain had fallen (Hobbs and Atkins, 1991). Similarly the occurrence of sandalwood in the Pilbara along watercourses could be ascribed to both a better nutrient regime and better soil structure for water penetration and soil moisture (author's observation).

Observations which suggest some importance to water include the limited occurrence of sandalwood in the wandoo understorey where the sub-soil clay component heightens seasonal water stress (Havel, 1976; author's observations on eucalypt water potentials). Secondly large size appeared to be linked to increased water availability. One very large tree was present in the population at sites 3, 16, 26, and 33. Site three was between two slopes alongside a drainage culvert. Site 16 in a main drainage line from a granite monolith under *Allocasuarina huegeliana* woodland. Site 26 was on river bank sand. Site 33 was on sand in an *Ecdeiocolea* sedgeland which may indicate a perched watertable.

The general avoidance by sandalwood of situations where inundation or osmotic stress may occur also points to the influence of water. All these factors point to extreme water availability situations, whether a surfeit or a deficit, being the exception rather than the rule for sandalwood.

Other factors suggest water is generally in adequate supply. First, as noted above, the occurrence of sandalwood with a range of species should give access to a range of water extraction strategies. This is supported by the observation that sandalwood is always cool to the touch inland, in contrast to other plants in the vicinity (Mitchell and Wilcox, 1988). This indicates that the tree wastes water at the expense of its hosts. Second the ability to fix shell diameter suggests that water (and carbon dioxide) are readily available to make carbohydrate (this report). While within the wheatbelt the apparent predominance of the broader leaf form may reflect greater climatic water availability. In short it appears that throughout its main habitats of occurrence in the wheatbelt water is not the main limiting factor for sandalwood.

There is strong circumstantial evidence which points not only to nutrient constraints on wider distribution but on sandalwood production within preferred habitat types. Clearly sandalwood avoids the nutrient poor deep sands and heaths. Similarly sandalwood's avoidance of pure stands of species (apart from acacias) suggests that mixed hosts may be linked to adequate resources. Acacias are linked with sandalwood leaf colour suggesting a primary role in nutritional status. The percent cover of acacias is linked to shell and flesh weight. Finally it is in fruit production that resource (nutrient) availability is implicated as a primary limiting factor. It is implicated through the intermittent fruiting, which indicates the need to acquire and store resources over time to compensate for their scarcity at any one time. From the current work it is clear that it is tree size which determines the quantity of fully-formed fruit which a tree produces; where rainfall only influences the incompletely-formed fruit which represent a low-quality and smaller investment to the tree. That is, the incompletely-formed fruit have aborted kernels and therefore l investment of oils, protein and sugars.

8.6 WOODGRAIN OBSERVATIONS

I. Carmichael (Sandalwood harvester - Ravensthorpe) noted several trends in wood type.

Regionally the wood is fine-grained inland and coarse-grained on the coast. (Apparently reflecting rainfall). This is matched by the greater inland oil content noted above.

Granite has the effect of causing the tree to produce a wider grain.

Water and/or greenstone soil cause a darkening of the grain.

8.7 WOOD OIL OBSERVATIONS

I. Carmichael also noted that inland wood had a higher oil content than wood from the Ravensthorpe area.

8.8 SPROUTING OBSERVATIONS

It was reported in Loneragan (1990) that sprouting was noted at Bendering in 1921. Strong regeneration typified large trees after fire and after cutting at ground level.

In the current work resprouting from the base was noted at site 4 after cutting, at site 65 after a tree had blown over and at site 66 after fire in mallee.

Such observations suggest that the central western and south-western wheatbelt may be intermediate between the poor sprouting response in the goldfields and the good response at Shark Bay (P. Ryan pers. com.).

9 GERMINATION

The aim of this section was to test if germination of seeds was related to climatic, individual tree or habitat features.

METHODS

Germination was attempted in preference to viable staining after consultation with S. Wijesurya on the efficacy of tests of Indian sandalwood (Santalum album) and in light of germination having historically been the main mode of investigation and therefore comparison (Loneragan, 1990).

Only fully-formed fruit were used in germination trials.

Fruit from each tree were treated in two ways. In one treatment five were cracked open in a vice, shelled, and were only accepted if there was no obvious damage and sealed in a snap-lock plastic bag with 2mls of sterilized, deionized, water. In the second treatment, 35 nuts were defleshed but left with their shells intact, and sealed in snap-lock plastic bags with 20mls of sterilized, deionized, water and 5 mls of Ridomil (by Ciba-Geigy; 6 g/15 l). The latter approach was adopted to avoid any possible damage due to compression of the kernel as a consequence of cracking the nuts. Treatments where contamination was evident were disregarded for analysis.

Seeds were stored in the dark and were subject to ambient temperatures for Kalamunda. The relevant maxima and minima were :

	April	May	June		April	May	June
Maximum				Minimum			
High	34	25	19	High	21	15	14
Low	14	15	12	Low	9	7	6
Average	24.4	19.1	16.1	Average	13.0	10.7	9.3

Trials started on the 2nd of April 1991 and final counts were taken on the 30th of June 1991. This exceeded the 16 days (shelled) and 36 days (with shells) found adequate for germination at Narrogin (Loneragan, 1990).

A germinant was considered to be where a radicle could be seen to be protruding from the endosperm.

Germination was expressed as a proportion of the total nuts in each trial (namely #/5 for kernels & #/35 for whole nuts) for each tree. The total number of trees involved, combining both shelled and unshelled nut trials, was 120.

For analysis the proportion of germinants per tree was correlated against rainfall for the preceding year (Jan 1990 - March 1991), average rainfall, number of seedlings per tree, sandalwood density (# trees/ha), tree diameter at 15cm, the # of days in the formative season at or over 30oC and at or over 35oC, the # of days in the preceding winter at or under 5oC and at or under 2oC *, and the percent cover of acacias, casuarinas and eucalypts respectively. Fruit component features were also regressed against whole nut germination proportions. Germination was treated as the dependent variable and transformed using the arcsin transformation for proportions ($X' = \arcsin(\text{square root } X)$; Zar, 1974). In all cases the number of dependent observations available for analysis exceeded 70.

TABLE 29: PROPORTIONS OF GERMINANTS IN POPULATIONS OF NUTS FROM INDIVIDUAL TREES WHICH WERE WITH OR WITHOUT FLESH OVER PART OF THE SUMMER OF MATURATION.

INTACT NUTS

	PROPORTION OF GERMINANTS			
	0.000-0.249	0.250-0.499	0.500-0.749	0.750-1.000
# OF SAMPLES WITH NO FLESH	10	3	1	0
# OF SAMPLES WITH FLESH	37	37	13	1

BARE KERNELS

# OF SAMPLES WITH NO FLESH	3	0	5	3
# OF SAMPLES WITH FLESH	22	14	14	28

TABLE 30 : THE PROPORTION OF GERMINATION PER TREE FOR ALL TREES PRODUCING FRUIT IN THE 1990/1991 SEASON.

		GERMINATION				GERMINATION	
SITE	TREE	KERNEL	NUT	SITE	TREE	KERNEL	NUT
3	lying	0.75	0.03	34	e5	0.67	0.33
3	split	-	0.03	35	1 small	0.2	0.5
5	2 wandoo	0.8	0.12	35	1 large	0.75	0.43
7	mixture	-	0	35	2	0	0.47
9	mixture	1	0.3	36	1	0.4	0.42
11	1	-	0.2	36	3	0.75	0.17
11	junction	0.2	0.03	37	1	-	0.5
11	*	0.4	0.23	37	2	0.5	0.37
12	100m south	0.5	0.27	39	2	1	-
12	1	-	0.1	40	1a	0	0.07
12	2	-	0.13	41	330m	-	0.05
12	^	0.25	0.37	41/42		0	0
12	ridge	1	0.17	42	2	0.75	0.13
12	2	0.2	0.4	43	2a	0.5	0
13	1	1	0.23	43	3	0.25	0.23
13	3	1	0.3	44	2	0.6	0.04
13	3a	0.4	0.3	45	1	0.33	0.6
14	4	0.4	0.47	45	2	0.5	0.13
15	1	0.75	0.33	45	3	0.2	0.6
15	4a	0.75	0.33	47	1	1	0.17
15	5	1	0.2	47	3@	0.75	0.03
15	6	1	0.03	47	2.6	1	0
16	1	0	0.07	47	1.7	0.6	0.1
16	2	0.5	-	47	1.9	0.4	0
16	4	-	0.13	48	1	0.2	0.27
17	1	-	-	48	2	0.2	0.31
17	2	-	0.13	48	3	1	0.1
17	3	0.75	0.2	49	1	0	0.22
17	4	1	-	49	1b	0.5	0.3
18	1	0.5	0.57	49	2	0.8	0
18	2 1st	0.5	0.13	50	1	0.8	0.13
18	2 2nd	1	0.27	51	2	0.2	0.4
18	2 3rd	0.5	0.63	51	b	0	0.41
18	2 4th	-	0.57	52	1	0.6	0
18	1.8m	0.5	0.43	52	2	0.67	0.17
18	1.9m	-	0.37	53	1	1	0
19	1	0	0.57	53	2	0.5	0.47
19	3	-	0.1	54	2	0.4	-
20	3	0.33	0.06	54	3	-	0.37
23	1	-	0	54	7	0.5	0.17
23	b new	-	0	55	4	1	0.63
23	b old	-	0.86	55	5	1	0.17
26	large	-	0	56	3	1	0.4
24	last years	1	1	57	1	1	0.3
28	1	0.67	0.1	58	1	0.2	0.63
28	2	0.2	0.37	59	2	1	0.2
28	5	0.33	0.4	59	3	0.5	0.23
30	1	0	0.13	60	1	0.2	0.33
30	2	0.5	0.4	60	2	0.2	0.
30	3	0	0.03	60	3	0.4	0.41
30	4	1	0	60	4	0.25	0.5
31	1	-	0	61	1	-	0.77
31	2	1	0.37	62	group 1	-	0.2
32	2	-	0.03	62	group 2	-	0.06
33	1	0	0.2	63	1	-	0.2
33	2	-	0.28	65	1	0.25	0.4
33	3	0	0.4	65	2	0.6	0.57
34	last years	1	0.33	68	1	0	0.7
34	a12	0.75	0.63	68	2	-	0.33
34	b12	0	0.2	71	1	1	0.33

As some of the trees' nuts were predominantly fleshless when collected a secondary contingency test was conducted comparing the proportion of germination in fleshless samples to that in fleshed nuts. This was done for the intact fruit and for the bare kernels. Both subtables were analyzed as 2 x 2 contingency tables with the proportion of germinants categorised as being either 0 - 0.499 or 0.50 - 1.0.

RESULTS

Three variables showed a relationship with germination (of kernels in shells). One positive correlation was tree diameter at 15cm. (Proportion of germinating nuts = 2.07 + 0.02 (tree diameter at 15cm); r=0.1951; p=0.049). The others were negative correlations of kernel diameter and kernel weight. (Proportion of germinating nuts = 3.95 - 1.40 (kernel diameter cm); r= -0.3233; p=0.027). (Proportion germinating nuts = 6.65 - 3.07 (kernel weight gm); r= -0.3429; p=0.018).

No other significant correlations were found for transformed germination proportions.

There was no significant effect of coat absence during late summer on the proportion of germinating nuts per sample (Table 29;Chi Square Test; 2, 0.05). The proportion of germinants per tree are listed in Table 30.

DISCUSSION

The weak correlation of the proportion of germinants on tree size may reflect the tree's "competence" to produce viable fruit; its maturity.

The negative correlations of germination on kernel size and weight suggests that large size is not a germination advantage (under the conditions pertaining in these trials) for fully-formed fruit. In fact germinability declines with kernel size increase. It also suggests that the larger shelled populations to the west, north and south of the survey area do not produce the largest proportion of germinants. The implication may be that these peripheral areas are suboptimal for competent seed production. Certainly they are at the edge of the specie's distribution and of the cooler and wetter southwest.

This pattern is corroborated by Brand (1991) who found sandalwood germination was low near the coast (10%), intermediate in the wheatbelt (40%) and high inland (70 - 90 %).

The absence of any other trends of germination against the rest of the range of variables including rainfall, tree density (included as possibly reflecting cross-pollination potetnial), per annum days of extreme temperature, and dominant species cover, may be attributed to three factors of ascending relevance. The first may have been the sample size being too small. This was unlikely as the smallest sample size was 74 trees. Second a "behavioural" feature of the trees, such as biennial bearing, may have influenced viability and therefore germination. Thirdly nutrient sinks in hosts and the soil may be more important to viability than the variables tested.

All these factors could be addressed. The first by increasing the sample size greatly. The second by making repeated visits to the same trees and assessing their performance over a series of years. The third by analysing soils for nutrients and by assessing potential host vigour and performance (in terms of leaf and fruit production during the relevant growing/nut production season) and assessing the size and position of potential hosts (the latter would be more specific and less variable than generic % cover estimates). Another factor which could be addressed would be the timing of germination trials. For, although early autumn germination is effective in the field, optimal timing may have been in the warmer months from January (Loneragan, 1990). Also relative timings of maturation and the interval to germination testing may have differed. This could only be corrected by frequent visits to assess when fruit matured, collect them at that time and attempt germination a prescribed time from collection.

Note that the absence of any correlation of naked kernel germination and intact nut germination may be attributed to three possible causes. One is some inhibitory effect of the fungicide. Another shell-enforced dormancy. The third some effect of cracking the shell, or of actual shell removal, or both upon the kernel. Note that in field trials the shells are only cracked, and the best method is to soak the defleshed nuts overnight and then let the drying out crack them. In a trial at Narrogin the shelled kernels had lower germination (62%) than those with shells (80%) (Loneragan, 1990). Similarly field trials at Geraldton have used 4 cracked nuts per host to assure one germinant/establishment (Pat Ryan pers. com.).

Further testing is indicated. This could be in conjunction with field planting trials. Preferably field trials could be conducted on the same seed stock at two different latitudes within the wheatbelt.

The nuts showed no significant difference in germination between those that had flesh over summer and those that did not. This must be qualified as the length of time each batch of fleshless nuts had been in that condition was unknown. However it is likely that the fleshless nuts had experienced extreme summer temperatures. This was because of extremes occurring in the 2 months preceding collection and also because nuts of populations without flesh appeared weathered indicating that they had been fleshless for a number of weeks. Therefore it appears that there was no insulative advantage to flesh persistence around the nut.

10 RECOGNISING PHENOTYPES OR PROVENENCES

To select seed which may be different in provenance trials the results suggest that it should be selected from the north, south, western mid-west and eastern mid-west of the study area. (Figure 2 may be used as a guide in this regard). A disparity between the former two and the latter two in fruit size should result. It is unlikely to be a clear-cut disparity because observation suggests the variation within populations may cause a degree of overlap.

The absence of any correlates of genetics or oil content preclude determination of any other suitable selection pattern.

However, if the trend to very low oil content in the Ravensthorpe region (I. Carmichael pers. com.) is an indication, the larger fruited types from the wetter portions of the survey area may not be as desirable as those from the mid-west eastern section.

11 POTENTIAL LEGACIES OF TROPICAL ORIGINS

The order to which *Santalum spicatum* belongs, the Santales, has its stronghold in the tropical and subtropical regions of the world. While the members of the family Santalaceae are similarly distributed with best development in relatively dry areas (Takhtajan, 1986).

If *Santalum spicatum's* origins were tropical then some residual features, either physical or behavioural might have been expected to reflect such origins. For example *Santalum lanceolatum*, which has a tropical and eremaean distribution, has two fruit sets. In the "wet" (January-March) and in the "cool" (May-June) (Lands, 1987).

For the current study it was reasoned that summer rainfall influenced features may reflect such origins. For *Santalum spicatum* this may take the form of growth during summer.

Incompletely-formed fruit numbers were independent functions of long-term rainfall and of days at or above 30 oC (a negative relationship). That the first was positive indicates increasing (winter) rainfall toward the periphery of the species range is not ideal. While the declining number of warm days was clearly also not ideal. Both may conform to a sub-tropical preference for the species.

Similarly the apparent decline in competence to produce germinable seed at the boundary of the cool/wet southwest may reflect a sub-tropical preference.

Mast, or delayed, fruiting may be a, partial, tropical legacy. As it persists with the relative surfeit of water near the wetter deep southwest zone.

Finally the strong link with acacias and their nitrogen fixation ability has tropical links. For, although acacias are widespread and predominant throughout much of the arid and semi-arid areas that make up the range of Australian sandalwood, overwhelmingly these acacias have strong tropical affinities (Maslin and Hopper, 1982). It is therefore possible that the acacia-sandalwood relationship developed in the tropics before more recent radiation and speciation in acacias. Such a thesis may imply that *S. acuminatum* is a more recent development than *S. spicatum*. As it has adapted to the predominance of heath-forms and Proteaceous and Myrtaceous species that have been engendered by the Tertiary climatic oscillations in Australias recent geological history.

The divergence of *S. acuminatum* from potential tropical origins in recent geological history is matched by the adaptation of *S. spicatum* to semi-arid to arid conditions in the predominantly winter rainfall southern half of the western portion of the Australian continent. That is, under tropical conditions summer rainfall prevails, whereas the distribution of *S. spicatum* is now below the line of summer and winter rainfall (Figures 10 & 11). In each species the respective moves to a different host resource and a different rainfall regime may represent physiological changes.

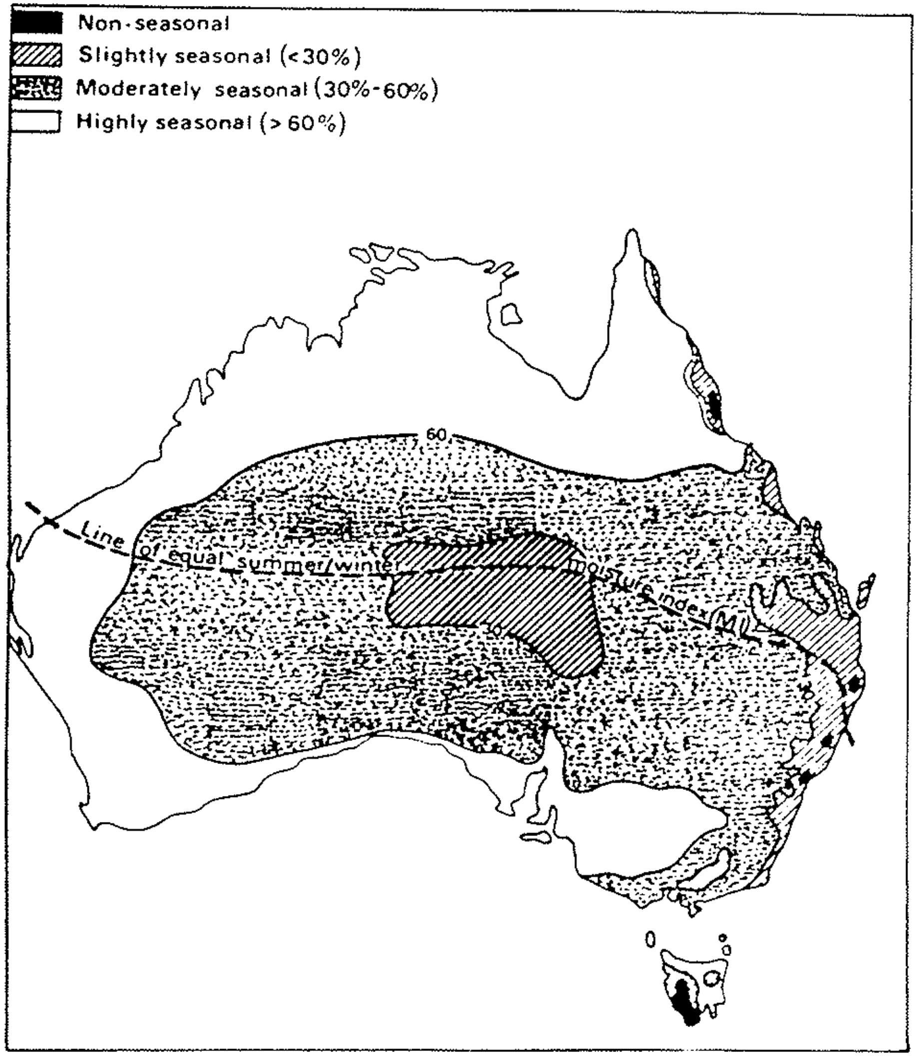


FIGURE 10 : THE POSITION OF THE EQUAL SUMMER/ WINTER RAINFALL BOUNDARY IN AUSTRALIA. (NIX 1982)

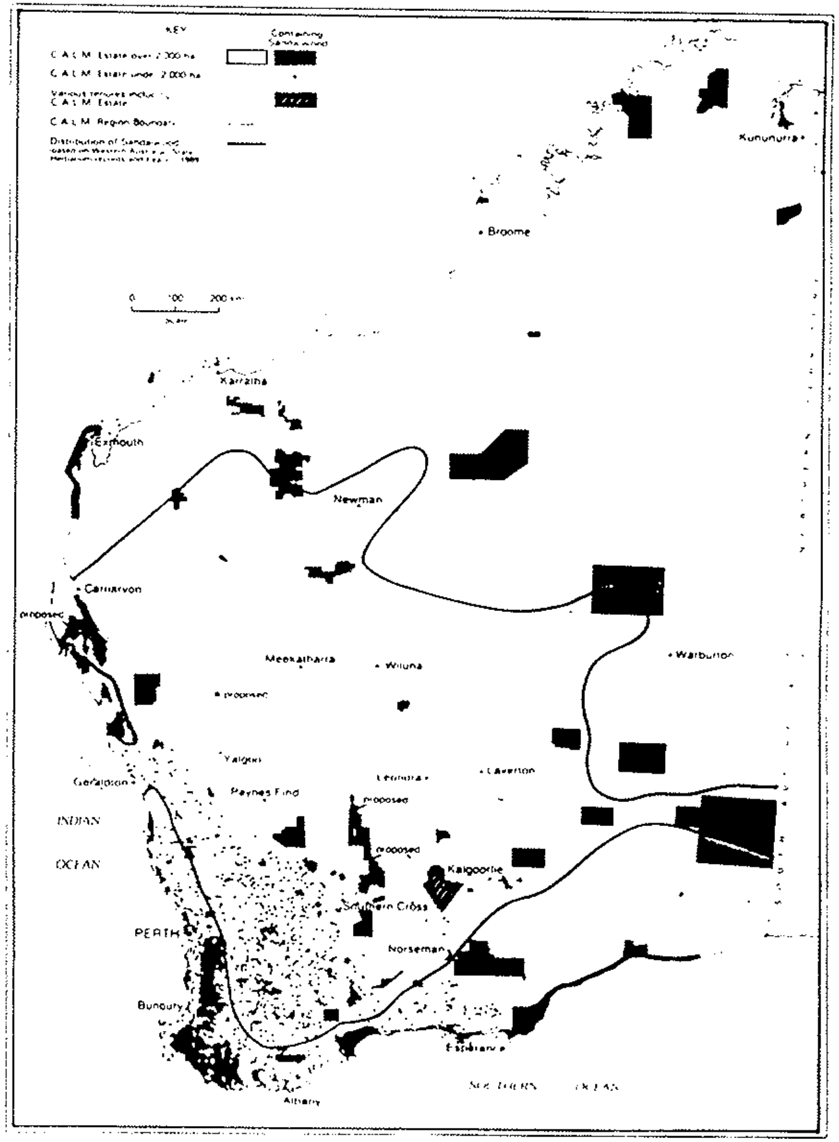


FIGURE 11 : THE DISTRIBUTION OF SANTALUM SPICATUM. (LONNERAGAN 1990)

12 OBSERVATIONS AND SPECULATION : TOWARDS A MODEL

In this section sundry evidence is cross-related so as to reconstruct some aspects of the specie's biology as it may have been before the disruption of the fully integrated ecosystems of which it was part.

Santalum spicatum has attributes which conform to a "k strategist" (Pianka, 1970). The three major characteristics are the apparent longevity of the individual, a capacity to delay or forego reproduction and the relatively large investment in each progeny.

Each of these characteristics would appear to be multifacetted.

Facets which contribute to longevity are the wood oil which observation suggests is an effective termite deterrent. Dead sandalwood, whether a whole or part tree, persists and is not subject to the attack of other species. This is abetted by the contribution of another facet - increased wood grain density in the more arid regions. That the oil may have an adaptive significance is emphasized by the presence of very similar analogues in five other plant species, all from different families, but all of which are pan- to sub-tropical and may encounter termites (Kuijt, 1969).

Longevity may also be enhanced by the apparent self-mulching noted above. Note that it could have a water, as well as nutrient, conserving effect.

Similarly it is clear from this work that an element of "hedging bets" is engendered in the parasitic strategy of the species. Indications are that the plants are buffered from the soil environment, by their hosts.

For instance, although the preference throuhout the study range was for acidic to neutral shallow soils there were instances where limestone occurred at depth. This suggests that the hosts at the latter sites may compensate the parasite for a non-ideal soil pH and therefore nutrient avaiability characteristics. Similarly the absence of any marked trend related to a preferential localized water regime conforms to host buffering (it may well be that any climatic correlations are features of the hosts as much as they are of the sandalwood). If how this may be achieved is considered, the hosts may be placed in compartments on the basis of their most likely major contribution. Providing nitrogen, by virtue of their nodulation, would be the clearly associated acacias and allocasuarinas. Providing cheifly deep water, by virtue of well developed taproots, would be the eucalypts. While a minor contribution of phosphorus would be made by the Proteaceous plants by virtue of their proteoid roots. All of the above host groups, and other groups, may contribute to general nutrition, and to the water pool, the latter probably from extraction of soil moisture. In other words sandalwood could use the full range of root morphologies within contact. All the preceding facets contribute to persistence in the face of adversity, and a capricious climate, for no one facet need be relied upon. This equates to longevity. Contributions from mychorrhizal symbionts would only increase the "bet hedging". (For details on root forms see Lamont (1984) and Dodd et al (1984)).

With longevity comes the ability to forestall reproduction, to wait for suitable conditions in the face of climatic unpredictability and to store resources in the face of poor resource availabilty. This is evident in the intermittent reproduction of sandalwood. Other evidence points to these factors preventing nut formation for some of the trees in this study. At Kalgoorlie in the late 1960's drought was implicated in inhibiting crown recovery, flowering and seed set for up to 2 years after average rainfall reinstatement (Loneragan, 1990). Inhibition of fruiting may also be a manifestation of phosphorus deficiency in the plant as retarded development (especially blooming and ripening), and poor flowering and fruiting are symptomatic of this (Davidescu, D. and Davidescu, V., 1982). Over time retardation may well develop into gradual nutrient acquisition over several seasons until a threshold quantity (probably a function of tree size) is stored and flowering and fruiting can proceed.

In practice these functions of aridity would be difficult to distinguish from the tropical phenomenom of mast fruiting and the two may be intertwined in the expression of intermittent production in sandalwood. Mast-fruiting is the production of large amounts of fruit in synchrony at irregular intervals. It is a device for protection from predators and ensures that predator numbers fall to low levels between crops. Building up enough resources as reserves for an enormous mast-fruit may take years. Several animal seed dispersed species are mast-fruiters (Wilson, 1983).

There is evidence that sandalwood used/uses animal vectors in the reproductive process. When flowering there is a strong faecal odour with definite undertones of the wood oil fragrance. This brings a host of indigenous flies which may benefit from nectar production (authors observations). Such a strategy reflects resource conservation. For the use of the modified volatile essence may be chemically cheap while ensuring that the flowers can be small, indistinctly coloured and nondescript in shape and thus also a minimal investment in terms of resources. In line with the apparent mast-fruiting features is the observation of a wheatbelt farmer that the medium-sized marsupial, the boodie (*Bettongia leseur*), was involved in the distribution of the fruit of sandalwood. Its behaviour with sandalwood fruit was very similar to that of the northern hemisphere squirrel. Consuming some nuts and caching others by burying them. This lead to dispersal and "planting" of seed (Battye Library). Similarly, in the northwest, there was a clear association of old stick-nest rat (*Leporillus ? apicalis*) nests with sandalwood trees (author's observation).

There are three possible consequences of vector seed dispersal. First progeny may escape from disproportionate mortality near parent plants. Second they may colonize open habitat. Third the progeny may be directed to rare special microhabitats suited to seedling establishment; note that this is important when the seed is large as in sandalwood (Murray, 1986).

To gain dispersal advantages such as the above the plant must trade against loss of progeny and so attempt to maximise the former and minimise the latter. It has already been noted that mast fruiting is one device for reducing the effect of predators. Another defence is to physically protect the seed. Sandalwood may do this in three ways. First the flesh may act as a sacrificial resource. The author observed that the flesh was consumed by termites. It is also possible that it provides a low quality resource for emus (while the shell might be useful in the crop for grinding). Emus were observed to distribute nuts at Dryandra (Lonneragan, 1991). Second the shell provides mechanical protection. Third the presence of oils in the seed which have a cumulative disruptive effect on mammalian digestion would deter over consumption by vectors capable of cracking the shell (Kallis and Hernadi, 1991). Of course protection is unlikely to be the only selective advantage to these features. So that a hard shell that prevents water penetration or oils that retard active seed metabolism until they are internally consumed could also function as dormancy enforcing mechanisms.

Clearly a large seed would be attractive to a potential vector and so could confer advantages to the species; however there are other advantages to large seeds. Seed size affects seedling size at emergence, a large seed may give a seedling a size advantage up to thirty days after germination. In addition large size is frequently associated with an ability to emerge from a greater depth (important if the seed is buried by a vector). Similarly large seeds give an advantage for establishment in shade and are more common in late successional species (Wilson, 1983). In the Australian context the large size of *Santalum spicatum* seeds when compared with the Indian sandalwood (*S. album*) may be related to the need to cope with poor soil nutrients. This may have its counterpart in the fact that the poor Australian soils result in a lower wood oil content in the Australian sandalwood than in the Indian version. Of course it is possible that another influence on the nut size difference may be the different Indian and Australian faunal complements.

Large-seededness could also be another feature associated with longevity of the parent as large seeds are generally expensive to produce. They require long development times and so also promote negative feedback on the interval between crops (Wilson, 1983).

Comparison with the quandong (*S. acuminatum*) places the features discussed so far in perspective.

As outlined under soil nutrients above the quandong apparently tolerates more nutrient deficiency than Australian sandalwood. As a consequence it produces fruit less often, appears to not store the aromatic wood oil, has leaves that are less susceptible to insect attack and readily utilizes the (?lower quality) resource represented by Myrtaceous and Proteaceous plants. In line with the last feature it generally has a shrub habit, though with a single straight stem, that may be better suited to getting up amongst dense shrub-form competition (author's observation).

In terms of dispersal the distinct morphological difference between the quandong and sandalwood shell is striking. It could be speculated that the marked ridging and convolution of the quandong shell would make it a better candidate as an emu crop grindstone than the smooth sandalwood shell. Such a preferential selection could be enhanced by the greater desirability of the flesh of the quandong. Certainly preferential selection of the quandong fruit may explain its relatively wide-ranging distribution as a consequence of the nomadic wanderings of emus. The resultant increased likelihood of encountering a nutrient poor situation would tend to reinforce the need to cope with such a situation in the quandong. In this context the high salt tolerance of the quandong may also be significant (Walker, 1989). In contrast the smooth sandalwwod shell with its poor quality flesh seems more likely the target of marsupials capable of cracking the shell to consume the kernel. More frequent association with mammalian vectors would mean a localized seed distribution and a greater likelihood of encountering the same habitat as that of the parent. Such a scenario is compatible with the more stringent nutrient requirements of sandalwood noted under soil nutrients above.

13 CONSERVATION NEEDS

There are several conservation issues related to sandalwood.

First is the weed congestion under many of the sandalwood trees. The effects of competition on the germination and establishment of sandalwood are unknown. As are the counterbalancing factors such as shading and protection from grazing.

Second is predation of seed and seedlings. At site 2 it was noted that some of the previous seasons nuts had been consumed by mice. This was the only site where this was observed. At many sites it was clear that seedlings had been grazed. Sheep clearly played a part on the private properties while rabbits probably grazed plants on reserves.

Third is the predation of hosts. The grazing of *Acacia acuminata* by sheep was evident at sites 1 and 2 at the south-west of the range. Both this and the former point indicate that fencing may be required for outlying privately-owned populations.

Fourth is the need to promote general community health. While this engenders encouraging germination and establishment of primary hosts such as *Acacia acuminata* the role of a range of species in assisting persistence of sandalwood should not be ignored.

Fifth is the need for dispersal. Virtually all nuts at the populations visited now fall directly under the tree canopy and stay there. This is far removed from active removal and planting that they once received from mammals. In the long-term future they may need planting to ensure an even distribution and age structure on reserves. Along this line the use of the occasional sandalwood should be encouraged on replanting so that the broad geographic scale is considered. As with all replanting exercises it would be better that all seeds are sourced locally if the aim is to have a population that is capable of interbreeding and being self-sustaining in the long-term. That is it is conceivable that seed stock from widely separated places may not produce many viable progeny when they mature and should cross-pollinate.

14 FURTHER RESEARCH

Themes that were not covered in the current work but which are required for the wheatbelt are :

i) the soil nutrients from the various soil groups / habitat types.

ii) the genotypes of the recognised subgroups.

iii) the wood oil content of the recognised subgroups.

iv) the composition of the fruit components, especially the kernels, of the recognised subgroups.

v) field germination trials and growth and habit assessment

vi) ongoing monitoring of the study sites for year of fruit production, total fruit production and seed germination ability in each year.

In field trials of the species four aspects are suggested for investigation :

i) the effect of pollination within and between stock from different populations on germination and vigour of progeny.

ii) the effect on sandalwood growth of incorporating hosts with different rooting strategies in relation to soil nutrient extraction.

iii) the effect on sandalwood growth of incorporating hosts with different rooting strategies in relation to soil water extraction.

iv) the effect of using a range of hosts of different longevity so that the need for seral replacement as one host group ages is diminished or obviated.

15 SUMMARY

Sites which had populations of *Santalum spicatum* were selected throughout the wheatbelt. They were chosen for the local populations apparent remnant or relictual status. So that a priority was placed on populations in reserves over sites on private property; except where no geographical alternatives existed.

The study sites were used to :

* elucidate which plant communities and soil types were habitat for this species

* determine whether any sub-specific groups were evident across the wheatbelt on the basis of gross morphological (phenotypic) characters.

* identify relationships between habitat and phenotype

* test germination of the populations encountered

Given the vagaries of the effects of settlement and the different stages in the successional sequence the approach adopted in this report was to corroborrate as many aspects of the species biology as possible. This was strengthened by the wide geographic range and number of sites.

Throughout the study area sandalwood populations were generally healthy; though all trees were characterized by dead limbs. If a range of heights used as an indication of a healthy, and potentially propagating population, then the occurrence of such a population was positively correlated with soil depth and a neutral to acidic soil pH.

There was a tendency for trees to be multi-stemmed. This may be related to basal sprouting which was noted at three locations in response to felling, toppling and fire.

Several sandalwood parameters could be derived with a high degree of confidence from the measurement of primary ones. For example width from height and diameter at breast height from diameter at 15 cm.

A litter layer was present under many of the trees; generally it comprised leaf and then fruit material. In many instances it was colonized by exotic annual plant species. Evidence from other researchers suggests that this "mulch" represents a significant nutrient resource. Such pockets pose problems for reserve management as they represent nuclei for weed invasion.

Classification of sites in which *S. spicatum* occurred on the basis of plant species presence/absence produced broad groupings related to the general soil types. These were aeolian dunes, inland red earths, Victoria Plateau soils, sandy-gravels of lateritic origin and granitic soils. The species was absent from the deep yellow sands at the north and south-east of the region. The general soil type groups could be further subdivided into geographical/average rainfall groups. They were north, central east (250 - 300 mm), central (270 - 380 mm), central (380 - 400 mm), southwest (400 mm) and granite (300 - 350 mm).

There was a high degree of relatedness between the vegetation associations so that the division between groups was weak. This was partly attributable to the widespread co-occurrence of other species with *S. spicatum* at a range of sites. Two commonly co-occurring species which utilized the microhabitat under the sandalwood canopy were *Dianella revoluta* and *Stipa elegantissima*. Acacias were present at all sites, with *Acacia acuminata* present at the majority. To a lesser extent sandalwood was associated with *Allocasuarina* species.

Sandalwood density was weakly positively correlated with the percent cover of *Acacia* species and *Allocasuarina* species and weakly negatively correlated with the percent cover of members of the Proteaceae.

The average percent cover of other, potentially shading, species at the study sites was 23.62 %.

Cheif hosts throughout the central and southern wheatbelt were *Acacia acuminata*, *Allocasuarian campestris*, *Allocasuarina huegeliana* and *Eucalyptus loxophleba*. Though potentially as important may be a spread over minor complements from several plant families. This may be important to persistance if it provides access to a variety of root systems and hence different water and nutrient extraction strategies.

The vegetation types where *S. spicatum* acheived moderate densities were *Eucalyptus loxophleba* woodland, *Allocasuarina huegeliana* woodland, *A. campestris* shrubland, *E. salmonophloia* woodland, and *E. wandoo* woodland. The latter tended to have the weakest development of the species. Only isolated individuals, with small basal diameters occurred in mallee dominated areas. The nearly monotypic stands and competitive effects may make such habitat sub-optimal for sandalwood. The species was absent from Myrtaceaous/Proteaceous dominated heathlands and shrublands. In sedgeland and shrubland it was usually associated with pockets of preferred species.

On a local scale the species often occurred in an interzone situation between vegetation and soil types; sometimes matching small-scale mosaic patterning in the vegetation and soil. This typically occurred between the boundary of heath and woodland (sandy loams and sandy laterites). Such pocketing may have contributed to the loose association of sandalwood with eucalypts (in particular *E. salmonophloia*).

Consideration of the area occupied by sandalwood prior to European settlement indicates as much as 60 to 80 % of the central wheatbelt may have been suitable habitat.

Reference to known soil properties and dominant species soil type preferences from other research showed a clear replacement series for tree hemiparasites based on nutrients. On a comparative spectrum *S. spicatum* was associated with sandy, silty, loam soils of moderate nutrient content, *Nuytsia floribunda* with deep sandy soils of poor nutrient content, while *S. acuminatum* appeared intermediate in preference. Though it was noted that the latter also extended into the deep sands and Myrtaceous/Proteaceous heathlands that sandalwood avoided.

As an extension of this nutrient pattern other research provides evidence that the litter from sandalwood trees improves the immediate soil environment and may form part of an external nutrient recycling process. Complementary recycling within the tree was indicated by the distinct blackening of fallen leaves and to a lesser extent fruit flesh, which suggests that they have little phosphorus content at the time that they separate from the tree.

Throughout the study area sandalwood's preference was for intermediate soil physical properties. Soils could be typified as gravelly-sands with a silt component. They had low bulk densities indicating good rainfall penetrability (though the associatied acacias appeared to prefer higher bulk densities/lesser penetrabilities within the range encountered). Soils were of low salinity and of neutral to acidic pH. Generally soil depths were moderate to shallow with good drainage. Site location and major dominants indicated that these soils tended to be gradational to duplex at depth.

There was no apparent topographic or aspect preference by sandalwood.

Observation from outside the region suggests that wheatbelt may contain a sandalwood sub-group. Wheatbelt sandalwood leaves may be broader than those in the arid inland. There may also be trends in woodgrain and wood oil. While other research has implicated genetic trends. This conforms to the wheatbelt being largely subject to seasonal rainfall as opposed to the moderately seasonal rainfall in the east.

Assessment of subspecific variation throughout the study range centered on leaf morphology, leaf colour and nut shell dimensions. Only the latter two demonstrated any patterns.

Within the wheatbelt a number of patterns appeared on the basis of standardized leaf colours. First the yellow colour of the leaves (and the general habit) of the quandong, *S. acuminatum*, suggested classic symptoms of nitrogen deficiency reinforced by sulfur deficiency. Secondly this was matched in *S. spicatum* by lighter shades of green, with a tendency to yellow, in the leaves on sandy lateritic soil. These latter soil groups were the main areas where there was any overlap of distribution on the local scale between the two species. Similar linkage of sandalwood leaf colour to the percent cover of acacias indicated a nutritional basis to leaf colour that might involve nitrogen. Thirdly, on a wider geographic basis, *S. spicatum* had deeper green leaves on the Victoria Plateau soils of the north and greenstone soils of the south (both groups had limited sandy laterite development). This, taken with the evident soil nutrient regimes from other sources, strongly suggested soil-type linked differences to colouration between the midwestern populations and the northern and southern populations. Overall the pattern echoed that from classification of sites on the basis of plant species.

Fruit size features indicated a couple of trends within the wheatbelt. First it was established that shell diameter did not change with year of production. (It appeared to be true to the tree, which made it potentially a feature of the genetics of the tree.) Second there were trends on the basis of shell diameter for the grouping of smaller shells at the midwest sites as opposed to the larger shells of the northern and southern populations, and generally for the western sites to have larger shells. (Here the lack of distinct boundaries to these separations is again consistent with a genetic feature with less variation between populations than within them.) Thirdly flesh separated the sites on a direct north-south basis. This matched the strong negative correlation of flesh weight on the number of days per year that exceeded 30oC. It suggests that this is a feature which was more plastic than shell diameter and is constrained where the development of size may be limited by a warm summer.

Only shell weight and flesh weight appeared to be influenced by plant species density. They were both correlated with the percent cover of acacias. While only flesh weight was negatively correlated with the density of *S. spicatum* at the site, again attesting to its plasticity. This lead to the conclusion that either the shell was more "important" to the tree and the flesh may be allocated "resource" less preferentially. Or the shell was made of poor quality resource, and so was easily provided for, but the flesh, being more "resource expensive", was preferentially detracted from in deference (it was assumed) to kernel weight.

Shell diameter, in line with being a genetically-linked character, appears to be a main cross correlate, and therefore possibly a determinant, of other fruit features. As a feature shell diameter was linked to avearage rainfall and therefore was clearly a function of the long-term position of trees and populations in the rainfall gradient. This also has overtones of a genetically-linked feature.

Average rainfall was also linked to shell weight and flesh weight.

Fruit features linked to the short-term, current, rainfall were kernel weight and diameter.

Winter was important to seed development. As the kernel weight and diameter were correlated with both winter rain and the number of days less than or equal to 5oC per annum.

Total fruit production per tree and the weights of the individual subcomponents were assessed and were found to be largely correlated to tree size. The total number of fully formed fruit was also related to tree size. Only the total weight of incompletely formed fruit was both a function of tree size and rainfall. While total incompletely-formed fruit weight was also independently adversely affected by days at or above 30 oC. The number of incompletely-formed fruit was not correlated with any factor. Clearly there there was some tree-size linked limitation on the number of fully-formed fruit that could be formed.

This· was the limiting feature ("resource"), not rainfall. As rainfall induced excess numbers of incompletely formed (and therefore incompletely supplied) fruit.

Germination also correlated to tree size. Again suggesting that trees had a limited amount of resource that would permit only a finite number of fully-formed seeds that were able to germinate. As there was no correlation of density with germination it appeared that cross pollintion (insofar as it is represented by density) was less important than tree size.

On an individual nut basis large size diminished the probability of germination. This may conform to large size being associated with the outer (southern and western) edge of the species distribution. Therefore the selection of large nut size and/or seed stock for trials from within the study area may need to be compensated for by oversowing.

There was no germination advantage conferred to the seed from retention of the fruit flesh after fruit maturation and fall.

Seed selection for future provenance trials could be based on the north, south, western midwest and eastern mid-west zones of the study area. Low wood oil content may be expected from seed stock from the southern and western periphery of the species range.

The performance of sandalwood in various categories of habitat types was assessed. There was no significant association of the proportion of trees with fruit, the grams of fruit produced per centimeter of tree diameter, mean tree diameter or tree density, with Allocasuarina dominated versus eucalypt tree-form dominated sites, sites with low and higher percent cover of acacias, and lateritic versus non-lateritic soils. Only mallee eucalypt sites were associated with lower sandalwood stem diameters when compared with the combined Allocasuarina and eucalypt tree-form sites. (In addition high densities and high fruit production were absent for mallee sites; though no significance was achieved.)

Localized water status (as opposed to rainfall) was generally not associated with sandalwood population status. Overall this suggests that within the sites surveyed water avaiability per se may not have been a limiting factor. This underscores the importance of nutrient constraints on the wider distribution, representation and production of sandalwood. The one exception was the marginal significance accorded the association between sandalwood density and soil moisture. This suggests that further research could be directed to the interplay between the direct effect of soil moisture on sandalwood and the indirect effects through host responses to soil moisture.

In a trial situation where nut production is to be maximised (assuming that the best producing stock was selected) the results suggest that this could be achieved by increasing tree density. This would be important while trees are young and their production is limited by their small size. There should be reasonable leeway to increase density without affecting the kernels as the fruit flesh appears to be the feature which is sacrificially affected under increasing competition.

As kernel production is favoured by winter rainfall and days per year with minimum temperatures less than or equal to 5 oC the more profitable areas for production may be in the south and west of the wheatbelt.

Tropical links in the biology of sandalwood may be features such as : the raised numbers of incomplete-fruit formed as a result of the declining number of warm days and increasing rainfall (cheifly in winter) at the edge of the specie's range; a similarly placed decline in the ability to produce germinable nuts; the persistence of mast-flowering; and the link with acacias, which have strong tropical affinities.

Some movement away from a tropical heritage is indicated by the confinement of the species to a winter-wet distribution.

The overall strategy of the species is considered. Longevity is considered in terms of oil production and a parasitic strategy. With it comes an ability to forestall reproduction, a characteristic which may have been reinforced by the use of animals as seed dispersal agents. Large seededness may be related to both of these features and also to the selection of favourable soils and hosts / nutrient regimes.

Conservation and research requirements are outlined.

(The signifcant regressions and contingency tests from the suite considered in this work, and discussed in this summary, are represented in Tables 31 and 32. Table 31 is set out so that the first division is between individual fruit components in one half and total fruit component production in the second half. In the first half it can be seen that individual fruit components are linked to the climate. Specifically weights and diameters are linked to rainfall and then to days at or above 30 oC. Next only the flesh and shell are linked to the percent cover of acacias. While only flesh is affected by sandalwood density. In the second half it can be seen that, first, all production total weights and total numbers are linked to tree size, and second only incompletely-formed fruit are linked to tree size and also to rainfall and days at or above 30 oC. Table 32 shows which habitat features (left of page) were associated with sandalwood parameters (top of page).)

TABLE 31 : SUMMARY OF THE REALTIVE STRENGTH OF THE RELATIONSHIPS BETWEEN CLIMATE AND TREE SIZE VARIABLES, AND, RESPECTIVELY, INDIVIDUAL FRUIT COMPONENT WEIGHTS AND SIZES, AND TOTAL TREE FRUIT PRODUCTION AND ITS COMPONENTS. (NB PRODUCTION VALUES COULD HAVE BEEN ASSIGNED # 21 - 34; IE THE TWO REGRESSION GROUPS ARE VIRTUALLY SEQUENTIAL).

	--- RAINFALL --			-# DAYS/YEAR (oC)-			ACACIA	SANDALWOOD	--- JOINT FUNCTION ---- DIAM 15CM + ...			DIAM 15CM	RAINFALL
	AV.	90WS	W	≥ 30	≥ 35	≤ 5	%COVER	DENSITY	AV RAIN	≥ 30	89/90WS		89/90WS
INDIVIDUAL													
COMPONENTS:													
WEIGHT													
FLESH	1			-3			17	-18					
SHELL	4	6		-12		13	15						
KERNEL	11	5	9	-15									
DIAMETER													
SHELL	2			-7									
KERNEL	14	10	8		-17	16							

TABLE 31 CONTINUED.

	--- RAINFALL --			-# DAYS/YEAR (oC)-			ACACIA	SANDALWOOD	--- JOINT FUNCTION ---- DIAM 15CM + ...			DIAM 15CM	RAINFALL
	AV.	90WS	W	≥ 30	≥ 35	≤ 5	%COVER	DENSITY	AV RAIN	≥ 30	89/90WS		89/90WS
PRODUCTION:													
TOT. WEIGHT													
FRUIT												4	
I.F.F.	11	(11)		-13					1	2	3	5	9
FLESH												6	
KERNEL												7	
SHELL												8	
# FRUIT													
POTENTIAL												12	
I.F.F.												10	

AV. = AVERAGE; 90WS = 1990 WINTER & SUMMER; 89/90WS = 1989 + 1990 WINTER & SUMMER; (-) CORRELATION WAS NEGATIVE

TABLE 32 : SUMMARY OF THE THE RESULTS OF CONTINGENCY TESTS OF HABITAT FEATURES VERSUS SANDALWOOD PARAMETERS. (ABSENCE - NOT TESTED; --- - NOT SIGNIFICANT; *** - SIGNIFICANT (2 TAILED TEST; $P \leq 0.05$).

	HIGH AND LOW CATEGORIES					
	SANDALWOOD DENSITY	AVERAGE DIAM 15	FRUIT GM /DIAM 15	LEAF COLOUR	YELLOW	PROP TREES + FRUIT
ALLOCASUARIANA /DOMINANTS/ EUCALYPTUS	---	---	---	---		---
EUC. & ALLOC. /DOMINANTS/ "MALLEE"	***	***	***	---		---
ACACIA ≤ 1% VS ACACIA > 1%	---	---	---	***	***	---
LATERITES VS OTHER SOILS	---	---	---	---	***	---
HIGH BULK DENSITY LOW	---	---	---	---		---
MOIST SOIL VS DRIER SOIL	---	---	---	---		---
WATER GAINING SITE NOT GAINING	---	---	---	---		---

16 ACKNOWLEDGEMENTS

With such an extensive mandate welcome information and, in some cases, physical help was provided by :

Jeni Alford, Ken Atkins, Diana Barrett, Judith Brown, Paul Brown, Allen Carmichael, Tim Catling, Keith Davis, John Day, Mal Graham, Bernie Haberley, Ian Keally, Kim Kershaw, Libby Mattiske, Trevor Mattiske, Laurie & Nicole North, David Parnell, Bob & Dawn Porter, Pat Ryan, Leon Silvester, Mike Tagliaferri, Klaus Tiedeman, Ken Wallace, Peter Wilhelm, Greg Woodman.

Special thanks are extended to my parents for their support.

An honourable mention to Barry Muir for producing correct and accurate vegetation maps of wheatbelt reserves.

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APPENDIX 1 : POPULATION PARAMETERS FOR SANTALUM SPICATUM

SITE#	# TREES	HEIGHT AV	HEIGHT SD	WIDTH AV	WIDTH SD	SITE#	# TREES	HEIGHT AV	HEIGHT SD	WIDTH AV	WIDTH SD
60	*	*	*	*	*	24	7.00	2.66	1.50	2.32	0.78
57	1.00	5.80	0.00	3.50	0.00	23	5.00	1.78	0.51	2.12	0.63
46	2.00	2.30	0.71	1.65	0.49	20	5.00	3.02	1.18	1.87	0.76
45	3.00	3.57	0.51	3.07	0.12	70	4.00	2.08	0.80	1.70	0.52
7	3.00	1.60	0.00	1.43	0.21	65	4.00	3.68	1.20	3.53	1.16
6	3.00	2.10	0.66	1.23	0.45	16	4.00	5.05	3.27	2.89	1.66
48	7.00	1.68	1.57	1.26	1.42	40	11.00	0.91	1.63	0.87	1.51
47	12.00	1.62	1.56	1.17	1.23	59	3.00	3.07	0.95	1.83	0.68
44	3.00	3.40	2.65	2.57	1.88	42	6.00	2.55	1.34	2.16	1.28
69	1.00	3.50	0.00	2.00	0.00	71	3.00	1.90	0.89	1.53	0.80
43	4.00	2.58	0.56	2.28	0.17	67	1.00	3.30	0.00	3.50	0.00
38	1.00	2.50	0.00	2.00	0.00	56	3.00	4.07	1.90	4.00	2.29
37	10.00	0.65	0.75	0.47	0.69	41	2.00	2.55	0.64	2.10	0.14
36	3.00	3.30	0.61	2.83	0.29	30	4.00	3.40	0.79	3.25	1.04
10	4.00	4.62	0.56	2.75	0.20	51	3.00	4.90	1.15	2.73	0.68
12	3.00	3.73	0.87	4.41	1.13	27	7.00	5.70	6.48	2.72	1.73
9	3.00	3.83	1.04	3.30	1.53	31	9.00	2.37	1.20	1.74	0.88
11	3.00	4.23	1.67	2.78	0.20	32	5.00	2.30	0.77	2.35	0.60
8	3.00	6.66	1.15	4.13	1.34	17	4.00	3.30	0.80	2.77	0.79
19	3.00	2.77	1.08	2.07	0.60	18	8.00	2.63	0.94	2.66	1.60
66	1.00	2.40	0.00	2.10	0.00	15	13.00	2.90	1.52	2.08	1.64
22	1.00	2.20	0.00	2.40	0.00	34	9.00	3.13	1.69	2.76	1.53
33	5.00	2.88	1.83	2.56	1.59	35	14.00	1.44	0.91	1.11	0.80
72	2.00	2.30	0.71	2.50	0.71	14	4.00	2.88	1.04	2.63	1.30
39	2.00	1.34	1.65	1.15	1.54	28	6.00	5.33	5.77	3.24	1.09
29	7.00	2.56	0.93	2.63	1.28	26	9.00	2.77	1.64	2.49	1.98
21	2.00	2.75	0.07	1.85	0.07	25	1.00	4.80	0.00	3.75	0.00
52	2.00	3.10	0.57	1.95	0.64	62	20.00	1.35	1.29	1.00	1.17
50	3.00	2.53	3.01	1.47	2.20	61	2.00	4.65	1.63	3.73	0.18
49	14.00	1.61	2.34	1.04	1.68	64	4.00	3.90	2.41	2.70	1.17
63	4.00	2.28	1.94	1.48	1.66	5	2.00	3.70	0.42	3.60	1.24
58	4.00	3.35	1.10	2.09	0.69	4	2.00	3.70	0.42	3.60	1.24
55	5.00	2.92	1.65	1.94	1.19	3	1.00	11.00	0.00	8.00	0.00
53	9.00	2.00	1.96	1.38	1.66	2	2.00	5.55	0.07	4.75	0.00
13	4.00	2.63	0.51	2.50	1.21	54	4.00	3.03	1.59	2.45	1.28
68	5.00	3.34	2.61	2.14	1.70	1	4.00	4.90	1.21	4.50	0.58

APPENDIX 1 : POPULATION PARAMETERS FOR SANTALUM SPICATUM

SITE #	# STEMS 15CM AV	# STEMS 15CM SD	# STEMS DBH AV	# STEMS DBH SD	DIAM 15CM AV	DIAM 15CM SD	SITE #	# STEMS 15CM AV	# STEMS 15CM SD	# STEMS DBH AV	# STEMS DBH SD	DIAM 15CM AV	DIAM 15CM SD
60	*	*	*	*	*	*	24	1.00	0.00	2.29	1.80	12.66	[illegible]
57	5.00	0.00	5.00	0.00	34.00	0.00	23	2.20	0.45	2.10	2.37	5.60	[illegible]
46	1.00	0.00	2.00	2.83	12.50	2.12	20	2.40	2.07	2.40	2.07	14.00	[illegible]
45	1.00	0.00	5.33	2.08	13.67	1.15	70	1.00	0.00	2.75	2.22	9.25	[illegible]
07	1.00	0.00	2.00	1.73	4.03	0.35	65	1.75	1.50	6.50	5.07	25.75	[illegible]
06	1.66	1.15	0.00	0.00	13.43	2.64	16	1.00	0.00	1.75	1.71	13.93	[illegible]
48	1.14	0.38	1.71	2.43	6.14	6.23	40	1.00	0.00	1.20	3.13	4.44	[illegible]
47	1.08	0.29	0.92	2.02	4.75	6.24	59	1.33	0.58	2.67	1.53	9.33	[illegible]
44	1.00	0.00	6.67	9.87	14.00	12.53	42	1.33	0.52	4.67	6.19	12.83	[illegible]
69	1.00	0.00	2.00	0.00	12.00	0.00	71	2.33	1.15	2.67	2.52	12.33	[illegible]
43	1.00	0.00	6.25	3.30	9.38	3.45	67	5.00	0.00	5.00	0.00	45.50	[illegible]
38	1.00	0.00	3.00	0.00	12.00	0.00	56	2.67	2.08	5.33	3.21	34.67	[illegible]
37	1.20	0.63	1.30	2.83	4.50	7.14	41	4.50	4.95	3.00	0.00	23.75	[illegible]
36	2.33	1.53	5.67	4.62	19.33	16.50	30	1.75	1.50	4.50	2.38	15.85	[illegible]
10	1.00	0.00	2.25	0.50	20.60	6.43	51	1.33	0.58	4.00	1.73	20.83	[illegible]
12	1.00	0.00	2.67	1.15	19.66	4.31	27	2.00	1.15	1.71	0.95	17.14	[illegible]
09	1.00	0.00	2.67	2.08	26.86	8.53	31	1.56	1.33	1.70	1.95	12.26	[illegible]
11	1.00	0.00	2.33	1.15	20.73	5.15	32	1.60	0.55	3.80	3.56	15.92	[illegible]
08	1.00	0.00	2.33	0.58	48.50	13.17	17	1.50	0.58	2.50	1.00	11.33	[illegible]
19	1.00	0.00	3.67	1.53	12.20	3.78	18	1.75	1.75	3.50	2.14	13.75	[illegible]
66	3.00	0.00	4.00	0.00	15.00	0.00	15	1.55	0.69	3.10	1.79	16.31	[illegible]
22	1.00	0.00	4.00	1.00	16.00	0.00	34	1.44	1.33	2.00	2.60	15.88	[illegible]
33	2.20	1.79	2.80	1.92	15.20	14.31	35	1.50	1.34	0.57	1.02	5.62	[illegible]
72	4.00	4.24	8.00	1.41	17.50	13.44	14	1.00	0.00	0.00	0.00	28.45	[illegible]
39	1.00	0.00	5.00	7.07	7.50	9.19	28	1.33	0.82	1.83	1.17	15.83	[illegible]
29	3.43	2.88	4.29	3.15	23.64	17.95	26	2.00	3.00	5.33	5.98	21.62	[illegible]
21	1.00	0.00	7.50	2.12	19.50	11.31	25	1.00	0.00	7.00	0.00	15.50	[illegible]
52	1.00	0.00	3.50	2.12	10.50	3.54	62	1.40	1.39	0.90	1.62	6.11	[illegible]
50	3.00	2.83	2.33	4.04	19.33	33.49	61	1.50	0.71	4.50	0.71	23.75	[illegible]
49	1.36	1.08	1.36	2.41	7.93	15.91	64	1.50	0.58	3.25	2.87	22.50	[illegible]
63	1.00	0.00	1.50	1.73	7.50	6.56	05	1.50	0.71	5.50	0.71	21.80	[illegible]
58	1.75	1.50	2.25	0.96	3.88	4.33	04	1.50	0.71	5.50	0.71	21.80	[illegible]
55	2.40	1.34	2.80	3.35	19.90	16.35	03	1.00	0.00	6.00	0.00	30.00	[illegible]
53	1.44	0.88	3.44	4.77	10.33	14.07	02	1.00	0.00	1.50	1.71	22.30	[illegible]
13	1.50	0.58	2.25	2.63	24.58	25.25	54	1.00	0.00	3.00	3.16	11.25	[illegible]
68	1.00	0.00	2.60	2.61	9.90	9.20	01	1.25	0.50	1.50	1.00	23.40	[illegible]

APPENDIX 1 : POPULATION PARAMETERS FOR SANTALUM SPICATUM

SITE	DBH		# DEAD		# CLUMPS			SITE	DBH		# DEAD		# CLUMPS		
#	AV	SD	AV	SD	PROPORT	AV	SD	#	AV	SD	AV	SD	PROPORT	AV	SD
60	*	*	*	*	*	*	*	24	9.51	8.02	0.00	0.00	0.29	2.00	[illegible]
57	29.00	0.00	0.00	0.00	0.00	0.00	0.00	23	1.52	2.44	0.00	0.00	0.63	5.00	[illegible]
46	8.00	11.31	0.33	0.58	0.00	0.00	0.00	20	11.80	8.07	0.00	0.00	0.33	2.00	[illegible]
45	13.17	4.19	0.00	0.00	0.00	0.00	0.00	70	8.38	7.23	0.25	0.50	0.00	0.00	[illegible]
07	8.00	6.93	0.00	0.00	0.00	0.00	0.00	65	35.38	31.39	0.00	0.00	0.00	0.00	[illegible]
06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16	17.18	12.03	0.00	0.00	0.00	0.00	[illegible]
48	5.06	6.96	0.00	0.00	0.00	0.00	0.00	40	6.09	15.88	0.00	0.00	0.00	0.00	[illegible]
47	2.92	5.53	0.00	0.00	1.00	3.67	2.89	59	8.50	7.47	0.00	0.00	0.00	0.00	[illegible]
44	18.00	13.08	0.00	0.00	0.67	2.00	0.00	42	15.33	18.27	0.00	0.00	0.33	2.00	[illegible]
69	14.50	0.00	0.00	0.00	0.00	0.00	0.00	71	7.00	7.55	0.00	0.00	0.00	0.00	[illegible]
43	10.75	4.94	0.00	0.00	0.00	0.00	0.00	67	37.00	0.00	0.00	0.00	0.00	0.00	[illegible]
38	9.50	0.00	0.00	0.00	0.00	0.00	0.00	56	29.83	20.53	0.00	0.00	0.00	0.00	[illegible]
37	4.80	10.13	0.00	0.00	1.00	3.50	0.71	41	7.25	2.47	0.50	0.71	0.00	0.00	[illegible]
36	17.33	9.45	0.00	0.00	0.00	0.00	0.00	30	22.28	15.12	0.00	0.00	0.00	0.00	[illegible]
10	22.25	1.44	0.00	0.00	0.00	0.00	0.00	51	26.33	12.00	0.00	0.00	0.00	0.00	[illegible]
12	23.20	1.21	0.00	0.00	0.00	0.00	0.00	27	10.73	7.99	0.00	0.00	0.00	0.00	[illegible]
09	27.46	24.76	0.00	0.00	0.00	0.00	0.00	31	8.06	6.85	0.10	0.32	0.80	3.00	[illegible]
11	18.40	3.59	0.00	0.00	0.00	0.00	0.00	32	12.40	12.22	0.00	0.00	1.00	2.50	[illegible]
08	35.63	17.61	0.00	0.00	0.00	0.00	0.00	17	11.98	2.20	0.00	0.00	0.00	0.00	[illegible]
19	11.50	3.87	0.00	0.00	0.00	0.00	0.00	18	14.38	19.15	0.00	0.00	1.00	4.00	[illegible]
66	8.50	0.00	0.00	0.00	0.00	0.00	0.00	15	25.24	25.31	0.08	0.28	0.20	2.50	[illegible]
22	8.60	0.00	0.00	0.00	0.00	0.00	0.00	34	12.91	20.08	0.11	0.33	0.00	0.00	[illegible]
33	17.26	24.47	0.00	0.00	0.60	3.00	0.00	35	2.43	5.00	0.07	0.27	0.43	6.00	[illegible]
72	16.25	8.13	0.00	0.00	0.00	0.00	0.00	14	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]
39	8.00	11.31	0.00	0.00	0.00	0.00	0.00	28	13.62	10.69	0.00	0.00	0.33	2.00	[illegible]
29	18.61	17.54	0.14	0.38	0.00	0.00	0.00	26	12.28	15.23	0.11	0.33	0.00	0.00	[illegible]
21	10.97	0.84	0.00	0.00	0.00	0.00	0.00	25	19.20	0.00	0.00	0.00	0.00	0.00	[illegible]
52	13.75	10.25	0.00	0.00	0.00	0.00	0.00	62	4.28	7.88	0.00	0.00	0.95	19.00	[illegible]
50	16.33	28.29	0.00	0.00	0.00	0.00	0.00	61	40.25	8.13	0.00	0.00	0.00	0.00	[illegible]
49	8.91	17.27	0.00	0.00	0.00	0.00	0.00	64	23.50	27.84	0.50	0.60	0.00	0.00	[illegible]
63	9.00	10.42	0.00	0.00	0.00	0.00	0.00	05	37.65	18.88	0.00	0.00	0.00	0.00	[illegible]
58	7.38	3.50	0.00	0.00	0.00	0.00	0.00	04	37.65	18.88	0.00	0.00	0.00	0.00	[illegible]
55	15.80	18.89	0.00	0.00	0.00	0.00	0.00	03	30.00	0.00	0.00	0.00	0.00	0.00	[illegible]
53	14.14	21.43	0.00	0.00	0.75	6.00	0.00	02	21.00	3.68	0.00	0.00	0.00	0.00	[illegible]
13	10.80	14.31	0.00	0.00	0.00	0.00	0.00	54	16.00	17.51	0.00	0.00	0.00	0.00	[illegible]
68	14.40	17.21	0.00	0.00	0.40	2.00	0.00	01	22.15	13.64	0.00	0.00	0.00	0.00	[illegible]

APPENDIX 1 : POPULATION PARAMETERS FOR SANTALUM SPICATUM

SITE#	SANTALUM %COVER	(#/HA) DENSITY	ACACIA %	ALLOCAS %	EUCALYPT %
60	*	*	*	*	*
57	0.10	4.00	0.00	8.00	1.00
46	0.40	8.00	0.00	0.00	0.00
45	0.80	12.00	7.20	0.00	0.00
7	3.00	3.00	8.00	0.00	15.00
6	4.00	8.00	15.00	0.00	0.00
48	0.40	16.00	6.40	0.00	28.00
47	1.00	12.00	15.00	0.00	0.30
44	0.20	4.00	5.00	0.00	2.00
69	0.20	0.50	4.20	0.00	27.30
43	0.50	12.00	7.00	0.00	10.00
38	0.10	2.00	1.80	0.00	35.00
37	0.50	3.00	4.00	0.00	3.20
36	1.00	12.00	8.20	0.00	0.40
10	0.50	10.00	25.00	0.00	4.00
12	1.00	6.00	29.00	3.00	0.00
9	0.50	5.00	30.00	0.00	0.00
11	0.20	8.00	35.00	0.00	0.30
8	1.00	9.00	15.00	0.00	0.00
19	0.20	7.00	10.00	0.00	25.00
66	0.10	0.50	0.50	25.00	10.00
22	2.00	1.00	0.00	0.00	10.00
33	0.40	8.00	4.10	19.00	5.00
72	0.40	20.00	0.10	60.00	0.00
39	0.20	1.00	0.00	3.00	5.00
29	0.80	24.00	0.10	15.00	0.00
21	0.20	2.00	0.00	0.10	0.00
52	0.70	12.00	0.10	12.00	0.00
50	0.30	4.00	0.50	0.50	0.00
49	1.00	12.00	0.60	3.10	3.00
63	0.20	12.00	1.20	0.20	0.00
58	0.50	32.00	0.20	11.00	0.00
55	0.30	60.00	0.10	0.50	0.00
53	0.40	20.00	0.00	5.70	0.00
13	1.00	3.00	1.20	4.00	30.00
68	2.00	52.00	6.00	0.20	20.00

SITE#	SANTALUM %COVER	(#/HA) DENSITY	ACACIA %	ALLOCAS %	EUCALYPT %
24	1.00	25.00	7.00	4.00	0.00
23	1.00	3.00	13.00	2.00	21.00
20	1.00	80.00	10.10	13.00	18.00
70	0.40	20.00	0.60	7.00	0.30
65	0.80	16.00	0.20	0.50	0.00
16	2.00	48.00	0.50	44.00	0.00
40	0.40	8.00	11.00	0.10	0.00
59	0.80	60.00	0.90	0.10	30.00
42	0.30	4.00	5.10	0.00	3.50
71	0.10	3.00	1.60	0.00	16.50
67	0.30	0.50	5.30	0.20	18.00
56	0.30	20.00	0.50	0.00	10.00
41	0.30	6.00	3.00	0.00	0.30
30	0.80	6.00	8.00	10.00	1.00
51	0.20	8.00	2.20	3.00	0.00
27	2.00	20.00	2.00	2.50	30.00
31	2.00	60.00	20.00	0.00	8.00
32	0.50	16.00	6.50	0.10	6.00
17	1.00	48.00	21.10	0.00	1.20
18	0.30	48.00	22.10	0.00	7.00
15	4.00	52.00	20.10	0.10	0.20
34	5.00	10.00	3.00	1.00	1.00
35	0.20	32.00	10.10	6.00	8.00
14	1.00	5.00	20.00	1.00	25.00
28	3.00	28.00	30.00	0.00	0.00
26	3.00	24.00	10.00	10.00	0.00
25	0.20	1.00	4.00	0.00	27.00
62	0.20	20.00	17.00	0.20	20.00
61	0.30	10.00	10.00	0.00	18.00
64	0.20	24.00	19.00	0.00	3.00
5	0.10	5.00	8.00	0.00	10.00
4	0.20	5.00	10.00	0.00	11.00
3	1.00	0.20	3.00	0.00	5.00
2	0.30	2.00	5.00	25.00	30.00
54	3.50	60.00	5.00	10.00	5.00
1	2.00	23.00	25.00	25.00	0.00

APPENDIX 2.: SURVEY SITE PLANT SPECIES LIST

SITE # [1]	Height (m)	Cover (%)
Low Open Woodland A (LAr)		
Santalum spicatum	5.0	2.0
Dianella revoluta	0.5	0.1
Stipa ? campylachne	0.3	10.0
Neurachne alopecuroidea	0.2	2.0
Acacia acuminata	1.0	0.1
Loxocarya aspera	0.15	0.1
Lomandra effusa	0.3	0.1
Borya sphaerocephala	0.1	1.0
Allocasuarina huegeliana	5.0	1.0
Ursinea anthemoides	0.15	0.1
Acaena sp	0.01	0.1
Arctotheca calendula	0.05	0.1
Aira caryophyllea	0.1	8.0
Vulpia myuros	0.2	2.0
Lepidosperma tenue	0.4	0.1
Astroloma compactum	0.2	0.1
Cucurbitaceae sp	0.1	0.1

SITE # [2]	Height (m)	Cover (%)
Open Woodland (Mr)		
Santalum spicatum	5.6	0.3
Stipa elegantissima	0.7	0.1
Stipa ? campylachne	0.4	3.0
Neurachne alopecuroidea	0.2	3.0
Acacia acuminata	5.0	0.1
Stypandra imbricata	0.4	0.1
Lepidosperma tenue	0.4	0.1
Eucalyptus wandoo	15.0	0.1
Eucalyptus loxophleba	17.5	5.0
Allocasuarina huegeliana	10.5	1.0
Avena fatua	0.7	2.0
Hypocheris glabra	0.1	1.0
Romulea rosea	0.2	2.0
Ehrharta calycina	0.5	80.0
Hordeum leporinum	0.3	2.0
Trifolium campestre	0.2	0.1
Stipa ? tenuiglumis	0.5	0.1
Hakea ? prostrata	0.1	0.1
Jacksonia furcellata	2.0	5.0

APPENDIX 2.: SURVEY SITE PLANT SPECIES LIST

SITE # [3]	Height (m)	Cover (%)
Open Low Woodland A (LAr)		
Santalum spicatum	4.5	1.0
Stipa elegantissima	0.4	0.1
Stipa ? campylachne	0.5	0.1
Neurachne alopecuroidea	0.2	0.1
Acacia acuminata	8.0	3.0
Eucalyptus loxophleba	11.0	5.0
Avena fatua	0.4	80.0
Hypocheris glabra	0.3	0.2
Romulea rosea	0.15	0.3
Ehrharta calycina	0.5	0.5
Danthonia caespitosa	0.3	1.0
Jacksonia furcellata	3.0	0.1

SITE # [4]	Height (m)	Cover (%)
Woodland (Mi)		
Santalum spicatum	2.0	0.2
Stipa elegantissima	0.7	0.1
Dianella revoluta	0.6	0.1
Opercularia ? spermacocea	0.2	0.1
Stipa ? campylachne	0.3	0.1
Stipa ? campylachne	0.4	5.0
Neurachne alopecuroidea	0.15	1.0
Acacia acuminata	3.0	0.1
Loxocarya aspera	0.15	2.0
Eucalyptus wandoo	13.0	1.0
Eucalyptus salmonophloia	17.0	10.0
Borya sphaerocephala	0.1	0.1
Olearia ? revoluta	0.3	0.1
Podolepis capillaris	0.2	0.1
Avena fatua	0.7	5.0
Ursinea anthemoides	0.2	0.3
Aira caryophyllea	0.1	1.0
Vulpia myuros	0.4	0.5
Ehrharta calycina	0.5	0.1
Hordeum leporinum	0.3	0.1
Templetonia sulcata	1.0	0.1
Jacksonia furcellata	2.0	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [5]	Height (m)	Cover (%)
Open Low Woodland A (LAr)		
Santalum spicatum	2.5	0.1
Stipa elegantissima	0.35	2.0
Dianella revoluta	0.6	0.1
Dodonaea pinifolia	0.25	0.1
Neurachne alopecuroidea	0.15	20.0
Acacia acuminata	2.0	1.0
Halgania preissiana	0.2	0.1
Dampiera lavandulacea	0.30	0.1
Eucalyptus cylindriflora	13.0	8.0
Eucalyptus loxophleba	0.15	20.0
Borya sphaerocephala	0.07	20.0
Avena fatua	0.4	10.0
Ursinea anthemoides	0.15	2.0

SITE # [6]	Height (m)	Cover (%)
Scrub (Si)		
Santalum spicatum	2.0	4.0
Melaleuca acuminata	2.0	0.3
Acacia rostellifera	2.75	15.0
Blackallia biloba	0.25	0.1
Lasiopetalum compactum	0.9	60.0
Anthocercis intricata	2.5	2.0
Myrtaceae sp	0.3	0.1
Chenopodium sp	1.5	1.0

SITE # [7]	Height (m)	Cover (%)
Open Tree Mallee (KTi)		
Santalum spicatum	1.0	3.0
Stipa elegantissima	0.4	0.1
Melaleuca acuminata	0.8	10.0
Phylanthus calycinus	0.6	0.1
Bossiaea ? spinescens	0.4	0.1
Acacia rostellifera x xanthina	4.0	8.0
Dodonaea aptera	0.4	0.1
Lasiopetalum compactum	0.25	0.1
Eucalyptus sp I	3.8	15.0
Templetonia retusa	0.7	0.1
Rhagodia ulicina	0.5	0.1
Westringia dampieri	0.4	1.0
Frankenia cordata	0.5	1.0
Acanthocarpus preissii	0.2	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [8]	Height (m)	Cover (%)
Open Low Woodland A (LAr)		
Santalum spicatum	6.7	1.0
Acacia acuminata	8.5	5.0
Hakea preissii	3.5	1.0
Acacia cupularis	3.0	0.1
Pimelea microcephala	2.0	2.0
Carthamnus sp	0.1	60.0

SITE # [9]	Height (m)	Cover (%)
Scrub (Si)		
Santalum spicatum	3.8	0.5
Dianella revoluta	0.6	0.2
Melaleuca uncinata terete form	1.5	0.1
Stipa ? campylachne	0.6	0.1
Aristida contorta	0.05	0.1
Acacia acuminata	2.0	0.4
Acacia tetragonophylla	3.5	17.0
Mirbelia microphylla	1.0	0.4
Euphorbia drummondii	0.06	0.1
Ptilotus obovatus	0.1	0.1
Hakea preissii	2.5	7.0
Podolepis capillaris	0.2	0.8
Maireana triptera	0.3	0.1
Solanum ellipticum	0.4	0.1
Enchylaena tomentosa	0.5	0.1
Senna glutinosa ssp charlesiana	3.0	0.1
Chenopodium gaudichaudianum	1.5	0.2
Maireana brevifolia	0.4	0.1
Apiaceae sp	0.4	0.1
Amyema preissii	*	0.1
Sida calyxhemenia	0.4	0.1
Maireana carnosa	0.15	0.1
Eragrostis sp	0.5	1.0
Acacia dielsii	2.0	0.1

APPENDIX 2.: SURVEY SITE PLANT SPECIES LIST

SITE # [10]	Height (m)	Cover (%)
Open Scrub (Sr)		
Santalum spicatum	3.75	0.5
Stipa elegantissima	2.0	0.3
Acacia filifolia	4.0	0.2
Acacia acuminata	2.25	5.0
Acacia tetragonophylla	3.5	3.0
Amyema miquelii	*	0.1
Pittosporum phylliraeoides	5.0	0.2
Hakea preissii	1.5	1.0
Eucalyptus loxophleba	5.0	1.0
Helipterum cotula	0.1	25.0
Rhagodia drummondii	1.0	0.1
Avena fatua	0.6	10.0
Astroloma serratifolium v horrid.	1.0	0.1

SITE # [11]	Height (m)	Cover (%)
Open Scrub (Sr)		
Santalum spicatum	4.23	0.2
Stipa elegantissima	0.5	0.1
Acacia acuminata	2.5	8.0
Acacia tetragonophylla	1.5	1.0
Ptilotus obovatus	0.4	0.1
Hakea preissii	1.5	1.0
Borya sphaerocephala	0.5	5.0
Maireana triptera	0.3	0.1
Solanum orbiculatum	0.35	0.2
Avena fatua	0.8	1.0
Aira caryophyllea	0.1	0.1
Lupinus sp	0.5	0.2
Stipa ? scabra	0.5	0.1
Eucalyptus coolabah v rhodoclada	12.0	5.0
Eucalyptus subangustata ssp s/a	10.0	0.1
Solanum lasiophyllum	0.4	1.0
Silene gallica	0.3	0.1
Chenopodium gaudichaudianum	0.4	0.1
Clematicissus angustissima	*	0.1
Comesperma intergerrimum	*	0.1
Maireana planifolia	0.2	0.1
Porana sericea	*	0.1
Mirbelia floribunda	1.5	0.1
Sida cardifolia	0.5	0.1
Pimelea microcephala	1.5	0.1

APPENDIX 2.: SURVEY SITE PLANT SPECIES LIST

SITE # [12]	Height (m)	Cover (%)
Open Low Woodland A (LAr)/Open Scrub (Sr)		
Santalum spicatum	3.0	1.0
Stipa elegantissima	0.9	0.1
Acacia resinomarginea	3.0	8.0
Acacia acuminata	4.0	6.0
Acacia tetragonophylla	3.0	2.0
Dodonaea inaequifolia	2.5	0.1
Ptilotus obovatus	0.6	0.2
Borya sphaerocephala	0.1	0.1
Helipterum cotula	0.2	1.0
Solanum ellipticum	0.2	0.1
Allocasuarina huegeliana	6.5	3.0
Aira caryophyllea	0.1	0.1
Stipa ? scabra	0.6	0.2
Acacia ? spinosissima	0.5	0.1
Acacia quadrimarginea	4.0	2.0
Acacia ? kochii	1.5	0.1
Dysphania kalpari	0.1	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [13]	Height (m)	Cover (%)
Low Woodland A (LAi)		
Santalum spicatum	2.6	1.0
Stipa elegantissima	0.45	20.0
Dianella revoluta	0.4	0.5
Olearia muelleri	0.45	2.0
Dodonaea pinifolia	0.25	0.1
Opercularia ? spermacocea	0.15	0.1
Cryptandra glabriflora	0.3	0.1
Baeckea preissiana	1.6	0.1
Verticordia venusta	0.5	0.1
Amphipogon strictus	0.2	1.0
Stipa ? flavescens	0.4	0.1
Neurachne alopecuroidea	0.15	1.0
Acacia acuminata	10.0	0.2
Daviesia sp	0.6	0.1
Acacia pulchella var subsessilis	0.4	1.0
Cassytha racemosa	*	1.0
Glischrocaryon aureum	0.4	0.1
Tricoryne elatior	0.3	0.1
Amyema miquelii	*	0.1
Hibbertia exasperata	0.2	0.1
Platysace cirrosa	0.2	0.1
Lepidosperma gracile	0.35	1.0
Mesomelaena preissii	0.2	0.1
Schoenus hexandrus	0.15	0.1
Dryandra fraseri	0.3	0.1
Dryandra armata	0.8	0.1
Isopogon divergens	1.2	0.2
Dampiera lavandulacea	0.2	0.2
Lomandra effusa	0.3	0.1
Eucalyptus wandoo	14.0	30.0
Borya sphaerocephala	0.1	15.0
Olearia ? revoluta	1.2	1.0
Keraudrenia integrifolia	0.4	0.1
Allocasuarina huegeliana	2.0	0.1
Allocasuarina campestris	2.0	4.0
Avena fatua	0.6	0.1
Briza maxima	0.2	1.0
Vulpia myuros	0.25	0.2
Portulaca sp	1.5	0.2
Leucopogon sp	0.45	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [14]	Height (m)	Cover (%)
Low Woodland A (LAi)		
Santalum spicatum	2.9	1.0
Stipa elegantissima	0.7	1.0
Dianella revoluta	0.6	0.1
Olearia muelleri	0.35	2.0
Alyxia buxifolia	0.8	0.1
Beyeria brevifolia	0.45	2.0
Cryptandra glabriflora	0.5	0.1
Melaleuca radula	1.2	0.1
Amphipogon strictus	0.45	1.0
Stipa ? flavescens	0.4	2.0
Stipa ? semibarbata	0.4	1.0
Acacia acuminata	3.0	18.0
Acacia sphacelata	1.25	2.0
Exocarpus aphyllus	1.5	0.5
Hibbertia hypericoides	0.75	0.1
Grevillea paniculata	1.2	0.1
Eucalyptus loxophleba	12.0	25.0
Borya sphaerocephala	0.15	1.0
Helichrysum bracteatum	0.1	0.5
Rhagodia drummondii	0.8	0.2
Allocasuarina campestris	1.75	1.0

SITE # [15]	Height (m)	Cover (%)
Low Woodland A (LAi)		
Santalum spicatum	3.5	4.0
Stipa elegantissima	0.7	0.2
Dianella revoluta	0.6	0.1
Stipa ? flavescens	0.65	2.0
Neurachne alopecuroidea	0.12	2.0
Aristida contorta	0.25	0.1
Acacia acuminata	5.0	15.0
Acacia lasiocalyx	2.7	0.1
Cheilanthes austrotenuifolia	0.05	0.1
Ptilotus polystachyus	0.2	0.5
Lepidosperma tenue	0.9	0.1
Hakea reflexa	3.5	10.0
Lomandra effusa	0.6	0.2
Eucalyptus salmonophloia	18.0	0.2
Borya sphaerocephala	0.08	20.0
Helichrysum bracteatum	0.25	30.0
Rhagodia drummondii	0.5	0.1
Solanum ellipticum	0.15	0.1
Allocasuarina huegeliana	4.5	0.1
Avena fatua	1.0	0.1
Hypocheris glabra	0.1	0.2
Ursinea anthemoides	0.2	0.2
Briza maxima	0.2	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [16]	Height (m)	Cover (%)
Low Forest A (LAc)		
Santalum spicatum	5.05	2.0
Stipa elegantissima	1.0	0.2
Dianella revoluta	0.8	1.0
Bossiaea aff concinna	1.6	0.2
Dodonaea viscosa ssp angustissima	1.5	0.1
Leptospermum erubescens	2.0	3.0
Neurachne alopecuroidea	0.15	2.0
Acacia acuminata	4.5	0.5
Glischrocaryon aureum	0.3	0.1
Cheilanthes sieberi	0.2	0.1
Stypandra imbricata	0.3	0.1
Tricoryne elatior	0.5	0.1
Ptilotus polystachyus	0.15	0.1
Lasiopetalum rosmarinifolium	1.7	0.5
Grevillea paniculata	1.5	0.2
Persoonia quinquenervis	1.6	0.1
Allocasuarina humilis	2.0	4.0
Allocasuarina huegeliana	12.0	40.0
Avena fatua	0.6	10.0
Hypocheris glabra	0.05	6.0
Briza maxima	0.15	5.0
Ehrharta calycina	0.15	50.0
Trifolium campestre	0.1	2.5
? *Ipomoea* sp	*	0.2
Asparagus asparagoides	*	0.2

APPENDIX 2.: SURVEY SITE PLANT SPECIES LIST

SITE # [17]	Height (m)	Cover (%)
Low Woodland A (LAi)		
Santalum spicatum	3.5	1.0
Stipa elegantissima	0.5	0.1
Dianella revoluta	0.3	0.1
Opercularia ? spermacocea	0.2	2.0
Stipa ? semibarbata	0.25	5.0
Neurachne alopecuroidea	0.2	3.0
Aristida contorta	0.25	5.0
Acacia acuminata	9.0	20.0
Acacia sphacelata	1.3	0.1
Stackhousia monogyna	0.3	0.1
Loxocarya aspera	0.15	2.0
Grevillea paniculata	1.2	10.0
Dampiera lavandulacea	0.25	2.0
Lomandra effusa	0.35	0.1
Eucalyptus loxophleba	12.0	0.2
Eucalyptus salmonophloia	19.0	1.0
Borya sphaerocephala	10.0	5.0
Olearia ? revoluta	1.4	0.1
Helichrysum bracteatum	0.2	40.0
Avena fatua	0.6	0.1
Ursinea anthemoides	0.15	0.5
Danthonia caespitosa	0.15	0.3

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [18]	Height (m)	Cover (%)
Open Woodland (Mr)/ Low Woodland A (LAi)		
Santalum spicatum	2.63	0.3
Stipa elegantissima	0.6	0.2
Dianella revoluta	0.7	2.0
Stipa ? campylachne	0.4	10.0
Aristida contorta	0.2	3.0
Acacia acuminata	7.0	20.0
Acacia tetragonophylla	1.2	0.1
Cheilanthes austrotenuifolia	0.15	1.0
Euphorbia drummondii	0.15	2.0
? Pleurosaurus sp	0.18	0.1
? Cheilanthes sp	0.2	0.1
Lepidosperma tenue	0.3	0.1
Grevillea paniculata	1.4	0.1
Hakea falcata	2.5	1.0
Eucalyptus loxophleba	16.0	7.0
Borya sphaerocephala	0.1	0.25
Helipterum cotula	0.15	2.0
Osteospermum clandestinum	0.15	0.2
Solanum ellipticum	0.1	0.1
Solanum nigrum	0.35	0.1
Enchylaena tomentosa	0.5	0.1
Avena fatua	0.8	1.0
Hypocheris glabra	0.05	1.0
Ursinea anthemoides	0.3	0.2
Danthonia caespitosa	0.35	0.1

SITE # [19]	Height (m)	Cover (%)
Woodland (Mi)		
Santalum spicatum	2.77	0.2
Dianella revoluta	0.6	0.1
Gastrolobium parviflorum	0.8	0.1
Alyxia buxifolia	0.8	0.1
Acacia acuminata	3.0	10.0
Acacia erinacea	0.3	0.1
Dodonaea inaequifolia	2.5	0.2
Hakea falcata	1.0	2.0
Eucalyptus wandoo	25.0	10.0
Eucalyptus hypochlamydea	25.0	15.0
Helichrysum bracteatum	0.15	0.5
Maireana enchylaeoides	0.18	0.2
Rhagodia preissii	1.1	0.1
Danthonia caespitosa	0.2	25.0

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [20]	Height (m)	Cover (%)
Woodland (Mi)		
Santalum spicatum	2.0	2.0
Stipa elegantissima	1.2	0.1
Dianella revoluta	0.2	0.1
Melaleuca violacea	1.5	0.2
Thryptomene cuspidata	2.0	0.1
Leptospermum erubescens	3.0	3.0
Neurachne alopecuroidea	0.1	2.0
Acacia tetragonophylla	1.0	0.1
Acacia saligna	6.0	8.0
Cassytha racemosa	*	0.1
Lepidosperma drummondii	0.5	0.2
Lepidosperma gracile	0.5	0.1
Lepidosperma pruinosum	0.4	0.1
Lomandra effusa	0.45	1.0
Dampiera lavandulacea	0.6	0.1
Xanthorrhoea reflexa	0.65	0.1
Eucalyptus salmonophloia	18.0	15.0
Olearia ? revoluta	1.3	10.0
Rhagodia preissii	1.2	0.1
Allocasuarina campestris	2.6	3.0
Allocasuarina huegeliana	14.0	10.0
class Musci	2.0	0.1

SITE # [21]	Height (m)	Cover (%)
Open Low Sedges (VLi)		
Santalum spicatum	2.7	0.2
Stipa elegantissima	0.7	0.1
Dianella revoluta	0.8	0.1
Melaleuca conothamnoides	0.45	5.0
Melaleuca subtrigona	0.3	0.1
Melaleuca macronycha	1.5	0.1
Amphipogon strictus	0.2	0.1
Cassytha racemosa	*	0.1
Drosera sp	0.4	0.1
Ecdeiocolea monostachya	0.45	25.0
Lepidosperma drummondii	0.6	0.2
Schoenus hexandrus	0.25	0.1
Harperia lateriflora	0.2	0.1
Hakea falcata	2.5	0.2
Persoonia coriacea	1.7	0.1
Borya sphaerocephala	0.1	18.0
Allocasuarina campestris	1.3	0.1
Laxmannia sp	0.05	1.0

APPENDIX 2 .: SURVEY SITE PLANT SPECIES LIST

SITE # [22]

Very Open Tree Mallee (KSr)/ Open Tall Sedges (VTi)	Height (m)	Cover (%)
Santalum spicatum	2.2	2.0
Stipa elegantissima	0.6	0.1
Verticordia sp	0.3	0.1
Melaleuca uncinata terete form	2.1	0.5
Phlebalium tuberculosum	0.8	0.1
Ecdeiocolea monostachya	0.7	20.0
Lepidosperma drummondii	0.7	2.0
Hakea invaginata var invaginata	1.8	0.1
Eucalyptus loxophleba	3.5	0.1
Eucalyptus annulata	3.5	10.0
Borya sphaerocephala	0.1	0.15
Leucopogon hamulosus	0.6	2.0

SITE # [23]

Open Low Woodland A (LAr)/ Open Tree Mallee (KTr)	Height (m)	Cover (%)
Santalum spicatum	2.0	1.0
Stipa elegantissima	0.7	0.1
Dianella revoluta	0.7	0.2
Dodonaea ptarmicaefolia	1.0	0.1
Melaleuca viminea	3.5	1.0
Melaleuca acuminata	2.6	1.0
Amphipogon strictus	0.08	0.2
Stipa ? flavescens	0.35	0.1
Acacia burkittii	2.1	8.0
Acacia saligna	2.0	1.0
Acacia patiagiata	1.3	4.0
Exocarpus sparteus	2.5	0.5
Dodonaea caespitosa	0.7	1.0
Spartochloa scirpoidea	1.3	2.0
Lepidosperma drummondii	1.0	2.0
Harperia lateriflora	0.3	1.0
Loxocarya aspera	0.15	0.2
Grevillea pectinata	0.5	0.1
Dryandra fraseri	0.4	0.1
Banksia media	4.0	0.1
Acacia assimilis ssp atroviridis	1.8	0.2
Grevillea paniculata	0.7	0.1
Lomandra rupestris	0.6	0.1
Eucalyptus perangusta	3.5	5.0
Eucalyptus scyphocalyx	3.5	5.0
Eucalyptus aff cylindrocarpa	1.5	0.1
Eucalyptus annulata	5.0	10.0
Eucalyptus perangusta	2.6	1.0
Olearia ? revoluta	1.2	3.0
Rhagodia preissii	0.7	0.1
Allocasuarina huegeliana	9.0	2.0
class Musci	0.05	2.0

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [24]	Height (m)	Cover (%)
Open Low Woodland A (LAr)/ Open Low Woodland B (LAr)		
Santalum spicatum	2.5	1.0
Labichea lanceolata v. lanceolata	1.2	0.4
Alyxia buxifolia	1.7	0.2
Dodonaea viscosa ssp angustissima	1.0	0.1
Opercularia ? spermacocea	0.15	0.4
Leptospermum fastigiatum	2.0	0.1
Indigofera astralis	1.0	0.2
Acacia acuminata	4.75	6.0
Acacia lasiocalyx	3.0	1.0
Cheilanthes sieberi	0.1	0.1
Santalum acuminatum	1.9	0.1
Pittosporum phylliraeoides	2.3	0.4
Phylanthus calycinus	0.2	0.2
Lasiopetalum rosmarinifolium	1.6	0.4
Grevillea pterosperma	0.01	5.0
Compositae sp 2 (? senecio)	0.05	0.1
Olearia ? revoluta	1.4	1.0
Helichrysum bracteatum	0.2	0.3
Senecio ? gregorii	0.25	6.0
Rhagodia preissii	1.2	2.0
Allocasuarina huegeliana	5.25	4.0
Ursinea anthemoides	0.15	0.3
class Musci	0.15	0.2
Carpobrotus edulis	0.15	5.0
Anagallis arvensis	0.05	0.4

SITE # [25]	Height (m)	Cover (%)
Woodland (Mi)		
Santalum spicatum	4.8	0.2
Templetonia retusa	0.7	5.0
Stipa ? flavescens	0.3	4.0
Stipa elegantissima	0.25	3.0
Acacia acuminata	12.0	4.0
Gahnia ancistrophylla	0.35	1.0
Eucalyptus salmonophloia	30.0	25.0
Rhagodia candolleana	0.5	2.0
Enchylaena tomentosa	0.3	1.0
Rhagodia drummondii	0.2	0.1
Avena fatua	0.3	0.2
Oxalis pes-caprae	0.2	0.2
Solanum nigrum	0.1	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [26]	Height (m)	Cover (%)
Low Woodland A (LAi)		
Santalum spicatum	3.0	3.0
Stipa elegantissima	1.2	1.0
Dianella revoluta	0.6	0.1
Stipa ? flavescens	0.25	0.2
Acacia acuminata	5.5	10.0
Hibbertia enervia	0.35	3.0
Allocasuarina huegeliana	8.0	10.0
Enchylaena tomentosa	0.6	0.2
Rhagodia drummondii	0.8	0.2
Ehrharta calycina	0.5	70.0
class Musci	0.02	0.6

SITE # [27]	Height (m)	Cover (%)
Open Woodland (Mr)		
Santalum spicatum	3.8	2.0
Stipa elegantissima	1.0	0.2
Dianella revoluta	0.9	0.2
Stipa ? flavescens	0.2	0.2
Neurachne alopecuroidea	0.1	25.0
Acacia saligna	3.5	1.0
Stackhousia huegelii	0.3	0.1
Keraudrenia hermanniifolia	1.5	5.0
Hibbertia enervia	0.8	3.0
Lepidosperma tenue	1.0	8.0
Grevillea paniculata	1.5	0.2
Dampiera lavandulacea	0.2	0.3
Lomandra effusa	0.6	1.0
Eucalyptus loxophleba	20.0	3.0
Helichrysum bracteatum	0.15	0.2
Allocasuarina campestris	4.0	2.0
Allocasuarina huegeliana	10.0	0.5
Avena fatua	0.6	2.0
Briza maxima	0.15	1.0

SITE # [28]	Height (m)	Cover (%)
Low Woodland A (LAi)		
Santalum spicatum	4.0	3.0
Dianella revoluta	1.5	0.2
Stipa ? flavescens	0.7	1.0
Acacia acuminata	13.0	20.0
Avena fatua	0.5	80.0
Hypocheris glabra	0.05	1.0

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [29]	Height (m)	Cover (%)
Scrub (Si)		
Santalum spicatum	2.56	0.8
Stipa elegantissima	1.1	0.2
Dianella revoluta	0.7	0.2
Daviesia juncea	0.25	0.2
Dodonaea pinifolia	0.5	0.1
Baeckea preissiana	1.4	0.1
Stipa ? flavescens	0.5	0.1
Neurachne alopecuroidea	0.1	0.2
Drosera sp	0.01	0.4
Stypandra imbricata	0.7	0.1
Hibbertia exasperata	0.5	0.1
Eremophila oppositifolia	0.55	0.1
Ecdeiocolea monostachya	0.9	0.25
Lepidosperma drummondii	0.9	0.4
Mesomelaena preissii	0.35	0.3
Harperia lateriflora	0.35	2.0
Hakea invaginata var invaginata	2.6	1.0
Persoonia erinacea	0.9	0.1
Burtonia conferta	0.3	0.1
Leptosema daviesioides	1.2	0.1
Lomandra hermaphrodita	0.15	0.1
Borya sphaerocephala	0.1	2.0
Helichrysum bracteatum	0.2	0.2
Allocasuarina campestris	3.5	15.0
Hypocheris glabra	0.05	0.2
Arctotheca calendula	0.02	0.1
Hordeum leporinum	0.25	0.1

SITE # [30]	Height (m)	Cover (%)
Open Low Scrub A (SAr)		
Santalum spicatum	3.4	0.8
Stipa elegantissima	1.0	0.2
Baeckea preissiana	0.5	0.2
Stipa ? flavescens	0.1	0.1
Neurachne alopecuroidea	0.05	1.0
Neurachne alopecuroidea	0.05	5.0
Acacia acuminata	6.0	6.0
Lepidosperma drummondii	0.7	0.1
Eucalyptus salmonophloia	12.0	1.0
Borya sphaerocephala	0.1	25.0
Schoenus clandestinus	0.2	15.0
Podolepis capillaris	0.2	0.1
Rhagodia drummondii	0.15	0.1
Allocasuarina campestris	2.0	10.0
Enchylaena tomentosa	0.1	0.1
Chamaescilla sp	0.05	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [31]	Height (m)	Cover (%)
Open Woodland (Mr)		
Santalum spicatum	3.25	2.0
Stipa elegantissima	0.8	1.0
Dianella revoluta	1.0	0.5
Burtonia obcordatum	0.25	0.2
Opercularia ? spermacocea	0.15	0.5
Amphipogon strictus	0.45	1.0
Stipa ? flavescens	0.55	0.5
Neurachne alopecuroidea	0.3	2.0
Acacia acuminata	6.0	18.0
Drosera sp	0.15	0.1
Stackhousia huegelii	0.25	0.2
Wurmbea tenella	0.1	0.2
Lepidosperma gracile	1.2	0.2
Loxocarya aspera	0.2	5.0
Grevillea paniculata	1.5	18.0
Dampiera lavandulacea	0.5	0.5
Eucalyptus loxophleba	16.0	7.0
Borya sphaerocephala	0.05	20.0
Helichrysum bracteatum	0.2	35.0
Helipterum cotula	0.1	0.1
Avena fatua	1.0	0.2
Ursinea anthemoides	0.3	0.2
Eucalyptus transcontinentalis	19.0	1.0

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [32]	Height (m)	Cover (%)
Open Woodland (Mr)		
Santalum spicatum	2.5	0.5
Stipa elegantissima	0.6	1.0
Dianella revoluta	0.6	0.2
Burtonia obcordatum	0.2	0.2
Stipa ? semibarbata	0.5	6.0
Neurachne alopecuroidea	0.5	0.1
Acacia acuminata	4.5	3.0
Acacia sphacelata	1.0	0.4
Melaleuca uncinata	1.2	0.1
Rhyncharrhena linearis	*	0.2
Lepidosperma drummondii	1.0	0.1
Loxocarya aspera	0.2	3.0
Grevillea paniculata	0.9	6.0
Dampiera lavandulacea	0.2	0.2
Lomandra micrantha ssp teretif.	0.2	0.1
Eucalyptus wandoo	20.0	6.0
Borya sphaerocephala	0.05	20.0
Velleia trinervis	0.05	0.1
Olearia ? revoluta	1.0	1.0
Helichrysum bracteatum	0.3	0.1
Rhagodia drummondii	0.8	0.1
Astroloma microdonta	0.3	0.1
Allocasuarina huegeliana	4.0	0.1
Enchylaena tomentosa	0.2	0.1
Avena fatua	0.7	0.1
Acaena sp	0.01	0.1
Danthonia caespitosa	0.3	1.0
Conyza bonariensis	0.05	0.1
Dampiera ? linearis	0.1	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [33]	Height (m)	Cover (%)
Tall Sedges (VTc)		
Santalum spicatum	2.88	0.4
Stipa elegantissima	0.9	1.0
Dianella revoluta	1.0	1.0
Platysace effusa	0.6	0.1
Gastrolobium calycinum	0.3	0.1
Phytomatocarpus porphyrocephalus	1.2	0.5
Amphipogon strictus	0.2	1.0
Acacia stereophylla v stereoph.	5.0	2.0
Acacia erinacea	1.0	0.1
Drosera sp	*	0.2
Cryptandra leucophracta	0.5	0.2
Hibbertia recurvifolia	0.5	0.8
Eremophila ionantha	0.5	0.3
Ecdeiocolea monostachya	0.9	40.0
Lepidosperma drummondii	0.7	0.3
Schoenus caespititius	0.4	0.4
Harperia lateriflora	0.3	0.1
Grevillea pterosperma	4.0	0.3
Hakea invaginata var invaginata	1.0	0.2
Hakea incrassata	0.8	0.2
Grevillea paradoxa	1.8	0.2
Lomandra micrantha ssp teretif.	0.2	0.1
Eucalyptus hypochlamydea	4.0	5.0
Borya sphaerocephala	0.1	2.0
Helichrysum bracteatum	0.3	0.1
Leucopogon hamulosus	0.7	0.1
Astroloma serratifolium	0.5	0.1
Allocasuarina acutivalvis	7.0	18.0
Allocasuarina huegeliana	3.0	1.0
Enchylaena tomentosa	0.5	0.2
Danthonia caespitosa	0.4	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [34]	Height (m)	Cover (%)
Open Scrub (Sr)		
Santalum spicatum	3.13	5.0
Amphipogon strictus	0.3	1.0
Stipa ? semibarbata	0.1	6.0
Aristida contorta	0.1	5.0
Poaceae sp 1	0.1	5.0
Acacia acuminata	3.0	1.0
Acacia lasiocalyx	5.0	1.0
Nicotiana occidentalis	0.3	0.3
Hibbertia glomerosa	0.2	0.2
Dampiera lavandulacea	0.2	0.1
Eucalyptus loxophleba	10.0	1.0
Borya sphaerocephala	0.2	0.5
Compositae sp	0.1	0.4
Podolepis capillaris	0.5	0.2
Senecio ? gregorii	0.2	0.1
Rhagodia preissii	3.0	1.0
Solanum orbiculatum	0.5	0.2
Solanum ellipticum	0.2	0.2
Allocasuarina campestris	3.5	1.0
Enchylaena tomentosa	0.6	2.0
Arctotheca calendula	0.05	0.4
Aira caryophyllea	0.1	0.2
Chenopodium sp	0.05	0.4

APPENDIX 2.: SURVEY SITE PLANT SPECIES LIST

SITE # [35]	Height (m)	Cover (%)
Open Low Woodland A (LAr)		
Santalum spicatum	1.44	0.2
Stipa elegantissima	0.6	0.2
Dianella revoluta	0.6	0.1
Melaleuca uncinata terete form	1.5	1.0
Melaleuca eleuterostachya	3.2	2.0
Melaleuca radula	1.8	0.2
Baeckea preissiana	1.5	2.0
Calytrix formosa	0.9	0.2
Stipa ? semibarbata	0.4	1.0
Acacia acuminata	3.5	6.0
Mirbelia microphylla	0.2	0.1
Comesperma intergerrimum	*	0.2
Cheilanthes austrotenuifolia	0.05	2.0
Drosera sp	*	0.2
Hibbertia glomerosa	0.3	0.1
Spartochloa scirpoidea	1.0	0.2
Lomandra micrantha ssp teretif.	0.1	0.1
Eucalyptus loxophleba	8.5	8.0
Borya sphaerocephala	0.1	20.0
Goodenia sp 3	0.1	0.1
Podolepis capillaris	0.2	0.1
Helichrysum bracteatum	0.2	0.4
Podotheca ? chrysantha	0.2	0.1
Maireana triptera	0.3	0.1
Solanum ellipticum	0.2	0.1
Allocasuarina campestris	2.0	6.0
Enchylaena tomentosa	0.3	0.1
Avena fatua	0.7	0.1
Ursinea anthemoides	0.2	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [36]	Height (m)	Cover (%)
Open Scrub (Sr)		
Santalum spicatum	2.0	1.0
Stipa elegantissima	0.8	1.0
Dianella revoluta	1.0	0.1
Olearia muelleri	0.4	0.1
Dodonaea viscosa ssp angustissima	1.6	1.0
Stipa ? semibarbata	0.3	0.1
Aristida contorta	0.1	0.5
Hordeum ? leporinum	0.1	0.1
Acacia burkittii	4.0	7.0
Acacia acuminata	3.0	0.2
Acacia tetragonophylla	1.0	1.0
Zygophyllum simile	0.2	0.1
Ptilotus obovatus	0.3	0.2
Pimelea spiculigera	1.3	0.1
Lycium australe	0.8	0.8
Eremophila oppositifolia	6.0	0.2
Pittosporum phylliraeoides	7.0	1.0
Eucalyptus redunca	16.0	0.2
Eucalyptus salmonophloia	22.0	0.2
Actinobole uliginosum	0.01	5.0
Velleia trinervis	0.05	1.0
Compositae sp	0.05	0.1
Olearia pimeleoides	0.7	0.1
Goodeniaceae sp	0.05	0.2
Goodeniaceae sp 1	0.2	0.1
Rhagodia drummondii	0.8	2.0
Maireana effusa	0.9	0.1
Solanum orbiculatum	0.4	0.1
Enchylaena tomentosa	0.6	0.5
Aira caryophyllea	0.1	0.2
Hordeum leporinum	0.2	0.2
Exocarpus sparteus	1.3	0.1
Danthonia caespitosa	0.4	4.0
Carpobrotus edulis	0.3	0.5
Brassicaceae sp	0.4	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [37]	Height (m)	Cover (%)
Open Woodland (Mr)		
Santalum spicatum	3.0	0.5
Stipa elegantissima	0.5	0.2
Platysace effusa	0.2	0.2
Olearia muelleri	0.4	0.2
Alyxia buxifolia	2.8	0.5
Amphipogon strictus	0.3	0.3
Stipa ? campylachne	0.3	2.0
Aristida contorta	0.1	0.2
Daviesia sp	0.9	4.0
Senna artemisioides ssp filifolia	1.3	0.3
Zygophyllum simile	0.2	0.1
Scaevola spinescens	1.2	0.8
Ptilotus exaltatus	0.05	0.5
Pimelea spiculigera	1.5	0.2
Lycium australe	1.2	0.3
Eremophila decipiens	0.6	0.1
Eremophila oppositifolia	1.0	0.2
Pittosporum phylliraeoides	3.0	1.0
Grevillea acuaria	0.8	0.2
Lomandra effusa	0.4	0.1
Eucalyptus salubris	16.0	3.0
Eucalyptus celastroides ssp vir.	10.0	0.2
Actinobole uliginosum	0.01	10.0
Velleia trinervis	0.1	0.2
Olearia exiguifolia	0.4	0.1
Senecio ? gregorii	0.1	0.1
Goodeniaceae sp	0.3	0.1
Atriplex stipitata	0.6	2.0
Sclerolaena uniflora	0.2	0.1
Rhagodia drummondii	0.6	0.2
Maireana triptera	0.3	0.2
Solanum orbiculatum	0.5	0.2
Exocarpus sparteus	2.8	1.0
Danthonia caespitosa	0.3	0.3

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [38]	Height (m)	Cover (%)
Woodland (Mi)		
Santalum spicatum	2.5	0.1
Olearia muelleri	0.4	0.5
Melaleuca lateriflora	2.1	1.0
Amphipogon strictus	0.3	0.2
Stipa ? flavescens	0.3	0.2
Acacia acuminata	2.8	0.5
Acacia colletioides	1.5	1.0
Acacia aff hemiteles	0.7	0.1
Acacia erinacea	1.2	0.2
Ptilotus polystachyus	0.3	0.2
Eremophila decipiens	0.8	0.2
Eucalyptus salubris var salubris	16.0	5.0
Eucalyptus salmonophloia	18.0	0.2
Eucalyptus salubris	20.0	30.0
Sclerolaena uniflora	0.1	0.1
Maireana triptera	0.1	0.1

APPENDIX 2.: SURVEY SITE PLANT SPECIES LIST

SITE # [39]	Height (m)	Cover (%)
Very Open Tree Mallee (KTr)/ Very Open Tall Sedges (VTr)		
Santalum spicatum	2.0	0.2
Stipa elegantissima	1.0	0.1
Dianella revoluta	0.9	0.2
Platysace effusa	0.4	0.5
Dampiera lavandulacea	0.3	0.1
Papillionaceae sp	0.6	0.2
Daviesia decurrens	0.5	0.2
Cryptandra glabriflora	0.6	0.2
*Melaleuca uncinata*flat leaf form	0.7	0.2
Melaleuca conothamnoides	1.5	0.3
Baeckea preissiana	1.2	5.0
Amphipogon strictus	0.5	4.0
Stipa ? flavescens	0.4	0.3
Neurachne alopecuroidea	0.3	0.2
Acacia acuminata	2.0	0.1
Acacia microbotrya	1.8	0.2
Acacia dielsii	1.0	2.0
Drosera sp	0.4	0.1
Santalum acuminatum	2.3	0.4
Beyeria calycina	1.1	0.8
Ecdeiocolea monostachya	0.6	8.0
Lepidosperma drummondii	1.0	0.5
Harperia lateriflora	0.3	1.0
Gahnia ancistrophylla	0.3	0.3
Hakea invaginata var invaginata	1.75	5.0
Grevillea yorkrakinensis	0.4	0.2
Dampiera lavandulacea	0.3	0.1
Eucalyptus redunca	7.0	5.0
Borya sphaerocephala	0.1	5.0
Helichrysum bracteatum	0.2	0.2
Allocasuarina campestris	2.0	3.0
Spyridium complicatum	0.3	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [40]	Height (m)	Cover (%)
Scrub (Si)		
Santalum spicatum	3.5	0.4
Stipa elegantissima	0.9	0.3
Dianella revoluta	0.6	0.2
Alyxia buxifolia	3.0	0.3
Opercularia ? spermacocea	0.1	0.1
Baeckea elderiana	2.5	0.2
Leptospermum erubescens	1.8	0.1
Stipa ? flavescens	0.5	0.2
Stipa ? semibarbata	0.4	2.0
Acacia acuminata	3.0	1.0
Acacia aff hemiteles	2.75	10.0
Senna artemisioides ssp filifolia	1.5	2.0
Comesperma intergerrimum	0.4	0.1
Cheilanthes caudata	0.2	0.2
Wurmbea tenella	0.1	0.1
Lepidosperma tenue	0.8	0.1
Grevillea paniculata	1.5	8.0
Eucalyptus wandoo	0.4	0.5
Actinobole uliginosum	0.01	2.0
Olearia pimeleoides	1.5	5.0
Podolepis capillaris	0.2	1.0
Helichrysum bracteatum	0.2	0.2
Centaurea melitensis	0.4	0.2
Allocasuarina huegeliana	2.5	0.2
Enchylaena tomentosa	0.7	0.2
Avena fatua	0.7	2.0
Hypocheris glabra	0.1	2.0
Briza maxima	0.1	0.2
Solanum nigrum	0.4	0.5

APPENDIX 2.: SURVEY SITE PLANT SPECIES LIST

SITE # [41]	Height (m)	Cover (%)
Open Low Scrub A (SAr)		
Santalum spicatum	2.2	0.3
Stipa elegantissima	1.0	0.1
*Melaleuca uncinata*flat leaf form	2.0	1.0
Amphipogon strictus	0.3	5.0
Stipa ? flavescens	0.8	1.0
Neurachne alopecuroidea	0.3	0.1
Aristida contorta	0.2	1.0
Mirbelia microphylla	1.8	2.0
Drosera sp	0.2	0.2
Stackhousia huegelii	0.2	0.2
Lepidosperma drummondii	0.8	0.2
Eucalyptus loxophleba	8.0	0.3
Borya sphaerocephala	0.05	0.1
Compositae sp	0.01	0.1
Olearia pimeleoides	1.5	1.0
Podolepis capillaris	0.2	0.1
Astroloma serratifolium	0.2	0.1
Enchylaena tomentosa	0.3	0.1
Hypocheris glabra	0.01	2.0
Solanum nigrum	0.2	0.1

SITE # [42]	Height (m)	Cover (%)
Open Woodland (Mr)		
Santalum spicatum	2.55	0.3
Stipa elegantissima	0.6	0.1
Dianella revoluta	0.6	0.1
Alyxia buxifolia	1.5	0.1
Amphipogon strictus	0.3	2.0
Stipa ? flavescens	0.6	2.0
Acacia aff hemiteles	1.0	0.1
Dampiera lavandulacea	0.2	4.0
Lomandra effusa	0.3	0.2
Eucalyptus wandoo	16.0	0.5
Eucalyptus salmonophloia	20.0	3.0
Borya sphaerocephala	0.05	0.1
Olearia pimeleoides	0.6	0.3
Podolepis capillaris	0.2	0.2
Helichrysum bracteatum	0.1	0.1
Rhagodia preissii	0.7	0.1
Solanum orbiculatum	0.5	0.1
Enchylaena tomentosa	0.2	0.2
Ursinea anthemoides	0.2	0.1
Danthonia caespitosa	0.3	0.2

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [43]	Height (m)	Cover (%)
Open Woodland (Mr)		
Santalum spicatum	2.58	0.5
Stipa elegantissima	0.5	3.0
Amphipogon strictus	0.3	5.0
Aristida contorta	0.2	0.1
Acacia anthochareara	2.8	0.2
Acacia aff hemiteles	2.0	1.0
Acacia erinacea	0.8	5.0
Senna artemisioides ssp filif.	1.2	0.5
Ptilotus exaltatus	0.4	0.2
Eremophila decipiens	0.3	0.1
Pittosporum phylliraeoides	1.0	0.2
Eucalyptus salmonophloia	22.0	4.0
Eucalyptus salubris	17.0	2.0
Podolepis capillaris	0.2	15.0
Atriplex stipitata	0.6	1.0
Maireana enchylaeoides	0.5	0.1
Rhagodia preissii	0.8	0.1
Maireana triptera	0.2	15.0
Avena fatua	0.7	8.0
Acaena sp	0.01	0.5
Trifolium campestre	0.1	0.1
Exocarpus sparteus	1.3	0.1

SITE # [44]	Height (m)	Cover (%)
Open Scrub (Sr)		
Santalum spicatum	3.4	0.2
Stipa elegantissima	0.6	0.2
Dodonaea viscosa ssp angust.	1.8	5.0
Acacia resinomarginea	4.5	1.0
Acacia longispinea	3.2	1.0
Senna artemisioides ssp filif.	1.7	0.5
Amyema miquelii	*	0.1
Ptilotus obovatus	0.4	0.2
Eucalyptus salmonophloia	20.0	1.0
Velleia trinervis	0.01	0.1
Goodeniaceae sp	0.05	0.1
Compositae sp	0.05	0.1
Olearia pimeleoides	0.7	0.1
Podolepis capillaris	0.2	0.1
Helichrysum bracteatum	0.2	0.1
Atriplex stipitata	0.4	0.8
Chenopodium gaudichaudianum	0.4	0.1
Maireana enchylaeoides	0.4	0.2
Rhagodia drummondii	0.7	0.8
Enchylaena tomentosa	0.3	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [45]	Height (m)	Cover (%)
Open Low Woodland A (LAr)/ Open Scrub (Sr)		
Santalum spicatum	3.57	0.8
Stipa elegantissima	0.3	0.1
Callitris columellaris	8.0	6.0
Acacia resinomarginea	3.5	5.0
Acacia tetragonophylla	1.8	0.2
Dodonaea inaequifolia	1.7	1.0
Comesperma intergerrimum	*	0.1
Amyema miquelii	*	0.1
Eremophila miniata	2.5	2.0
Lomandra effusa	0.6	2.0
Rhagodia drummondii	1.2	0.5
Jacksonia furcellata	2.0	0.1

SITE # [46]	Height (m)	Cover (%)
Open Dwarf Scrub (SDr)		
Santalum spicatum	2.3	0.4
Calytrix leschenaultii	0.8	0.5
Callitris columellaris	4.0	0.4
Dodonaea inaequifolia	1.3	0.2
Frankenia ambita	0.2	3.0
Verticordia pholydophylla	0.2	3.0
Maireana glomerifolia	0.4	3.0
Eremophila miniata	2.5	0.2
Lomandra effusa	0.5	0.1
Atriplex nana	0.1	1.0
Halosarcia ? syncarpa	0.4	5.0
Halosarcia ? peltata	0.2	2.0

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [47]	Height (m)	Cover (%)
Open Low Woodland A (LAr) / Scrub (Si)		
Santalum spicatum	3.2	1.0
Stipa elegantissima	0.4	0.1
Olearia muelleri	0.5	0.5
Alyxia buxifolia	2.0	0.3
Thryptomene prolifera	0.7	0.1
Acacia resinomarginea	3.5	6.0
Acacia tetragonophylla	3.3	6.0
Acacia microbotrya	1.8	2.0
Acacia erinacea	0.8	1.0
Dodonaea inaequifolia	1.5	1.0
*Senna glutinosa*ssp chatelainiana	1.5	0.1
*Senna artemisioides*ssp filifolia	1.6	1.0
Comesperma intergerrimum	*	0.2
Callitris columellaris	6.0	10.0
Baeckea maidenii	0.8	0.1
Scaevola spinescens	0.8	1.0
Ptilotus obovatus	0.4	0.3
Eremophila decipiens	1.0	1.0
Lomandra effusa	0.4	0.2
Eucalyptus corrugata	20.0	0.3
Podolepis capillaris	0.2	0.5
Exocarpus sparteus	1.8	0.4
(*Triodia scariosa*	adjacent)	

SITE # [48]	Height (m)	Cover (%)
Low Woodland A (LAi)		
Santalum spicatum	1.68	0.4
Stipa elegantissima	0.4	0.2
Olearia muelleri	0.7	5.0
Acacia acuminata	2.0	0.4
Acacia aneura	3.0	2.0
Acacia aff hemiteles	2.0	2.0
Senna artemisioides ssp filif.	1.2	0.3
Scaevola spinescens	1.5	1.0
Ptilotus obovatus	0.4	0.2
Eremophila drummondii	0.8	1.0
Eucalyptus loxophleba	12.0	16.0
Eucalyptus corrugata	14.0	12.0
Olearia pimeleoides	0.7	4.0
Helichrysum bracteatum	0.2	0.2
Rhagodia drummondii	0.5	0.3
Rhagodia preissii	0.7	0.2
Maireana triptera	0.4	0.1
Enchylaena tomentosa	0.2	0.1
Exocarpus sparteus	2.0	0.5

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [49]	Height (m)	Cover (%)
Open Low Woodland A (LAr) / Open Low Woodlan B (LBr)		
Santalum spicatum	5.5	0.4
Stipa elegantissima	0.6	2.3
Bossiaea aquifolium	0.5	0.2
Gastrolobium calycinum	1.0	0.2
Daviesia cardiophylla	0.4	0.2
Dodonaea pinifolia	0.5	0.2
Melaleuca subtrigona	0.3	0.1
Baeckea preissiana	0.9	0.1
Neurachne alopecuroidea	0.2	5.0
Acacia acuminata	4.0	0.2
Dampiera lindleyi	0.3	0.1
Acacia pulchella var subsessilis	0.4	0.2
Acacia stenoptera	0.3	0.2
Cassytha racemosa	*	0.3
Drosera sp	0.3	1.0
Lepidosperma drummondii	0.6	0.5
Loxocarya aspera	0.2	0.3
Dryandra armata	0.8	1.0
Persoonia ? quinquenervis	0.2	0.1
Hakea trifurcata	1.2	10.0
Hakea erinacea	0.2	0.2
Dampiera lavandulacea	0.3	0.1
Xanthorrhoea reflexa	1.0	0.1
Eucalyptus wandoo	10.0	3.0
Borya sphaerocephala	0.05	1.0
Schoenus clandestinus	0.01	2.0
Allocasuarina ? fibrosa	0.3	0.2
Allocasuarina humilis	1.2	0.2
Allocasuarina huegeliana	4.0	3.0
Avena fatua	0.7	0.2
Lepidosperma tenue	0.4	0.1
Chamaescilla sp	0.05	0.1
Gompholobium sp	0.2	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [50]	Height (m)	Cover (%)
Open Dwarf Scrub D (SDr)		
Santalum spicatum	5.0	0.3
Stipa elegantissima	0.5	0.5
Bossiaea aquifolium	1.1	0.2
Daviesia cardiophylla	0.3	0.1
Opercularia ? spermacocea	0.2	0.5
Cryptandra nutans	0.3	0.1
Calothamnus quadrifidus	2.1	1.5
Leptospermum erubescens	0.8	0.1
Neurachne alopecuroidea	0.2	2.0
Acacia acuminata	3.8	0.3
Drosera sp	0.3	2.0
Santalum acuminatum	3.5	2.0
Harperia lateriflora	0.2	0.5
Dryandra cirsioides	0.6	2.0
Isopogon divergens	1.0	3.0
Hakea incrassata	2.5	0.2
Persoonia coriacea	1.5	1.0
Xanthorrhoea reflexa	0.8	0.4
Borya sphaerocephala	0.05	0.1
Allocasuarina ? fibrosa	0.2	0.1
Allocasuarina huegeliana	2.5	0.5
Avena fatua	0.7	1.0
Hypocheris glabra	0.2	0.2
Briza maxima	0.2	0.1
Acaena sp	0.05	0.2
Romulea rosea	0.15	0.1
Acacia aff pulchella	0.3	0.2
Laxmannia sp	0.01	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [51]	Height (m)	Cover (%)
Open Low Woodland A (LAr)		
Santalum spicatum	4.0	0.2
Stipa elegantissima	0.9	0.8
Dianella revoluta	0.2	0.1
Melaleuca scabra	0.6	0.1
Melaleuca subtrigona	0.4	0.2
Calothamnus sangineus	0.8	1.5
Verticordia venusta	0.5	0.2
Stipa ? semibarbata	0.7	1.0
Neurachne alopecuroidea	0.05	0.3
Acacia filifolia	1.6	2.0
Acacia acuminata	3.8	0.2
Hemiandra incana	0.3	0.1
Lepidosperma drummondii	0.6	0.2
Mesomelaena preissii	0.5	5.0
Harperia lateriflora	0.25	10.0
Synaphaea spinulosa	0.3	0.5
Petrophile seminuda	0.6	0.2
Dampiera lavandulacea	0.2	0.5
Compositae sp	0.01	0.1
Helichrysum bracteatum	0.3	0.4
Allocasuarina ? fibrosa	0.3	0.1
Allocasuarina huegeliana	5.0	3.0
Ursinea anthemoides	0.05	0.1
Loxocarya fasciculata	0.5	0.2

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [52]	Height (m)	Cover (%)
Low Scrub A (SAi) / Open Low Sedges (VLr)		
Santalum spicatum	3.8	0.7
Daviesia decurrens	0.3	0.1
Opercularia ? spermacocea	0.1	2.0
Cryptandra glabriflora	0.5	0.5
Melaleuca scabra	0.7	0.1
Calothamnus quadrifidus	0.3	1.0
Olearia propinqua	0.4	0.2
Calytrix ? formosa	0.3	0.1
Baeckea pulchella	0.4	0.1
Neurachne alopecuroidea	0.2	0.5
Acacia stenoptera	0.2	0.1
Cassytha racemosa	0.1	0.1
Lepidosperma viscidum	0.3	0.2
Mesomelaena preissii	0.5	15.0
Schoenus subbarbatus	0.1	0.1
Harperia lateriflora	0.3	5.0
Persoonia coriacea	0.3	0.3
Persoonia ? quinquenervis	0.3	0.5
Borya sphaerocephala	0.1	0.2
Laxmannia sp	0.01	0.1
Anarthria polyphylla	0.2	0.1
Astroloma microdonta	0.3	0.1
Andersonia lehmanniana	0.2	0.1
Allocasuarina campestris	1.8	12.0
Ursinea anthemoides	0.2	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [53]	Height (m)	Cover (%)
Very Open Low Sedges (VLr) / Open Scrub (Sr)		
Santalum spicatum	3.8	0.4
Stipa elegantissima	0.6	0.4
Dianella revoluta	0.7	0.8
Daviesia cardiophylla	0.3	0.1
Opercularia ? spermacocea	0.1	0.6
Cryptandra nutans	0.6	0.2
Melaleuca subtrigona	0.8	0.5
Baeckea crispiflora	0.6	0.8
Amphipogon strictus	0.3	0.2
Neurachne alopecuroidea	0.1	1.0
Acacia sessilis	0.6	0.1
Dampiera lindleyi	0.4	0.1
Drosera sp	*	0.4
Comesperma scoparium	0.3	0.1
Mesomelaena preissii	0.4	10.0
Harperia lateriflora	0.2	0.5
Dryandra fraseri	0.4	0.2
Lomandra effusa	0.3	0.1
Borya sphaerocephala	0.1	2.0
Podolepis capillaris	0.2	0.1
Helichrysum bracteatum	0.2	1.0
Allocasuarina campestris	2.8	5.0
Allocasuarina humilis	1.0	0.3
Allocasuarina huegeliana	4.0	0.4
Avena fatua	0.7	2.0
Hypocheris glabra	0.01	0.3
class Musci	0.02	5.0
Asparagus asparagoides	*	0.3
Solanum nigrum	0.4	0.1
Cassytha racemosa	*	0.1
Banksia prionotes	5.0	0.3
Banksia sphaerocarpa	1.2	8.0

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [54]	Height (m)	Cover (%)
Open Low Woodland A (LAr)		
Santalum spicatum	2.5	3.5
Stipa elegantissima	0.4	0.2
Dianella revoluta	1.0	1.0
Calytrix leschenaultii	0.6	0.1
Neurachne alopecuroidea	0.1	9.0
Acacia acuminata	3.0	3.0
Cheilanthes sieberi	0.3	0.1
Gahnia trifida	1.0	0.5
Loxocarya aspera	0.15	3.0
Hakea erinacea	1.2	2.0
Lomandra effusa	0.3	0.2
Eucalyptus wandoo	14.0	5.0
Laxmannia sp	0.05	10.0
Osteospermum clandestinum	0.15	2.0
Podolepis ? auriculata	0.1	0.1
Allocasuarina huegeliana	5.0	8.0
Enchylaena tomentosa	0.2	0.1
Avena fatua	0.6	0.5
Hypocheris glabra	0.01	18.0
Ursinea anthemoides	0.2	10.0
Arctotheca calendula	0.01	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [55]	Height (m)	Cover (%)
Open Low Sedges (VLi) / Open Dwarf Scrub D (SDr)		
Santalum spicatum	2.92	0.4
Stipa elegantissima	0.6	0.5
Dianella revoluta	0.7	0.1
Daviesia decurrens	0.5	0.1
Daviesia cardiophylla	0.7	0.1
Cryptandra nutans	0.2	0.1
Melaleuca subtrigona	0.4	5.0
Calothamnus quadrifidus	1.2	0.1
Baeckea preissiana	0.8	0.1
Calytrix leschenaultii	0.9	0.2
Amphipogon strictus	0.2	0.5
Stipa ? semibarbata	0.6	0.1
Neurachne alopecuroidea	0.3	0.1
Acacia acuminata	4.0	0.1
Cassytha racemosa	*	0.3
Glischrocaryon aureum	0.3	0.1
Drosera sp	*	0.2
Comesperma scoparium	0.4	0.1
Amyema miquelii	*	0.1
Lepidosperma viscidum	0.4	0.1
Mesomelaena preissii	0.4	4.0
Schoenus hexandrus	0.2	0.1
Harperia lateriflora	0.2	15.0
Gahnia trifida	0.5	0.1
Dryandra fraseri	0.1	0.1
Isopogon divergens	1.5	0.5
Hakea incrassata	0.2	0.1
Persoonia ? quinquenervis	0.2	0.2
Hakea erinacea	0.3	0.1
Dampiera lavandulacea	0.2	1.0
Borya sphaerocephala	0.1	0.2
Helichrysum bracteatum	0.3	5.0
Allocasuarina campestris	2.5	0.3
Allocasuarina huegeliana	4.0	0.2
Enchylaena tomentosa	0.7	0.1
Ursinea anthemoides	0.2	0.1
Briza maxima	0.1	0.2
Asparagus asparagoides	*	0.1
Gastrolobium ? polystachyum	0.2	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [56]	Height (m)	Cover (%)
Open Low Woodland A (LAr)		
Santalum spicatum	4.0	0.3
Stipa elegantissima	0.6	0.1
Dianella revoluta	0.3	0.1
Melaleuca scabra	2.0	0.1
Calytrix leschenaultii	0.5	0.2
Stipa ? flavescens	0.6	5.0
Neurachne alopecuroidea	0.2	0.2
Acacia acuminata	5.0	0.2
Thysanotus manglesianus	0.2	0.1
Lepidosperma drummondii	0.8	20.0
Lomandra effusa	0.2	0.1
Eucalyptus loxophleba	12.0	10.0
Podolepis capillaris	0.2	0.4
Helichrysum bracteatum	0.2	0.2
Rhagodia preissii	2.0	0.2
Maireana triptera	0.2	0.2
Allocasuarina obesa	7.0	0.1

SITE # [57]	Height (m)	Cover (%)
Open Low Woodland A (LAr)		
Santalum spicatum	5.8	0.1
Melaleuca scabra	2.5	0.5
Stipa elegantissima	0.3	0.1
Eucalyptus wandoo	16.0	1.0
Podolepis capillaris	0.2	0.4
Maireana triptera	0.1	0.1
Allocasuarina campestris	2.0	0.3
Allocasuarina obesa	7.0	8.0
Carpobrotus edulis	0.1	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [58]	Height (m)	Cover (%)
Open Low Woodland A (LAr) / Dwarf Scrub D (SDi)		
Santalum spicatum	3.5	0.5
Stipa elegantissima	0.8	1.0
Olearia muelleri	0.4	0.1
Jacksonia restioides	0.4	0.1
Opercularia ? spermacocea	0.1	0.8
Melaleuca subtrigona	0.4	2.0
Verticordia venusta	1.0	2.0
Calytrix leschenaultii	0.5	0.1
Amphipogon strictus	0.3	0.2
Stipa ? flavescens	0.6	0.2
Neurachne alopecuroidea	0.1	0.2
Acacia acuminata	3.25	0.2
Acacia dielsii	0.3	0.1
Glischrocaryon aureum	0.3	0.1
Drosera sp	*	0.1
Stackhousia huegelii	0.7	0.2
Santalum acuminatum	2.0	2.0
Hibbertia exasperata	0.4	0.1
Lepidosperma gracile	0.4	0.2
Mesomelaena preissii	0.7	4.0
Schoenus caespititius	0.3	0.4
Harperia lateriflora	0.2	3.0
Dryandra cirsioides	1.0	0.3
Hakea invaginata var invaginata	1.5	0.3
Petrophile megalostegia	0.4	0.1
Hakea incrassata	0.2	0.1
Persoonia ? quinquenervis	0.4	0.2
Hakea erinacea	0.4	0.1
Conostylis dielsii	0.2	0.1
Borya sphaerocephala	0.05	0.2
Verticordia chrysantha	0.4	0.3
Helichrysum bracteatum	0.3	2.0
Leucopogon dielsianus	0.4	0.1
Allocasuarina campestris	2.6	1.0
Allocasuarina huegeliana	8.0	10.0

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [59]	Height (m)	Cover (%)
Low Woodland A (LAi)		
Santalum spicatum	2.8	0.8
Stipa elegantissima	0.6	10.0
Dianella revoluta	0.5	0.2
Opercularia ? spermacocea	0.1	0.1
Melaleuca subtrigona	0.5	0.2
Calytrix leschenaultii	0.8	0.2
Amphipogon strictus	0.2	8.0
Stipa ? flavescens	0.5	0.2
Neurachne alopecuroidea	0.1	0.1
Acacia acuminata	2.0	0.4
Ptilotus obovatus	0.2	0.4
Lepidosperma drummondii	0.5	0.2
Mesomelaena preissii	0.3	0.2
Schoenus subbarbatus	0.1	0.1
Hakea invaginata var invaginata	1.0	0.3
Dampiera lavandulacea	0.1	0.1
Lomandra effusa	0.4	0.1
Eucalyptus wandoo	12.0	20.0
Borya sphaerocephala	0.05	0.1
Conostephium preissii	1.8	0.2
Allocasuarina campestris	1.5	0.1
Carpobrotus edulis	0.1	0.1
Burchardia sp	0.2	0.1

SITE # [60]	Height (m)	Cover (%)
Open Low Woodland A (LAr)		
Acacia acuminata	6.0	10.0
Acacia lasiocalyx	6.0	0.5
Santalum acuminatum	3.5	8.0
Ursinea anthemoides	0.1	1.0
Aira caryophyllea	0.1	0.5
Allocasuarina obesa	14.0	1.0
Jacksonia furcellata	2.0	2.0
Conyza bonariensis	0.1	1.0

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [61]	Height (m)	Cover (%)
Low Woodland A (Lai)		
Santalum spicatum	4.5	0.3
Stipa elegantissima	0.7	0.5
Dianella revoluta	0.8	0.2
Stipa ? flavescens	0.5	1.0
Acacia acuminata	8.5	5.0
Rhyncharrhena linearis	*	0.2
Arthropodium capillipes	0.2	0.6
Pelargonium havlasae	0.01	0.1
Eucalyptus loxophleba	15.0	18.0
Osteospermum clandestinum	0.4	1.0
Avena fatua	0.4	85.0
Ehrharta calycina	0.4	0.2
Hordeum leporinum	0.3	0.1
class Musci	0.02	8.0
Anagallis arvensis	0.05	1.0

SITE # [62]	Height (m)	Cover (%)
Low Woodland A (LAi)		
Santalum spicatum	1.35	0.2
Stipa elegantissima	0.6	0.3
Dianella revoluta	0.5	0.2
Opercularia ? spermacocea	0.2	0.5
Amphipogon strictus	0.6	5.0
Neurachne alopecuroidea	0.1	0.3
Acacia acuminata	6.0	12.0
Rhyncharrhena linearis	*	0.2
Drosera sp	*	0.1
Stypandra imbricata	0.5	1.0
Arthropodium capillipes	0.2	0.3
Pelargonium havlasae	0.1	1.0
Lepidosperma tenue	0.5	0.2
Dampiera lavandulacea	0.2	0.2
Eucalyptus loxophleba	12.0	20.0
Allocasuarina campestris	2.0	0.1
Allocasuarina huegeliana	4.5	0.1
Briza maxima	0.4	0.3
Acaena sp	0.1	0.2
Ehrharta calycina	0.5	0.2
class Musci	0.02	0.8

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [63]	Height (m)	Cover (%)
Open Low Sedges (VLi) / Open Dwarf Scrub D (SDr)		
Santalum spicatum	3.5	0.2
Stipa elegantissima	0.7	0.5
Dianella revoluta	0.7	0.5
Daviesia juncea	0.4	0.1
Opercularia ? spermacocea	0.1	0.5
Melaleuca subtrigona	0.7	2.0
Thryptomene prolifera	0.3	0.1
Leptospermum erubescens	0.7	0.1
Amphipogon strictus	0.6	2.0
Neurachne alopecuroidea	0.05	0.2
Acacia acuminata	5.0	0.2
Cheilanthes caudata	0.5	0.1
Tricoryne elatior	0.2	0.1
Hibbertia exasperata	0.3	0.1
class Musci	0.1	0.1
Mesomelaena preissii	0.4	0.4
Schoenus subbarbatus	0.1	0.1
Harperia lateriflora	0.3	26.0
Petrophile aff ericifolia	0.4	0.1
Grevillea pterosperma	1.2	0.1
Hakea erinacea	0.6	0.6
Allocasuarina campestris	2.2	0.1
Hypocheris glabra	0.01	2.0
Ursinea anthemoides	0.1	1.0
Acaena sp	0.01	0.1
Aira caryophyllea	0.2	0.1
Ehrharta calycina	0.5	0.4
Danthonia caespitosa	0.1	0.1
Banksia sphaerocarpa	2.1	0.2

SITE # [64]	Height (m)	Cover (%)
Open Woodland (Mr) / Open Low Woodland A (LAr)		
Santalum spicatum	3.9	0.2
Stipa elegantissima	0.5	0.2
Dianella revoluta	0.8	0.5
Stipa ? flavescens	0.5	0.5
Acacia acuminata	7.0	6.0
Acacia lasiocalyx	4.5	1.0
Arthropodium capillipes	0.3	0.2
Romulea rosea	0.6	2.0
Halgania preissiana	0.2	0.3
Lepidosperma drummondii	0.8	4.0
Xanthorrhoea reflexa	0.8	0.2
Eucalyptus loxophleba	18.0	3.0
Keraudrenia integrifolia	0.5	0.1
Ehrharta calycina	0.5	70.0

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [65]	Height (m)	Cover (%)
Open Low Scrub A (SAr)		
Santalum spicatum	3.68	0.8
Stipa elegantissima	0.5	0.1
Dianella revoluta	0.6	0.1
Muehlenbeckia adpressa	0.4	0.1
Dodonaea viscosa ssp angustissima	2.0	2.0
Darwinia sp	0.8	0.2
Sporobolus virginicus	0.4	0.1
Stipa ? campylachne	0.6	0.1
Hordeum ? leporinum	0.2	15.0
Acacia acuminata	4.5	0.2
Cheilanthes caudata	0.3	0.2
Ptilotus polystachyus	0.5	3.0
Pittosporum phylliraeoides	1.2	0.1
Spartochloa scirpoidea	1.2	0.1
Erodium botrys	0.05	0.1
Osteospermum clandestinum	0.3	0.1
Rhagodia drummondii	1.0	0.2
Allocasuarina huegeliana	6.0	0.5
Avena fatua	0.2	20.0
Hypocheris glabra	0.05	0.3
Briza maxima	0.2	0.1
Arctotheca calendula	0.01	0.1
class Musci	0.01	30.0
Lupinus sp	0.3	2.0
Portulaca sp	0.01	0.1
Conyza bonariensis	0.2	0.1
Mitrasacme paradoxa	0.01	5.0

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [66]	Height (m)	Cover (%)
Open Low Woodland A (LAr) / Low Scrub A (SAi)		
Santalum spicatum	2.5	0.1
Dodonaea caespitosa	0.3	0.2
Melaleuca uncinata terete form	2.0	18.0
Melaleuca uncinata	1.4	0.2
Melaleuca scabra	0.7	0.2
Melaleuca platycalyx	0.7	0.2
Melaleuca adnata	0.7	0.4
Melaleuca macronychia	1.8	0.4
Calytrix formosa	0.8	0.1
Leptospermum erubescens	1.3	0.1
Stipa ? semibarbata	0.2	0.1
Neurachne alopecuroidea	0.1	0.1
Acacia resinomarginea	2.0	0.1
Acacia lachnophylla	0.5	0.4
Drosera sp	*	0.1
Santalum acuminatum	3.1	0.2
Stylidium repens	0.1	3.0
Spartochloa scirpoidea	0.5	0.2
Lepidosperma drummondii	0.3	0.1
Schoenus sp	0.3	0.1
Grevillea paniculata	1.4	0.1
Eucalyptus loxophleba	6.0	10.0
Borya sphaerocephala	0.1	0.1
Olearia ? revoluta	0.5	0.4
Helichrysum bracteatum	0.2	0.1
Allocasuarina campestris	2.0	25.0
Ursinea anthemoides	0.1	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [67]	Height (m)	Cover (%)
Low Woodland A (LAi) / Low Scrub A (SAi)		
Santalum spicatum	3.3	0.3
Stipa elegantissima	0.6	0.2
Dianella revoluta	0.6	0.1
Melaleuca uncinata terete form	2.3	0.3
Melaleuca cuneata	2.2	0.2
Melaleuca scabra	1.8	12.0
Melaleuca platycalyx	2.0	0.2
Melaleuca macronychia	2.0	0.5
Leptospermum erubescens	1.4	0.8
Stipa ? flavescens	0.5	0.2
Neurachne alopecuroidea	0.05	0.1
Acacia acuminata	6.5	5.0
Drosera sp	0.1	0.1
Stackhousia huegelii	0.2	0.1
Stylidium repens	0.05	0.1
Arthropodium capillipes	0.1	0.2
Hibbertia enervia	0.2	0.1
Loxocarya aspera	0.1	0.1
Grevillea sarissa	0.5	0.1
Lomandra effusa	0.2	1.0
Eucalyptus cylindriflora	11.0	18.0
Borya sphaerocephala	0.05	0.1
Olearia ? revoluta	0.8	0.3
Podolepis capillaris	0.1	0.5
Helichrysum bracteatum	0.2	0.2
Allocasuarina humilis	2.3	0.2
Aira caryophyllea	0.1	0.1
class Musci	0.02	2.0

SITE # [68]	Height (m)	Cover (%)
Low Woodland A (LAi)		
Santalum spicatum	3.0	2.0
Calytrix leschenaultii	0.3	0.2
Chamelaucium ciliatum	0.7	0.1
Stipa ? flavescens	0.5	0.1
Acacia acuminata	4.0	3.0
Stackhousia huegelii	0.2	0.1
Stylidium repens	0.01	25.0
Wurmbea tenella	0.05	0.1
Spartochloa scirpoidea	1.2	0.2
Eucalyptus loxophleba	12.0	20.0
Compositae sp	0.01	1.0
Olearia ? propinqua	0.2	0.1
Olearia ? revoluta	1.2	0.3
Helichrysum bracteatum	0.2	0.2
Allocasuarina huegeliana	8.5	0.2
class Musci	0.01	0.5

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [69]	Height (m)	Cover (%)
Woodland (Mi)		
Santalum spicatum	3.5	0.2
Olearia muelleri	0.5	4.0
Melaleuca uncinata terete form	2.2	0.2
Melaleuca uncinata	2.2	0.1
Melaleuca platycalyx	0.6	0.1
Stipa ? flavescens	0.1	0.1
Neurachne alopecuroidea	0.05	0.1
Acacia acuminata	3.0	1.0
Acacia aff hemiteles	0.6	0.4
Hakea preissii	2.8	0.1
Lomandra effusa	0.2	0.6
Eucalyptus loxophleba	12.0	8.0
Eucalyptus salmonophloia	24.0	12.0
Eucalyptus annulata	5.0	0.3
Podolepis capillaris	0.2	0.4
Osteospermum clandestinum	0.02	0.1
Chenopodium gaudichaudianum	0.4	0.2
Rhagodia preissii	0.9	0.1
Ursinea anthemoides	0.1	0.2
Acacia ? dermatophylla	0.3	2.0

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [70]	Height (m)	Cover (%)
Open Low Woodland B (LBr) / Open Dwarf Scrub C (SCr)		
Santalum spicatum	2.08	0.4
Stipa elegantissima	0.5	0.1
Pimelea argentea	0.7	1.0
Alyxia buxifolia	2.0	0.1
Dodonaea viscosa ssp angustissima	1.5	0.2
Stipa ? semibarbata	0.3	0.1
Neurachne alopecuroidea	0.1	0.2
Hordeum ? leporinum	0.1	4.0
Iseilema sp	0.6	0.2
Acacia acuminata	6.0	0.4
Cheilanthes caudata	0.15	0.2
Euphorbia drummondii	0.1	0.1
Drosera sp	0.3	0.1
Ptilotus polystachyus	0.2	0.2
Pittosporum phylliraeoides	2.2	1.0
Wurmbea tenella	0.05	0.1
Crassula colorata	0.02	1.0
Pelargonium havlasae	0.1	0.3
Spartochloa scirpoidea	1.0	0.5
Hakea invaginata var invaginata	2.1	0.2
Dampiera lavandulacea	0.2	0.5
Eucalyptus loxophleba	7.0	0.3
Rhaphanus sp	0.2	0.1
Erodium botrys	0.02	1.0
Velleia trinervis	0.05	0.1
Compositae sp	0.05	0.1
Osteospermum clandestinum	0.5	0.1
Allocasuarina huegeliana	4.0	4.0
Avena fatua	0.4	0.6
Hypocheris glabra	0.01	0.4
Ursinea anthemoides	0.1	0.3
class Musci	0.01	25.0
Aristida contorta	0.1	0.2
Portulaca sp	0.01	0.5

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [71]	Height (m)	Cover (%)
Open Woodland (Mr) / Open Low Woodland A (LAr)		
Santalum spicatum	2.6	0.1
Stipa elegantissima	0.3	0.2
Dianella revoluta	0.6	0.1
Gastrolobium parviflorum	1.8	0.1
Melaleuca uncinata terete form	3.8	0.1
Leptospermum erubescens	0.5	0.1
Amphipogon strictus	0.2	0.1
Stipa ? flavescens	0.2	0.2
Stipa ? semibarbata	0.2	0.5
Neurachne alopecuroidea	0.05	0.1
Acacia stereophyllav stereophylla	0.8	0.1
Acacia acuminata	3.0	0.2
Drosera sp	*	0.1
Santalum acuminatum	2.5	0.5
Westringia rigida	0.4	0.2
Lepidosperma drummondii	0.5	6.0
Harperia lateriflora	0.2	0.1
Grevillea sarissa	1.1	0.4
Lomandra effusa	0.3	0.2
Eucalyptus loxophleba	8.0	8.0
Eucalyptus salmonophloia	18.0	8.0
Borya sphaerocephala	0.05	5.0
Compositae sp	0.05	0.1
Podolepis capillaris	0.2	0.1
Ursinea anthemoides	0.1	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE # [72]	Height (m)	Cover (%)
Heath A (SAc)		
Santalum spicatum	2.0	0.4
Stipa elegantissima	0.7	0.2
Platysace effusa	0.5	0.3
Cryptandra nutans	0.2	0.1
Melaleuca platycalyx	0.4	0.2
Calytrix leschenaultii	0.6	0.1
Amphipogon strictus	0.3	3.0
Stipa ? flavescens	0.6	0.1
Neurachne alopecuroidea	0.2	0.1
Acacia filifolia	3.5	0.1
Cassytha racemosa	*	0.2
Drosera sp	0.3	0.1
Stypandra imbricata	0.4	0.4
Hibbertia recurvifolia	0.4	0.3
Lepidosperma drummondii	0.4	0.1
Harperia lateriflora	0.2	0.1
Grevillea yorkrakinensis	0.2	0.2
Dampiera lavandulacea	0.2	0.1
Lomandra micrantha ssp teretif.	0.3	0.1
Borya sphaerocephala	0.05	10.0
Helichrysum bracteatum	0.2	0.2
Leucopogon hamulosus	0.5	0.1
Allocasuarina campestris	1.8	60.0

SITES CENSUSSED AFTER THE INITIAL SURVEY

(The initial site was based on Santalum acuminatum at the north of Lake Toolibin, this site was on the eastern aeolian dune.)

SITE 60	Height (m)	Cover (%)
Eucalyptus loxophleba	18.0	10.0
Allocasuarina fraseriana	16.0	1.0
Acacia acuminata	15.0	5.0 (42% dead)
Santalum spicatum	4.0	0.5
Ptilotus polystachyus	0.6	20.0
Ursinea anthemoides	0.25	2.0
Helichrysum bracteatum	0.3	2.0
Brassica sp	0.5	0.2
Aira caryophyllea	0.1	0.2
Podotheca ? angustifolia	0.1	0.5
Euphorbia sp	0.15	0.1
Avena fatua	0.6	0.5
Stipa sp	0.6	0.5
Danthonia sp	0.6	0.1
Stypandra imbricata	0.2	0.1
? *Amphipogon* sp	0.3	0.1

APPENDIX 2 : SURVEY SITE PLANT SPECIES LIST

SITE 23	Height (m)	Cover (%)
(This site was located 200m west of the original and contrasted strongly with it, as it was an open low sedgeland with occaisional low trees over shallow rock. It was reminiscent of the central sedgelands and sandy laterites.)		
Allocasuarina huegeliana	8.0	5.0
Acacia saligna	2.0	1.0
Santalum spicatum	2.5	0.3
Melaleuca ? scabra	0.5	1.0
Lepidosperma ? tenue	0.6	15.0
Grevillea pectinata	1.2	0.5
Loxocarya cinerea	0.3	15.0
Persoonia ? striata	0.6	1.0
Jacksonia furcellata	2.0	0.1
Lepidosperma drummondii	0.8	0.5
Olearia ? revoluta	0.6	0.5

GERALDTON ROADSIDE	Height (m)	Cover (%)
(This site was near the embankment zone of a flowline between hills and had exposed rock which appeared like dolerite.)		
Eucalyptus rudis	14.0	1.0
Acacia acuminata	5.0	30.0
Grevillea sp	2.5	1.0
Dodonaea sp	3.0	1.0
Porana sp	*	0.1
Clematicissus angustissima	*	0.1
Themeda australis	0.6	0.5
Avena fatua	0.7	30.0
Briza maxima	0.3	30.0
Ehrharta brevifolia	0.3	15.0
Amyema miquelii	*	0.3
Amyema sp	*	0.3

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

class Musci	12
ADIANTACEAE	
Cheilanthes austrotenuifolia	3
Cheilanthes caudata	4
Cheilanthes sieberi	3
? *Cheilanthes* sp.	
ASPLENIACEAE	
? *Pleurosaurus* sp.	
CUPRESSACEAE	
Callitris columellaris	3
POACEAE	
Triodia scariosa	
Amphipogon strictus	21
Aristida contorta	10
Danthonia caespitosa	10
Eragrostis sp.	
Hordeum ? leporinum	3
Iseilema sp.	
Neurachne alopecuroidea	35
Poaceae sp. 1	
Spartochloa scirpoidea	6
Sporobolus virginicus	
Stipa ? campylachne	9
Stipa ? flavescens	27
Stipa ? scabra	2
Stipa ? semibarbata	12
Stipa elegantissima	57
Stipa ? tenuiglumis	
Aira caryophyllea	9
Avena fatua	26
Briza maxima	9
Ehrharta calycina	9
Hordeum leporinum	5
Vulpia myuros	3

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

CYPERACEAE	
Gahnia ancistrophylla	2
Gahnia trifida	2
Lepidosperma drummondii	18
Lepidosperma gracile	4
Lepidosperma pruinosum	
Lepidosperma tenue	8
Lepidosperma viscidum	2
Mesomelaena preissii	10
Schoenus caespititius	2
Schoenus clandestinus	2
Schoenus hexandrus	3
Schoenus subbarbatus	3
Schoenus sp.	
RESTIONACEAE	
Anarthria polyphylla	
Ecdeiocolea monostachya	5
Harperia lateriflora	14
Loxocarya aspera	9
Loxocarya fasciculata	
ASPARAGACEAE	
Asparagus asparagoides	3
DASYPOGONACEAE	
Acanthocarpus preissii	
Lomandra effusa	17
Lomandra hermaphrodita	
Lomandra micrantha ssp. teretifolia	4
Lomandra rupestris	
Lomandra effusa	
XANTHORRHOEACEAE	
Xanthorrhoea reflexa	4
PHORMIACEAE	
Dianella revoluta	39
Stypandra imbricata	4

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

ANTHERICACEAE	
Arthropodium capillipes	4
Borya sphaerocephala	33
Chamaescilla sp.	2
Laxmannia sp.	4
Thysanotus manglesianus	
Tricoryne elatior	3
COLCHICACEAE	
Burchardia sp.	
Wurmbea tenella	4
HAEMODORACEAE	
Conostylis dielsii	
IRIDACEAE	
Romulea rosea	4
CASUARINACEAE	
Allocasuarina ? fibrosa	3
Allocasuarina acutivalvis	
Allocasuarina campestris	20
Allocasuarina huegeliana	25
Allocasuarina humilis	4
Allocasuarina obesa	4
PROTEACEAE	
Banksia media	
Banksia prionotes	
Banksia sphaerocarpa	2
Dryandra armata	2
Dryandra cirsioides	2
Dryandra fraseri	4
Grevillea acuaria	
Grevillea paniculata	10
Grevillea paradoxa	
Grevillea pectinata	
Grevillea pterosperma	3
Grevillea sarissa	2
Grevillea yorkrakinensis	2

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

PROTEACEAE (Continued)	
Hakea ? prostrata	
Hakea erinacea	5
Hakea falcata	3
Hakea incrassata	4
Hakea invaginata var invaginata	7
Hakea preissii	5
Hakea reflexa	
Hakea trifurcata	
Isopogon divergens	3
Persoonia ? quinquenervis	4
Persoonia coriacea	3
Persoonia erinacea	
Persoonia quinquenervis	
Petrophile aff ericifolia	
Petrophile megalostegia	
Petrophile seminuda	
Synaphaea spinulosa	
SANTALACEAE	
Exocarpus aphyllus	
Exocarpus sparteus	6
Santalum acuminatum	7
Santalum spicatum	71
OLACACEAE	
Amyema miquelii	5
Amyema preissii	
POLYGONACEAE	
Muehlenbeckia adpressa	
CHENOPODIACEAE	
Atriplex nana	
Atriplex stipitata	3
Chenopodium gaudichaudianum	4
Chenopodium sp.	2
Dysphania kalpari	
Enchylaena tomentosa	17
Halosarcia ? peltata	
Halosarcia ? syncarpa	

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

CHENOPODIACEAE (Continued)	
Maireana brevifolia	
Maireana carnosa	
Maireana effusa	
Maireana enchylaeoides	3
Maireana glomerifolia	
Maireana planifolia	
Maireana triptera	9
Rhagodia candolleana	
Rhagodia drummondii	13
Rhagodia preissii	10
Rhagodia ulicina	
Sclerolaena uniflora	2
AMARANTHACEAE	
Ptilotus exaltatus	2
Ptilotus obovatus	8
Ptilotus polystachyus	5
AIZOACEAE	
Carpobrotus edulis	4
PORTULACACEAE	
Portulaca sp.	3
CARYOPHYLLACEAE	
Silene gallica	
LAURACEAE	
Cassytha racemosa	8
BRASSICACEAE	
Brassicaceae sp.	
Rhaphanus sp.	
DROSERACEAE	
Drosera sp.	18
CRASSULACEAE	
Crassula colorata	
PITTOSPORACEAE	
Pittosporum phylliraeoides	7

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

ROSACEAE	
Acaena sp.	6
PAPILIONACEAE	
Bossiaea ? spinescens	
Bossiaea aff concinna	
Bossiaea aquifolium	2
Burtonia obcordatum	2
Burtonia conferta	
Daviesia cardiophylla	4
Daviesia decurrens	3
Daviesia juncea	2
Daviesia sp.	2
Gastrolobium ? polystachyum	
Gastrolobium calycinum	2
Gastrolobium parviflorum	2
Gompholobium sp.	
Indigofera astralis	
Jacksonia furcellata	5
Jacksonia restioides	
Leptosema daviesioides	
Mirbelia floribunda	
Mirbelia microphylla	3
Templetonia retusa	2
Templetonia sulcata	
Papillionaceae sp.	
Lupinus sp.	2
Trifolium campestre	3
MIMOSACEAE	
Acacia ? kochii	
Acacia ? spinosissima	
Acacia acuminata	50
Acacia aff hemiteles	6
Acacia aff pulchella	
Acacia aneura	
Acacia anthochareara	
Acacia assimilis ssp. atroviridis	
Acacia burkittii	2
Acacia colletioides	
Acacia cupularis	
Acacia dielsii	3

APPENDIX 3 : PLANT SPECIES LIST

(After each name is the number of sites at which it occurred.)

MIMOSACEAE (Continued)	
Acacia erinacea	5
Acacia filifolia	3
Acacia lachnophylla	
Acacia lasiocalyx	5
Acacia longispinea	
Acacia microbotrya	2
Acacia patiagiata	
Acacia pulchella var subsessilis	2
Acacia quadrimarginea	
Acacia resinomarginea	5
Acacia rostellifera x xanthina	
Acacia rostellifera	
Acacia saligna	3
Acacia sessilis	
Acacia sphacelata	
Acacia stenoptera	2
Acacia stereophylla v stereophylla	2
Acacia tetragonophylla	9
Acacia ? dermatophylla	
Labichea lanceolata v. lanceolata	
CAESALPINIACEAE	
Senna artemisioides ssp. filif.	6
Senna glutinosa ssp. charlesiana	
Senna glutinosa ssp. chatelainiana	
GERANIACEAE	
Pelargonium havlasae	3
Erodium botrys	2
OXALIDACEAE	
Oxalis pes-caprae	
ZYGOPHYLLACEAE	
Zygophyllum simile	2
RUTACEAE	
Phlebalium tuberculosum	
POLYGALACEAE	
Comesperma intergerrimum	5
Comesperma scoparium	2

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

EUPHORBIACEAE	
Beyeria brevifolia	
Beyeria calycina	
Euphorbia drummondii	3
Phylanthus calycinus	2
STACKHOUSIACEAE	
Stackhousia huegelii	6
Stackhousia monogyna	
SAPINDACEAE	
Dodonaea aptera	
Dodonaea caespitosa	2
Dodonaea inaequifolia	5
Dodonaea pinifolia	4
Dodonaea ptarmicaefolia	
Dodonaea viscosa ssp. angustissima	6
RHAMNACEAE	
Blackallia biloba	
Cryptandra glabriflora	5
Cryptandra leucophracta	
Cryptandra nutans	4
Spyridium complicatum	
VITACEAE	
Clematicissus angustissima	
MALVACEAE	
Sida calyxhemenia	
Sida cardifolia	
STERCULEACEAE	
Keraudrenia hermanniifolia	
Keraudrenia integrifolia	2
Lasiopetalum compactum	2
Lasiopetalum rosmarinifolium	2

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

DILLENIACEAE	
Hibbertia enervia	
Hibbertia enervia	2
Hibbertia exasperata	4
Hibbertia glomerosa	2
Hibbertia hypericoides	
Hibbertia recurvifolia	2
FRANKENIACEAE	
Frankenia ambita	
Frankenia cordata	
THYMELAEACEAE	
Pimelea argentea	
Pimelea microcephala	2
Pimelea spiculigera	2
MYRTACEAE	
Baeckea crispiflora	
Baeckea elderiana	
Baeckea preissiana	7
Baeckea pulchella	
Baeckea maidenii	
Calothamnus quadrifidus	3
Calothamnus sangineus	
Calytrix ? formosa	
Calytrix formosa	2
Calytrix leschenaultii	10
Chamelaucium ciliatum	
Darwinia sp.	
Eucalyptus aff. cylindrocarpa	
Eucalyptus annulata	3
Eucalyptus celastroides ssp. virella	
Eucalyptus coolabah v rhodoclada	
Eucalyptus corrugata	2
Eucalyptus cylindriflora	2
Eucalyptus hypochlamydea	2
Eucalyptus loxophleba	24
Eucalyptus perangusta	2
Eucalyptus redunca	2
Eucalyptus salmonophloia	13
Eucalyptus salubris var. salubris	

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

MYRTACEAE	
Eucalyptus salubris	3
Eucalyptus scyphocalyx	
Eucalyptus sp. I	
Eucalyptus subangustata ssp. subangustata	
Eucalyptus transcontinentalis	
Eucalyptus wandoo	11
Leptospermum erubescens	8
Leptospermum fastigiatum	
Melaleuca acuminata	3
Melaleuca adnata	
Melaleuca conothamnoides	2
Melaleuca cuneata	
Melaleuca eleuterostachya	
Melaleuca lateriflora	
Melaleuca macronycha	
Melaleuca platycalyx	4
Melaleuca radula	2
Melaleuca scabra	6
Melaleuca subtrigona	8
Melaleuca uncinata	12
Melaleuca viminea	
Melaleuca violacea	
Melaleuca macronychia	2
Phytomatocarpus porphyrocephalus	
Thryptomene cuspidata	
Thryptomene prolifera	
Verticordia chrysantha	
Verticordia pholydophylla	
Verticordia venusta	3
Verticordia sp.	
Myrtaceae sp.	
HALORAGACEAE	
Glischrocaryon aureum	4
APIACEAE	
Apiaceae sp.	
Platysace cirrosa	
Platysace effusa	4

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

EPACRIDACEAE	
Andersonia lehmanniana	
Astroloma compactum	
Astroloma microdonta	2
Astroloma serratifolium var. horridum	
Astroloma serratifolium	2
Conostephium preissii	
Leucopogon dielsianus	
Leucopogon hamulosus	3
Leucopogon sp.	
PRIMULACEAE	
Anagallis arvensis	2
LOGANIACEAE	
Mitrasacme paradoxa	
APOCYNACEAE	
Alyxia buxifolia	8
ASCLEPIADACEAE	
Rhyncharrhena linearis	3
CONVOLVULACEAE	
? *Ipomoea* sp.	
Porana sericea	
BORAGINACEAE	
Halgania preissiana	2
LAMIACEAE	
Hemiandra incana	
Westringia dampieri	
Westringia rigida	

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

SOLANACEAE	
Anthocercis intricata	
Lycium australe	2
Nicotiana occidentalis	
Solanum ellipticum	6
Solanum lasiophyllum	
Solanum nigrum	
Solanum orbiculatum	5
Solanum nigrum	4
MYOPORACEAE	
Eremophila decipiens	4
Eremophila drummondii	
Eremophila ionantha	
Eremophila miniata	2
Eremophila oppositifolia	
RUBIACEAE	
Opercularia ? spermacocea	13
CUCURBITACEAE	
Cucurbitaceae sp.	
GOODENIACEAE	
Dampiera ? linearis	
Dampiera lavandulacea	18
Dampiera lindleyi	2
Goodenia sp. 3	
Scaevola spinescens	4
Velleia trinervis	5
Goodeniaceae sp.	3
Goodeniaceae sp. 1	
Goodeniaceae sp. 2	8
STYLIDIACEAE	
Stylidium repens	3

APPENDIX 3 : PLANT SPECIES LIST
(After each name is the number of sites at which it occurred.)

ASTERACEAE	
Actinobole uliginosum	3
Carthamnus sp.	
Centaurea melitensis	
Helichrysum bracteatum	25
Helipterum cotula	4
Olearia ? propinqua	
Olearia ? revoluta	10
Olearia exiguifolia	
Olearia muelleri	9
Olearia pimeleoides	6
Olearia propinqua	
Podolepis ? auriculata	
Podolepis capillaris	17
Podotheca ? chrysantha	
Senecio ? gregorii	3
Asteraceae sp. 2 (? Senecio)	
Arctotheca calendula	5
Conyza bonariensis	2
Hypocheris glabra	15
Osteospermum clandestinum	6
Ursinea anthemoides	20

APPENDIX 4 : SHALLOW SOIL PARAMETERS FROM STUDY SITES

SITE#	ASPECT	LANDFORM		DRAINAGE		SITE#	ASPECT	LANDFORM		DRAINAGE	
	DEGREES	1st	2nd	ESTIMATE	TYPE		DEGREES	1st	2nd	ESTIMATE	TYPE
60	*	7.00	*	2.00	7.00	24	45.00	7.00	*	1.00	7.00
57	45.00	8.00	*	4.00	10.00	23	270.00	7.00	*	1.00	7.00
46	240.00	7.00	4.00	2.00	7.00	20	60.00	7.00	*	2.00	7.00
45	240.00	7.00	3.00	1.00	7.00	70	0.00	1.00	*	3.00	7.00
7	180.00	2.00	*	1.00	7.00	65	*	1.00	*	2.00	7.00
6	180.00	2.00	*	1.00	7.00	16	225.00	2.00	*	4.00	10.00
48	*	5.00	*	1.00	7.00	40	120.00	4.00	*	1.00	7.00
47	*	1.00	*	1.00	7.00	59	90.00	4.00	*	1.00	7.00
44	90.00	5.00	*	3.00	7.00	42	120.00	4.00	*	1.00	7.00
69	45.00	3.00	*	2.00	7.00	71	90.00	4.00	*	3.00	7.00
43	180.00	3.00	*	1.00	7.00	67	0.00	2.00	3.00	1.00	7.00
38	90.00	3.00	*	3.00	7.00	56	60.00	4.00	7.00	4.00	7.00
37	90.00	7.00	*	1.00	7.00	41	120.00	4.00	*	1.00	7.00
36	30.00	7.00	4.00	1.00	7.00	30	180.00	4.00	8.00	1.00	7.00
10	210.00	1.00	*	2.00	7.00	51	210.00	4.00	*	1.00	7.00
12	270.00	4.00	*	1.00	7.00	27	60.00	7.00	8.00	2.00	7.00
9	180.00	3.00	*	2.00	7.00	31	180.00	2.00	*	1.00	7.00
11	180.00	7.00	*	2.00	7.00	32	180.00	2.00	*	1.00	7.00
8	90.00	1.00	*	1.00	7.00	17	0.00	1.00	*	1.00	7.00
19	210.00	2.00	*	2.00	7.00	18	45.00	3.00	*	1.00	7.00
66	0.00	2.00	*	3.00	7.00	15	180.00	4.00	*	2.00	7.00
22	150.00	2.00	*	2.00	7.00	34	90.00	2.00	*	2.00	7.00
33	90.00	1.00	*	2.00	7.00	35	135.00	2.00	*	2.00	7.00
72	45.00	1.00	*	2.00	7.00	14	0.00	1.00	*	2.00	7.00
39	120.00	5.00	*	1.00	7.00	28	180.00	4.00	5.00	2.00	7.00
29	180.00	2.00	*	2.00	7.00	26	90.00	7.00	*	3.00	7.00
21	30.00	3.00	*	2.00	7.00	25	180.00	6.00	*	2.00	7.00
52	210.00	4.00	9.00	3.00	7.00	62	90.00	2.00	*	2.00	7.00
50	0.00	1.00	2.00	2.00	7.00	61	180.00	3.00	*	2.00	7.00
49	0.00	1.00	2.00	1.00	7.00	64	180.00	9.00	4.00	4.00	7.00
63	90.00	2.00	*	2.00	7.00	5	270.00	4.00	*	3.00	7.00
58	90.00	3.00	*	2.00	7.00	4	270.00	4.00	*	3.00	7.00
55	270.00	3.00	*	3.00	7.00	3	225.00	9.00	*	4.00	10.00
53	*	1.00	*	3.00	7.00	2	0.00	3.00	*	1.00	7.00
13	210.00	1.00	*	1.00	7.00	54	270.00	4.00	5.00	3.00	7.00
68	180.00	3.00	*	2.00	7.00	1	45.00	4.00	*	2.00	7.00

APPENDIX 4 : SHALLOW SOIL PARAMETERS FROM STUDY SITES

SITE#	ORIGIN CODE		MOISTURE % 10cm	MOISTURE % 30cm	NON WET	DEPTH cm	HORIZONS A	HORIZONS B	SITE#	ORIGIN CODE		MOISTURE % 10cm	MOISTURE % 30cm	NON WET	DEPTH cm	HORIZONS A	HORIZONS B
60	J	*	4.00	5.00	1.00	130.00	20.00	*	24	D	I	0.00	1.00	1.00	200.00	2.00	*
57	E	J	6.00	8.00	1.00	130.00	15.00	*	23	C	J	0.20	1.00	3.00	45.00	5.00	30.00
46	J	*	3.00	5.00	1.00	130.00	10.00	*	20	D	*	2.00	1.00	1.00	72.00	2.00	20.00
45	J	*	4.00	4.00	1.00	111.00	10.00	*	70	D	J	2.00	*	1.00	20.00	*	*
7	J	F	3.00	7.00	3.00	28.30	15.00	25.00	65	D	J	0.00	*	3.00	70.00	*	*
6	F	J	2.00	2.00	1.00	52.50	30.00	*	16	D	*	2.00	3.00	1.00	105.00	10.00	*
48	I	E	3.00	3.00	1.00	52.00	3.00	*	40	D	E	2.00	3.00	1.00	80.70	3.00	*
47	I	F	3.00	4.00	1.00	97.00	4.00	30.00	59	E	J	5.00	3.00	1.00	30.00	10.00	*
44	E	I	3.00	1.00	1.00	62.70	*	*	42	D	E	4.00	2.00	3.00	56.70	3.00	20.00
69	E	J	3.00	3.00	2.00	36.00	7.00	*	71	D	J	5.00	5.00	3.00	90.00	5.00	30.00
43	A	H	6.00	8.00	1.00	56.30	5.00	30.00	67	E	J	2.00	4.00	1.00	30.00	5.00	28.00
38	D	I	0.00	*	1.00	30.00	2.00	*	56	E	J	6.00	9.00	1.00	80.00	9.00	*
37	E	J	4.00	4.00	1.00	85.00	2.00	30.00	41	D	E	4.00	8.00	1.00	51.70	4.00	*
36	E	I	0.00	0.00	1.00	59.30	3.00	25.00	30	E	J	4.00	5.00	1.00	60.70	2.00	*
10	E	*	0.00	0.00	1.00	57.00	1.00	*	51	J	*	4.00	1.00	1.00	75.00	5.00	25.00
12	A	*	2.00	0.00	1.00	33.50	2.00	25.00	27	E	J	5.00	5.00	1.00	110.00	1.00	25.00
9	E	J	4.00	2.00	1.00	41.00	2.00	28.00	31	E	J	4.00	1.00	1.00	62.00	3.00	*
11	A	J	1.00	2.00	1.00	34.00	0.50	27.00	32	E	J	3.00	4.00	1.00	50.00	6.00	30.00
8	E	A	3.00	3.00	1.00	77.00	10.00	30.00	17	D	J	2.00	5.00	1.00	50.00	8.00	*
19	E	J	2.00	5.00	1.00	53.70	10.00	20.00	18	D	*	5.00	2.00	1.00	43.00	2.00	30.00
66	E	I	3.00	*	2.00	22.00	5.00	*	15	D	*	4.00	4.00	1.00	61.70	15.00	*
22	J	*	3.00	2.00	1.00	48.30	1.00	30.00	34	D	I	7.00	9.00	1.00	41.00	3.00	*
33	E	I	6.00	0.80	1.00	98.70	3.00	30.00	35	D	E	5.00	6.00	1.00	45.30	3.00	30.00
72	E	J	10.00	*	1.00	110.00	5.00	20.00	14	D	E	5.00	0.70	1.00	46.30	20.00	*
39	E	J	5.00	5.00	1.00	64.30	4.00	30.00	28	D	J	4.00	4.00	1.00	130.00	2.00	*
29	E	J	7.00	6.00	1.00	76.00	3.00	25.00	26	C	J	3.00	0.00	1.00	200.00	*	*
21	J	*	6.00	6.00	1.00	120.00	1.00	30.00	25	C	I	7.00	0.00	1.00	130.00	10.00	20.00
52	D	E	5.00	6.00	1.00	50.00	10.00	20.00	62	E	I	3.00	3.00	1.00	75.00	16.00	25.00
50	D	E	7.00	7.00	1.00	60.00	5.00	25.00	61	D	I	5.00	5.00	2.00	60.00	13.00	*
49	D	J	7.00	5.00	1.00	60.00	3.00	27.00	64	D	J	5.00	7.00	1.00	130.00	5.00	30.00
63	E	J	5.00	8.00	1.00	130.00	5.00	8.00	5	J	*	7.00	0.00	1.00	57.70	5.00	*
58	E	J	7.00	6.00	1.00	30.00	15.00	25.00	4	J	*	1.00	0.00	1.00	57.70	10.00	23.00
55	E	J	3.00	3.00	1.00	30.00	15.00	*	3	E	*	4.00	3.00	1.00	63.30	11.00	24.00
53	D	J	6.00	7.00	1.00	60.00	3.00	20.00	2	D	E	1.00	1.00	1.00	48.50	8.00	25.00
13	E	*	0.70	0.00	1.00	11.30	15.00	25.00	54	D	E	5.00	5.00	1.00	27.00	7.00	20.00
68	E	J	4.00	6.00	2.00	108.00	5.00	15.00	1	D	*	2.00	0.50	1.00	46.70	9.00	14.00

APPENDIX 4 : SHALLOW SOIL PARAMETERS FROM STUDY SITES

SITE#	BULK DENSITY		TEXTURE 10CM				
	10cm	30cm	GRAVEL	PEBBLE	SAND	SILT	CLAY
60	1.25	1.37	0.00	0.00	10.00	0.00	0.00
57	1.11	1.14	0.00	4.00	6.00	0.00	0.00
46	1.30	1.40	0.00	0.00	10.00	0.00	0.00
45	1.29	1.35	0.00	0.00	10.00	0.00	0.00
7	1.37	1.70	6.00	0.00	3.00	1.00	0.00
6	1.54	1.39	1.00	0.00	6.00	3.00	0.00
48	1.33	1.39	0.00	3.00	6.00	0.70	0.30
47	1.30	1.38	0.00	0.00	8.00	1.50	0.50
44	1.36	1.50	0.00	0.00	7.00	3.00	0.00
69	1.49	1.49	0.00	4.00	5.00	1.00	0.00
43	1.05	1.02	0.00	0.00	1.00	6.00	3.00
38	1.14	*	0.00	0.00	0.00	5.00	5.00
37	1.22	1.28	0.00	0.00	8.00	2.00	0.00
36	1.12	1.07	0.00	0.00	8.50	1.50	0.00
10	1.76	1.70	1.00	1.00	1.00	3.00	4.00
12	1.61	1.80	3.00	2.00	1.00	4.00	0.00
9	1.66	1.57	0.00	3.00	2.00	5.00	0.00
11	1.65	1.60	0.00	2.00	1.00	6.00	1.00
8	1.48	1.45	0.50	6.50	1.00	2.00	0.00
19	1.40	1.42	0.00	3.00	2.00	4.00	1.00
66	1.27	*	0.00	6.00	2.50	1.50	0.00
22	1.16	1.40	0.00	4.00	5.00	1.00	0.00
33	1.21	1.70	0.00	4.00	5.00	1.00	0.00
72	1.14	*	3.00	2.50	1.50	0.00	3.00
39	1.22	1.30	0.00	0.00	7.00	3.00	0.00
29	1.13	1.23	0.00	0.00	8.00	2.00	0.00
21	1.29	1.29	0.00	3.00	7.00	0.00	0.00
52	1.11	1.15	0.00	6.00	3.00	1.00	0.00
50	1.07	0.98	3.00	3.50	3.50	0.00	0.00
49	1.40	1.23	5.00	2.00	2.50	0.50	0.00
63	1.40	1.30	0.00	0.00	9.00	1.00	0.00
58	1.22	1.54	0.00	0.30	8.70	1.00	0.00
55	1.36	1.56	5.00	0.00	5.00	0.00	0.00
53	1.05	1.14	0.50	5.00	4.00	0.50	0.00
13	1.81	1.77	5.00	0.00	5.00	0.00	0.00
68	1.31	1.42	0.00	3.00	6.00	1.00	0.00
24	1.92	1.59	5.00	3.00	1.00	1.00	0.00
23	1.40	1.39	0.00	5.00	3.00	2.00	0.00
20	1.37	1.52	0.00	3.00	4.00	3.00	0.00
70	1.11	*	0.00	6.00	2.00	2.00	0.00
65	1.17	*	0.00	5.00	2.00	3.00	0.00
16	1.18	1.26	0.00	6.00	1.00	3.00	0.00
40	1.18	1.10	0.00	4.00	4.00	2.00	0.00
59	1.19	1.39	0.00	0.00	8.00	1.50	0.50
42	1.27	1.48	0.00	5.00	4.00	1.00	0.00
71	1.34	1.30	0.00	5.00	4.00	1.00	0.00
67	1.45	1.45	0.00	6.00	3.00	1.00	0.00
56	1.02	1.04	0.00	3.00	6.50	0.50	0.00
41	1.19	1.33	0.00	4.00	4.00	2.00	0.00
30	1.30	1.25	0.00	5.00	3.00	2.00	0.00
51	1.12	1.05	0.00	3.00	7.00	0.00	0.00
27	1.30	1.38	0.00	3.00	5.00	2.00	0.00
31	1.44	1.50	0.00	2.50	4.50	3.00	0.00
32	1.41	1.43	0.00	3.50	3.00	3.50	0.00
17	1.40	1.34	0.00	6.00	2.00	2.00	0.00
18	1.27	1.44	0.00	3.00	6.00	1.00	0.00
15	1.37	1.47	0.00	3.00	6.00	1.00	0.00
34	1.13	1.12	0.00	2.00	6.00	2.00	0.00
35	1.32	1.37	0.00	4.00	4.00	2.00	0.00
14	1.49	1.92	0.00	1.00	7.00	2.00	0.00
28	1.13	1.54	0.00	5.00	3.00	2.00	0.00
26	1.23	1.39	0.00	3.00	7.00	0.00	0.00
25	0.93	1.13	0.00	0.00	2.00	5.00	3.00
62	1.29	1.13	0.00	3.00	4.70	2.00	0.30
61	1.15	1.28	0.00	4.00	5.00	1.00	0.00
64	1.24	1.00	0.00	2.00	6.00	2.00	0.00
5	1.57	2.00	1.00	7.00	1.00	1.00	0.00
4	1.50	1.63	0.00	5.00	2.00	3.00	0.00
3	1.35	1.52	0.00	2.00	4.00	3.50	0.50
2	1.48	1.42	0.00	5.00	2.00	3.00	0.00
54	1.26	1.23	0.00	0.00	8.00	2.00	0.00
1	1.40	1.36	0.00	0.00	3.00	7.00	0.00

APPENDIX 4 : SHALLOW SOIL PARAMETERS FROM STUDY SITES

SITE#	TEXTURE 30CM					COLOUR		SITE#	TEXTURE 30CM					COLOUR	
	GRAVEL	PEBBLE	SAND	SILT	CLAY	10cm	30cm		GRAVEL	PEBBLE	SAND	SILT	CLAY	10cm	30cm
60	0.00	0.00	10.00	0.00	0.00	54.30	54.30	24	5.00	2.50	1.00	1.50	0.00	33.50	32.50
57	0.10	7.90	1.00	0.50	0.00	43.00	64.10	23	0.00	4.00	3.00	3.00	0.00	63.20	63.40
46	0.00	0.00	10.00	0.00	0.00	68.20	68.20	20	0.00	4.00	5.00	1.00	0.00	54.20	66.20
45	0.00	0.00	10.00	0.00	0.00	68.20	68.20	70	*	*	*	*	*	32.40	*
7	6.00	0.00	3.00	1.00	0.00	63.20	63.20	65	*	*	*	*	*	33.40	*
6	1.00	0.00	6.00	3.00	0.00	63.20	62.20	16	0.00	4.50	4.50	1.00	0.00	56.30	56.30
48	0.00	3.00	6.00	0.70	0.30	48.50	48.50	40	0.00	4.00	4.00	2.00	0.00	33.40	34.40
47	0.00	0.00	8.00	1.50	0.50	58.30	58.30	59	3.00	1.00	4.00	1.50	0.50	54.20	76.20
44	0.00	0.00	7.00	3.00	0.00	48.50	48.50	42	0.00	5.00	4.00	1.00	0.00	58.20	68.20
69	0.00	4.00	5.00	1.00	0.00	63.20	54.50	71	0.00	6.00	4.00	0.00	0.00	56.40	74.30
43	0.00	0.00	2.00	5.00	3.00	46.40	46.40	67	0.00	6.00	3.00	1.00	0.00	64.50	74.20
38	0.00	0.00	0.00	5.00	5.00	43.60	52.60	56	1.00	0.00	8.50	0.50	0.00	44.20	66.20
37	0.00	0.00	8.00	2.00	0.00	58.30	58.30	41	0.00	4.00	4.00	2.00	0.00	58.30	58.30
36	0.00	0.00	8.00	2.00	0.00	44.30	48.50	30	0.00	5.00	3.00	2.00	0.00	72.20	72.20
10	1.00	1.00	3.00	2.50	2.50	56.40	56.40	51	0.00	4.00	6.00	0.00	0.00	63.00	72.20
12	3.00	2.00	1.00	4.00	0.00	46.50	46.50	27	0.00	5.00	3.00	2.00	0.00	34.20	53.20
9	0.00	3.00	2.00	5.00	0.00	56.40	56.40	31	0.00	2.50	4.50	3.00	0.00	63.20	73.20
11	0.00	2.00	2.00	5.00	1.00	66.30	66.30	32	1.00	2.00	4.00	3.00	0.00	58.20	59.20
8	0.50	5.50	2.00	2.00	0.00	54.30	54.30	17	0.00	6.00	2.00	2.00	0.00	72.30	73.20
19	0.00	3.00	3.00	3.00	1.00	64.30	64.30	18	0.00	2.00	5.00	2.00	1.00	54.30	56.30
66	*	*	*	*	*	44.40	*	15	0.00	3.00	6.00	1.00	0.00	54.30	54.30
22	0.00	4.00	5.00	1.00	0.00	64.20	66.20	34	0.00	2.00	7.00	1.00	0.00	48.90	48.90
33	1.00	4.00	4.50	0.50	0.00	56.20	58.20	35	2.00	4.00	3.00	1.00	0.00	56.30	58.40
72	*	*	*	*	*	56.30	56.30	14	6.00	1.00	1.00	2.00	0.00	64.30	73.40
39	0.00	3.00	5.00	2.00	0.00	58.20	58.20	28	0.00	5.00	3.00	2.00	0.00	36.20	44.20
29	0.00	0.00	8.00	2.00	0.00	73.20	78.20	26	1.00	6.00	3.00	0.00	0.00	33.40	34.30
21	0.00	3.00	7.00	0.00	0.00	78.20	88.20	25	0.00	0.20	0.00	4.80	5.00	26.80	46.60
52	1.00	5.00	3.00	1.00	0.00	66.10	74.10	62	2.00	3.00	3.70	1.00	0.30	44.40	56.40
50	5.00	3.00	2.00	0.00	0.00	34.40	58.40	61	0.00	4.00	5.00	1.00	0.00	34.40	56.40
49	2.00	4.50	3.50	0.00	0.00	46.30	56.30	64	0.00	0.00	9.00	1.00	0.00	54.20	66.30
63	0.00	0.00	10.00	0.00	0.00	76.20	68.20	5	3.00	3.00	1.00	3.00	0.00	72.30	62.30
58	3.00	0.00	5.00	1.00	0.00	64.30	74.30	4	0.00	4.00	2.00	4.00	0.00	62.40	71.40
55	7.00	1.00	2.00	0.00	0.00	56.50	56.50	3	0.00	2.00	4.00	3.50	0.50	73.40	62.40
53	0.50	5.00	4.00	0.50	0.00	58.20	66.20	2	0.00	5.00	2.00	2.00	0.00	84.20	84.20
13	5.00	0.00	5.00	0.00	0.00	72.30	76.20	54	0.00	0.00	9.00	1.00	0.00	64.20	73.20
68	0.00	4.00	5.00	1.00	0.00	43.40	52.40	1	0.50	3.50	4.00	2.00	0.00	72.30	73.20

APPENDIX 4 : SHALLOW SOIL PARAMETERS FROM STUDY SITES

SITE#	PH 10cm	PH 30cm	T.S.S. 10cm	T.S.S. 30cm	SITE#	PH 10cm	PH 30cm	T.S.S. 10cm	T.S.S. 30cm
60	7.00	7.00	0.00	0.00	24	6.00	6.00	0.01	0.01
57	6.00	5.50	0.07	0.12	23	7.00	7.00	0.01	0.01
46	7.70	8.00	0.00	0.01	20	6.00	6.00	0.01	0.01
45	5.50	5.50	0.00	0.00	70	7.00	*	0.01	*
7	9.00	9.00	0.06	0.08	65	6.00	*	0.04	*
6	8.50	9.00	0.01	0.01	16	7.00	7.50	0.01	0.01
48	6.50	6.00	0.01	0.02	40	5.50	6.00	0.01	0.00
47	8.50	8.50	0.01	0.02	59	7.00	7.00	0.00	0.01
44	6.00	6.50	0.01	0.00	42	6.00	6.00	0.01	0.00
69	7.50	7.50	0.00	0.00	71	5.50	5.00	0.02	0.01
43	9.50	9.50	0.22	0.49	67	8.00	8.00	0.01	0.01
38	9.50	8.50	0.09	0.09	56	7.00	7.00	0.05	0.06
37	6.00	7.00	0.00	0.03	41	4.70	5.50	0.00	0.00
36	5.80	7.20	0.00	0.04	30	5.00	6.00	0.00	0.00
10	5.00	5.00	0.00	0.01	51	7.00	7.00	0.00	0.00
12	7.00	7.00	0.00	0.00	27	5.50	6.00	0.00	0.02
9	5.00	5.00	0.01	0.00	31	6.00	5.50	0.00	0.00
11	6.00	6.00	0.00	0.00	32	6.50	7.00	0.00	0.00
8	6.00	6.00	0.01	0.03	17	7.00	7.00	0.00	0.00
19	5.50	4.50	0.00	0.01	18	5.50	6.00	0.00	0.00
66	7.00	*	0.01	0.01	15	6.00	6.50	0.00	0.00
22	6.00	6.00	0.00	0.00	34	6.00	5.50	0.00	0.00
33	5.50	5.00	0.00	0.00	35	7.00	7.00	0.00	0.00
72	6.00	6.00	0.00	*	14	7.00	7.00	0.01	0.01
39	6.00	7.00	0.00	0.00	28	4.50	5.00	0.00	0.00
29	6.50	7.00	0.00	0.00	26	7.50	7.50	0.00	0.00
21	4.50	6.50	0.00	0.00	25	8.50	8.50	0.01	0.02
52	7.00	7.00	0.01	0.01	62	7.00	7.00	0.00	0.00
50	7.00	7.00	0.01	0.01	61	7.50	8.00	0.03	0.01
49	7.00	6.00	0.01	0.01	64	6.00	7.00	0.00	0.00
63	6.00	7.00	0.00	0.00	5	7.00	7.00	0.00	0.00
58	7.00	7.00	0.01	0.00	4	7.00	7.50	0.00	0.00
55	7.00	7.00	0.00	0.00	3	5.50	5.00	0.00	0.00
53	7.00	7.00	0.00	0.00	2	6.50	6.00	0.01	0.01
13	6.00	6.00	0.01	0.00	54	7.00	7.00	0.00	0.00
68	7.00	7.00	0.00	0.02	1	5.00	6.00	0.00	0.00

APPENDIX 5 : AVERAGE TREE LEAF LENGTH AND WIDTH

site	tree	length	SD	width	SD	site	tree	length	SD	width	SD
1	1	3.84	0.91	1.04	0.28	16	4	5.78	0.95	1.36	0.18
2	1	4.74	0.64	1.55	0.43	17	1	4.37	0.95	1.40	0.33
2	2	4.36	1.65	1.17	0.38	17	2	3.31	0.61	0.95	0.32
3	1	3.39	1.26	1.26	0.43	17	3	3.39	0.78	0.70	0.19
3	2	3.75	1.39	1.37	0.34	17	4	4.79	0.76	1.31	0.36
4	1	3.96	1.06	1.25	0.32	18	1	4.91	0.86	1.06	0.23
5	1	5.07	1.29	0.85	0.28	18	2	4.97	0.77	1.22	0.22
5	2	4.88	1.37	1.35	0.31	18	3	4.78	0.85	0.94	0.23
6	1	4.88	1.46	1.40	0.29	18	4	4.83	1.19	1.23	0.38
6	2	3.00	0.00	1.54	0.51	19	1	4.60	0.82	0.83	0.18
6	3	3.86	0.92	1.32	0.40	19	2	4.89	1.00	0.71	0.16
6	4	3.67	0.94	*	*	19	3	4.37	0.74	0.78	0.16
7	1	5.46	0.60	1.32	0.30	20	1	3.45	0.48	1.05	0.26
7	2	4.08	0.45	1.0	0.12	20	2	4.14	1.00	0.91	0.25
7	3	5.21	0.38	1.47	0.12	20	3	4.14	0.95	1.07	0.23
8	1	5.11	0.47	1.26	0.18	20	4	3.87	0.61	0.99	0.30
8	2	6.36	0.66	1.26	0.25	20	5	3.81	0.87	0.78	0.12
8	3	6.10	0.64	1.48	0.11	20	6	4.85	0.99	1.06	0.18
9	1	5.49	0.59	0.87	0.13	20	7	2.99	1.02	1.35	0.39
9	2	3.65	0.30	0.66	0.18	21	1	2.89	0.62	0.86	0.17
9	3	4.96	0.76	1.00	0.16	21	2	3.45	0.63	1.06	0.28
10	1	3.53	0.53	0.88	0.17	21	3	3.54	0.88	0.86	0.12
10	2	4.12	0.52	0.90	0.14	22	1	2.86	0.67	0.63	0.16
10	3	4.29	0.43	0.71	0.18	22	2	2.81	0.42	0.69	0.15
10	4	3.83	0.55	0.76	0.12	23	1	3.85	1.15	0.76	0.11
11	1	4.97	1.50	1.45	1.61	23	2	4.57	0.83	0.76	0.14
11	2	5.50	0.73	0.99	0.40	24	1	4.49	0.49	1.16	0.36
11	3	2.36	0.45	0.63	0.18	24	2	4.71	1.17	1.19	0.25
12	1	4.60	0.93	1.02	0.24	24	3	4.35	1.14	1.08	0.24
12	2	4.96	0.54	1.08	0.31	24	4	4.26	1.18	0.80	0.12
12	3	4.37	1.04	1.03	0.23	26	1	5.08	0.95	1.26	0.34
12	4	4.81	1.03	0.76	0.21	26	2	4.69	0.88	1.47	0.61
13	1	3.39	0.75	0.74	0.18	26	3	4.83	1.51	2.12	1.66
13	2	3.96	0.81	0.86	0.20	27	1	3.77	0.83	1.09	0.24
14	1	4.09	0.68	0.73	0.19	27	2	3.82	0.78	1.16	0.25
14	2	5.34	1.23	1.51	0.28	27	7	3.45	1.06	0.93	0.30
14	3	5.61	1.71	1.85	1.48	27	3	4.37	1.68	1.05	0.33
14	4	4.77	1.04	1.07	0.29	27	4	3.89	1.13	2.42	2.48
15	a1	4.52	1.09	0.82	0.23	27	6	3.60	0.82	1.19	0.35
15	a2	4.80	1.18	1.11	0.26	28	1	4.30	1.48	1.44	0.26
15	a3	3.30	0.72	0.92	0.20	28	2	4.35	1.05	0.98	0.23
15	a4	3.78	0.49	0.87	0.22	28	3	4.03	1.22	1.08	0.37
15	b1	5.11	0.93	1.12	0.20	28	4	3.76	1.37	1.03	0.38
15	b2	4.20	1.02	1.00	0.24	28	5	3.97	0.81	0.88	0.34
15	b3	3.23	0.49	0.91	0.26	29	1	5.58	1.29	1.42	0.27
15	b4	4.64	1.27	1.12	0.26	29	2	4.41	0.78	1.23	0.31
15	b5	4.64	1.27	1.12	0.26	29	3	4.08	0.56	0.85	0.17
15	b6	4.18	0.88	1.01	0.25	29	4	3.96	1.11	0.91	0.30
15	b7	3.79	0.57	1.15	0.21	29	5	4.59	1.76	1.04	0.34
15	b8	4.15	0.55	1.12	0.13	30	1	3.86	0.77	0.96	0.16
16	1	5.19	0.97	1.16	0.23	30	2	3.79	0.75	0.94	0.23
16	2	5.56	1.45	1.74	0.24	30	3	4.73	0.20	1.16	0.27

APPENDIX 5 : AVERAGE TREE LEAF LENGTH AND WIDTH

site	tree	length	SD	width	SD	site	tree	length	SD	width	SD
31	2	4.86	1.23	1.23	0.32	51	1	4.72	1.16	1.65	0.35
31	3	4.96	0.86	1.10	0.20	51	2	4.50	1.68	1.63	0.49
31	4	4.27	0.61	0.99	0.19	51	3	3.37	0.75	1.35	0.20
32	1	5.46	1.59	1.28	0.30	52	1	4.11	0.75	1.28	0.24
32	2	4.87	1.60	1.08	0.29	52	2	4.11	0.74	1.03	0.23
32	3	3.42	1.37	0.96	0.26	53	1	3.79	1.15	1.21	0.34
32	4	3.11	1.18	0.85	0.25	53	2	4.29	1.19	1.24	0.29
33	1	4.22	0.87	1.49	0.29	53	3	3.81	1.28	1.03	0.27
33	2	5.34	0.77	1.92	0.33	54	1	3.58	1.05	1.09	0.38
33	3	4.23	0.98	1.04	0.18	54	2	2.98	0.95	0.90	0.15
33	4	4.85	0.85	1.22	0.25	54	3	3.14	0.93	1.02	0.38
33	5	5.45	0.97	1.40	0.31	54	4	3.38	0.78	1.14	0.28
34	1	4.52	0.63	0.99	0.23	55	1	2.67	0.65	0.89	0.21
34	2	4.68	0.87	0.95	0.26	55	2	3.09	1.00	0.89	0.25
34	3	5.20	0.58	0.94	0.16	55	3	3.16	0.69	0.99	0.45
35	1	5.04	0.92	0.89	0.26	55	4	3.38	0.86	0.86	0.36
35	2	5.01	1.75	1.08	0.25	55	5	3.09	0.72	0.83	0.26
35	3	5.15	0.96	0.99	0.21	56	1	3.90	1.69	0.90	0.12
35	4	5.42	1.00	0.97	0.15	56	2	3.33	1.05	1.09	0.21
36	1	4.92	1.30	0.95	0.27	56	3	3.94	1.20	1.16	0.30
36	2	4.38	1.07	1.16	0.34	57	1	4.36	1.45	0.91	0.20
36	3	4.99	1.35	1.03	0.26	58	1	3.74	1.30	0.93	0.41
37	1	5.39	0.97	0.84	0.20	58	2	3.62	0.85	1.51	0.29
37	2	4.87	0.94	0.97	0.21	58	3	3.07	0.87	0.83	0.17
38	1	4.83	1.12	0.92	0.22	58	4	3.73	1.05	1.11	0.23
39	1	3.65	0.79	0.52	0.11	59	1	3.46	0.93	1.36	1.06
40	1	4.87	0.94	1.04	0.27	59	2	4.33	1.04	1.03	0.25
40	2	4.38	0.47	0.66	0.17	59	3	3.86	1.21	1.08	0.27
41	1	4.03	0.72	0.93	0.27	61	1	*	*	*	*
42	1	4.65	1.00	0.66	0.15	62	1	4.82	1.67	1.87	0.68
42	2	4.24	0.90	0.66	0.19	62	2	4.45	1.27	1.36	0.51
42	3	4.99	1.44	0.77	0.18	62	3	4.50	0.99	1.35	0.40
43	1	4.41	0.60	0.98	0.20	63	1	5.77	1.41	1.64	0.44
43	2	4.89	0.67	0.85	0.31	63	2	2.96	1.05	1.20	0.35
43	3	4.75	0.68	1.09	0.17	63	3	3.90	1.50	1.03	0.29
44	1	5.02	1.03	0.86	0.19	64	1	3.60	1.34	1.00	0.24
44	2	5.67	1.04	1.03	0.28	64	2	3.99	1.14	1.11	0.19
45	1	5.76	1.89	1.11	0.25	65	1	3.92	0.69	0.92	0.20
45	2	4.51	0.81	1.14	0.23	65	2	3.40	0.97	0.99	0.38
45	3	5.52	0.91	1.27	0.28	65	3	3.84	0.83	1.19	0.38
46	1	4.18	1.23	0.75	0.15	66	1	3.15	0.67	0.90	0.28
46	2	4.79	0.90	0.97	0.27	67	1	3.75	0.68	1.35	0.39
47	1	6.10	1.05	1.02	0.36	68	1	3.57	0.86	1.27	0.39
47	2	3.57	0.55	0.68	0.09	68	2	3.57	0.75	1.26	0.27
47	3	4.95	0.77	0.86	0.11	68	3	2.80	0.88	1.26	0.48
48	1	4.41	0.68	0.99	0.19	69	1	3.85	1.55	1.15	0.31
48	2	4.55	0.85	0.92	0.20	70	1	4.93	0.88	1.10	0.24
48	3	4.55	0.91	0.70	0.13	70	2	3.57	0.98	1.20	0.21
49	1	3.69	0.93	1.16	0.24	70	4	3.92	0.70	1.05	0.28
49	2	3.93	0.75	1.13	0.18	71	1	3.06	0.40	0.77	0.17
49	3	5.63	1.02	1.69	0.35	71	2	2.84	0.69	0.74	0.18
50	1	5.00	0.59	1.21	0.25	71	3	2.53	0.82	0.65	0.17

APPENDIX 6 : PRE 1990 AVERAGE SHELL DIAMETERS PER TREE

SITE	TREE	--- SHELL DIAMETER CLASS --- old	medium	newer	new	SITE	TREE	--- SHELL DIAMETER CLASS --- old	medium	newer	new
1	1	2.13	2.08	*	2.20	30	1	1.63	1.58	1.57	*
2	1	1.80	*	1.80	1.60	30	2	1.58	1.73	*	*
3	1	2.16	2.11	1.93	2.00	30	3	1.99	1.96	*	*
4	1	2.09	2.28	2.11	*	30	4	1.50	1.74	1.70	*
5	1	1.97	*	*	*	30	5	1.60	*	*	1.65
6	1	1.92	2.00	1.90	*	31	1	1.84	1.89	*	1.92
7	1	2.00	*	*	1.70	31	2	1.60	1.68	*	1.87
8	1	1.68	1.70	1.69	1.70	31	3	1.71	1.90	*	*
9	1	1.87	1.81	1.98	*	32	2	1.56	1.66	*	1.56
10	1	1.68	1.74	1.75	1.76	32	3	1.90	2.00	*	1.78
11	1	1.70	1.71	*	*	33	1	1.55	1.91	1.97	1.86
12	1	2.06	*	*	*	33	2	1.76	1.87	1.80	1.72
12	2	1.81	1.82	*	1.72	33	3	1.82	2.00	1.83	1.93
13	1	1.94	1.99	2.14	1.86	34	1	1.68	1.68	1.66	1.63
14	1	1.71	1.91	1.93	1.90	35	1	1.75	1.79	1.76	1.84
14	1	1.80	1.93	1.87	1.85	35	2	1.82	1.85	1.80	1.85
15	1	1.74	1.73	1.69	1.68	35	1&2	*	*	*	1.83
16	1	1.73	1.76	1.68	1.85	36	1	1.65	1.87	*	*
17	1	1.77	1.81	1.87	1.72	36	2	1.70	1.78	*	*
18	1	1.81	1.79	1.74	*	36	3	1.59	1.68	1.77	*
19	1	1.83	*	*	*	37	1	1.46	1.67	1.66	1.63
19	2	1.74	1.72	*	*	37	2	1.65	1.68	1.69	1.70
20	1	1.60	1.68	1.65	1.68	38	1	1.58	*	*	*
21	1	1.80	1.80	*	*	39	1	1.58	1.66	1.71	1.71
22	1	1.70	*	*	*	40	1	1.76	1.73	1.73	1.76
24	mix	1.61	1.62	1.62	1.55	40	2	1.78	1.87	1.85	1.94
24	2b	1.62	1.73	1.73	*	42	1	1.72	1.80	1.69	1.71
24	2a	1.59	1.67	1.63	*	42	2/3	1.63	1.77	1.71	1.70
24	3	1.52	1.70	1.65	*	43	1	1.40	1.44	1.52	*
24		*	1.67	1.50	1.76	44	1	1.81	1.78	1.88	1.76
26	2	1.85	1.92	1.93	*	44	2	1.63	1.61	1.67	1.60
26	3	1.78	1.79	1.80	*	45	1	1.73	1.80	1.82	1.85
26	4	1.78	1.80	1.95	*	46	1	1.77	2.10	*	*
27	1	1.44	1.47	1.54	1.50	47	1	1.68	1.82	1.71	*
27	2	1.77	1.90	1.82	*	48	1	1.93	1.87	*	*
27	3	1.80	1.80	1.90	*	49	1	2.27	2.25	2.29	2.28
27	4	*	1.45	1.60	*	49	2	1.93	2.07	1.97	2.07
28	1	1.35	1.30	1.33	1.46	50	1	2.01	2.00	1.97	2.30
28	2	1.80	1.30	*	1.75	51	1	*	1.75	1.62	*
28	3	*	1.40	1.30	1.44	51	2	1.87	1.91	1.90	*
29	1	1.74	1.63	1.55	*	51	3	1.85	1.70	1.88	1.79
29	2	1.93	*	*	*	52	1	1.93	2.07	1.90	2.03

APPENDIX 6 : PRE 1990 AVERAGE SHELL DIAMETERS PER TREE

SITE	TREE	--- SHELL DIAMETER CLASS ---				SITE	TREE	--- SHELL DIAMETER CLASS ---			
		old	medium	newer	new			old	medium	newer	new
53	1	1.79	1.91	*	*	61	1	2.00	2.08	2.00	*
53	2	2.01	2.05	2.30	*	61	2	2.29	2.44	1.85	*
53	3	2.07	2.03	*	*	62	1	2.28	2.16	2.15	*
54	1	1.92	1.85	1.90	*	62	3	2.01	1.95	1.80	*
54	2	1.73	1.50	*	*	63	1	2.10	2.14	2.29	2.07
54	3	2.22	2.22	2.45	2.30	63	3	2.25	2.21	*	*
54	4	1.84	2.11	2.10	*	64	1	*	*	*	1.75
55	1	1.95	2.05	2.20	*	65	1	1.88	1.95	2.01	2.06
55	4	1.70	1.87	*	*	65	2	1.85	1.88	1.90	*
55	5	1.72	1.72	1.87	1.88	66	1	1.58	*	*	*
56	1	1.95	1.90	*	*	67	1	2.13	2.13	1.90	*
56	3	1.95	1.99	1.95	*	68	1	1.99	2.09	2.10	2.9
57	1	1.75	1.81	1.68	*	68	2	1.80	1.87	1.79	1.68
58	1	1.69	1.90	1.83	2.00	68	3	1.75	1.73	1.68	1.65
58	2	2.03	2.30	*	*	69	1	2.04	*	*	*
59	1	1.96	2.05	*	*	70	3	1.54	1.53	1.50	*
59	2	1.71	1.64	1.76	1.75	71	1	1.85	1.94	*	*
59	3	1.25	*	1.60	1.80	72	1	1.69	1.77	1.55	*
						72	2	1.90	1.88	1.92	*

APPENDIX 7 :POPULATION AVERAGES FOR INDIVIDUAL FRUIT COMPONENT MEASUREMENTS

SITE #	SHELL DIAMETER	KERNEL DIAM.	KERNEL WEIGHT	SHELL WEIGHT	FLESH WEIGHT
1.00	1.97	0.78	1.20	1.39	*
2.00	*	*	*	*	*
3.00	1.99	1.22	1.30	2.10	1.75
4.00	*	*	*	*	*
5.00	1.92	0.98	1.20	1.81	0.88
6.00	*	*	*	*	*
7.00	1.78	*	*	*	1.25
8.00	*	0.80	1.20	*	*
9.00	1.76	*	*	*	0.60
10.00	*	*	*	*	*
11.00	1.87	1.13	1.31	1.66	0.90
12.00	1.90	1.12	1.31	1.70	0.90
13.00	1.97	1.58	1.41	2.02	1.49
14.00	1.90	1.42	1.40	1.96	1.27
15.00	1.65	0.89	1.19	0.97	0.81
16.00	1.89	0.82	1.16	1.20	0.76
17.00	1.45	0.59	0.97	0.51	0.63
18.00	1.65	0.68	1.08	0.99	0.83
19.00	1.66	0.86	1.14	1.08	0.86
20.00	1.38	0.62	0.96	0.43	0.52
21.00	*	*	*	*	*
22.00	*	*	*	*	*
23.00	*	*	*	*	*
24.00	*	*	*	*	*
25.00	*	*	*	*	*
26.00	*	*	*	*	*
27.00	1.54	0.58	1.02	0.78	0.81
28.00	1.57	0.69	1.12	0.67	0.81
29.00	1.80	*	*	*	1.00
30.00	1.59	0.79	1.10	0.89	0.86
31.00	1.74	0.92	1.18	1.34	0.78
32.00	1.61	0.64	1.02	1.45	1.06
33.00	1.89	1.13	1.24	2.05	1.37
34.00	1.61	0.97	1.28	0.78	0.74
35.00	1.75	1.13	1.31	1.08	0.98
36.00	1.77	1.01	1.13	2.05	1.30
37.00	1.66	1.02	1.14	1.18	0.87
38.00	1.50	*	*	*	*
39.00	1.44	0.42	0.94	0.68	0.64
40.00	1.92	0.88	1.12	1.71	0.87
41.00	1.50	0.50	0.94	0.77	1.05
42.00	1.42	0.56	0.94	0.50	0.66
43.00	1.62	0.74	1.11	1.06	0.95
44.00	1.68	0.74	1.10	2.17	0.94
45.00	1.84	0.83	1.13	1.79	1.19
46.00	*	*	*	*	*
47.00	1.70	0.79	1.08	1.12	0.85
48.00	1.63	0.70	1.07	1.09	0.85
49.00	2.09	1.36	1.34	2.78	1.65
50.00	1.92	1.14	1.29	1.85	1.31
51.00	1.93	1.23	1.31	2.13	1.14

SITE #	SHELL DIAMETER	KERNEL DIAM.	KERNEL WEIGHT	SHELL WEIGHT	FLESH WEIGHT
52.00	1.92	1.06	1.25	2.10	1.23
53.00	1.89	1.16	1.28	1.91	1.71
54.00	2.07	1.55	1.45	2.20	1.31
55.00	1.75	0.79	1.14	2.42	1.29
56.00	1.90	1.06	1.24	2.08	1.65
57.00	1.68	0.72	1.10	2.24	1.39
58.00	1.77	0.88	1.14	1.56	1.13
59.00	1.73	0.71	1.09	1.27	0.78
60.00	1.81	1.16	1.29	1.65	1.27
61.00	1.93	1.38	1.38	1.81	1.69
62.00	2.16	1.60	1.46	3.63	0.71
63.00	*	1.20	1.40	*	*
64.00	*	*	*	*	*
65.00	1.78	1.32	1.30	2.62	1.48
66.00	*	*	*	*	*
67.00	*	*	*	*	*
68.00	1.78	1.09	1.24	1.56	0.76
69.00	*	*	*	*	*
70.00	1.86	*	*	*	*
71.00	1.66	0.83	1.07	1.33	0.93
72.00	*	*	*	*	*

APPENDIX 8 : TOTAL FRUIT PRODUCTION

TOTAL FRUIT PRODUCTION AND SUBCOMPONENTS FOR ALL STUDY TREES WHICH PRODUCED FRUIT FOR THE 1990/1991 SEASON

(I.I.F. = INCOMPLETELY FORMED FRUIT)

SITE # TREE #	TOTAL FRUIT WEIGHT /tree	TOTAL FRUIT # /tree	TOTAL I.F.F. # /tree	TOTAL I.F.F. WEIGHT /tree	TOTAL FLESH WEIGHT /tree	TOTAL KERNEL & SHELL WEIGHT /tree	KERNEL PROP.N n=5 fruit
3 lying	1270	222	126	275	498	498	.32
3 split	1063	182	63	170	473	420	.32
5 1	480	0	165	480	0	0	*
5 2	1825	3	1088	1735	26	64	.3
7 1	62	18	2	2	28	32	*
7 2	75	28	2	2	34	39	*
7 3	4.1	1	*	*	2	2	*
7 5	55	12	1	0.5	26	29	*
7 6	2.2	1	*	*	1	1	*
9 pop.n.	311	0	0	*	81	230	.35
11 junct.n	793	219	48	87	205	501	.34
11 *	3259	804	237	312	796	2151	.34
11 1	181	40	7	12	59	110	.34
12 ridge	1513	431	425	575	235	704	.33
12 -	342	52	33	108	66	168	.34
12 z	2095	676	163	200	625	1270	.34
12 2	196	31	20	35	45	116	.35
12 1	470	50	123	275	45	150	*
12 store	3531	592	783	1502	507	1522	.34
13 1	1241	301	63	147	416	678	.39
13 3a	290	58	4	15	118	157	.38
13 3	1220	263	46	102	481	637	.33
14	790	179	44	87	267	436	.33
15 1	3159	1227	57	70	1328	1761	.46
15 4	1346	402	65	70	434	842	.37
15 5	379	142	13	17	152	210	.37
15 6	4403	1328	83	110	1374	2919	.37
16 1	6282	2108	241	383	2302	2930	.38
16 2	62.5	17	1	*	24	39	.38
16 4	87.5	18	0	0	22	66	*
17 1	252	1	132	172	40	40	.33
17 2	216	55	107	94	61	61	.26
17 3	236	51	92	125	33	78	.34
17 4	162	42	65	65	60	37	.28
18 1	5345	1619	306	412	2171	2762	.36
18 1 1.9	225	43	19	26	88	111	.37
18 1 1.8	745	195	35	55	304	386	.37
18 2 2nd	1740	179	19	27	715	914	.36
18 2 1st	2688	228	48	73	447	1243	.36
18 2 3rd	250	79	7	7	117	126	.37
18 2 4th	382	137	13	16	176	190	.35
19 1	738	214	33	50	255	433	.31
19 3	25	10	7	6.7	8	10	*
20 3	35	10	21	15	7	13	.39
27 1	1870	642	215	297	787	787	.31

SITE # TREE #	TOTAL FRUIT WEIGHT /tree	TOTAL FRUIT # /tree	TOTAL I.F.F. # /tree	TOTAL I.F.F. WEIGHT /tree	TOTAL FLESH WEIGHT /tree	TOTAL KERNEL & SHELL WEIGHT /tree
27 3	75	21	1	1	30	4[illegible]
28 1	680	256	67	82	287	31[illegible]
28 2	375	139	4	10	183	18[illegible]
28 3	50	10	5	10	16	2[illegible]
28 5	400	68	149	216	79	1[illegible]
28 6	2	1	0	0	0.8	1.[illegible]
29 1	8	2	1	2	3	3
30 1	4538	1956	516	652	1632	22[illegible]
30 2	396	63	136	200	78	1[illegible]
30 3	405	9	157	375	10	2[illegible]
30 4	621	180	143	185	174	26[illegible]
31 1	60	12	17	20	16	2[illegible]
31 2	941	25[illegible]	44	163	272	5[illegible]
31 4	37	4	4	6	12	19
32 1	60	10	3	7	23	3[illegible]
32 2l	483	142	73	100	192	19[illegible]
32 2s	2	0	2	2	1	1
33 1	3319	534	199	500	1579	12[illegible]
33 2	100	25	3	4	32	6[illegible]
33 3	180	43	7	6	63	11[illegible]
33 A12	175	41	29	50	51	74
33 B12	291	79	69	109	75	10[illegible]
34 Es	273	97	38	56	89	12[illegible]
35 1s	289	76	38	55	95	13[illegible]
35 1	586	122	114	173	169	24[illegible]
35 2	697	133	85	165	213	319
36 1	879	150	279	550	122	20[illegible]
36 3	617	62	224	425	90	10[illegible]
37 1	21	1	14	15	1	5
37 2	215	61	29	40	81	95
38 1	11	4	1	1	4	6
39 2	40	12	12	10	12	18
40 1A	610	74	206	330	87	19[illegible]
41 1.8x1.5	64	27	2	3	31	3[illegible]
41 1	10	4	1	1	5	5
41/42	89	18	43	52	19	18
42 2	28	8	8	10	7	11
42 3	10	2	8	5	2	3
43 2A	118	20	41	50	33	35
43 2B	22	2	13	17	2	3
43 3	715	161	64	112	223	380
44 1	788	9	149	250	226	312
44 2	3358	1559	234	280	1231	1846
45 1	246	60	53	90	61	95
45 2	490	98	78	115	154	221

APPENDIX 8 : TOTAL FRUIT PRODUCTION

TOTAL FRUIT PRODUCTION AND SUBCOMPONENTS FOR ALL STUDY TREES WHICH PRODUCED FRUIT FOR THE 1990/1991 SEASON
(I.I.F. = INCOMPLETELY FORMED FRUIT)

SITE # TREE #	TOTAL FRUIT WEIGHT /tree	TOTAL FRUIT # /tree	TOTAL I.F.F. # /tree	TOTAL I.F.F. WEIGHT /tree	TOTAL FLESH WEIGHT /tree	TOTAL KERNEL & SHELL WEIGHT /tree	KERNEL PROP.N n=5 fruit
45 3	2722	399	3112	1588	488	646	.29
47 1	292	64	67	75	74	143	.28
47 1 2.6	126	28	28	25	34	67	.24
47 2 1.7	283	101	4	6	102	175	.29
47 2 1.9	150	47	69	45	39	66	.28
47 3 all	612	140	97	125	190	297	.34
48 1	2690	779	97	150	914	1626	.35
48 2	1700	435	45	45	662	993	.33
48 3	360	150	4	4.8	153	202	.28
49 1	4799	722	160	605	1929	2265	.39
49 1 B	450	40	47	148	139	163	.29
49 2	90	19	2	7	32	51	.29
50 1	1972	250	370	965	423	584	.34
51 2	1888	371	200	500	500	888	.32
51 3	20	5	5	5	5	10	*
51 B	177	27	6	20	57	100	.34
52 1	325	69	7	18	120	187	.3
52 2	115	23	6	15	36	64	.4
53 1	308	45	52	127	103	78	.28
53 2	1347	209	158	480	434	434	.36
53 3	48	3	2	4	19	25	.34
54 3	287	49	7	30	100	157	.39
54 7	230	18	47	152	28	50	.37
55 1	75	7	6	18	32	25	*
55 4	328	54	59	120	100	108	.27
55 5	1815	494	80	118	696	1001	.38
56 1	9	2	0	0	4.5	4.5	*
56 3	1733	353	92	220	756	757	.34
57 1	460	94	56	105	183	127	.34
58 1	2419	572	191	300	890	1229	.37
46 2	30	5	5	10	8	12	*
46 extra 1	32	5	3	8	13	11	*
46 extra 2	15	5	0	0	6	9	*
58 2	5	0	2	5	2	3	*
59 2	165	47	17	23	51	91	.3
59 3	140	40	5	6.5	40	93.5	.31
61 1	992	156	66	205	417	370	.4
61 2	27	13	0	0	14	13	*
62 C1	2490	131	415	1745	320	425	.34
62 C2	3712	193	609	2530	508	674	.35
63 1	875	37	213	700	84	91	.3
63 3	20	3	0	0	10	10	*
65 1	3085	625	308	615	1013	1457	.42
65 2	1675	497	92	188	877	610	.44
68 1	13	2	1	4	2	7	*

SITE # TREE #	TOTAL FRUIT WEIGHT /tree	TOTAL FRUIT # /tree	TOTAL I.F.F. # /tree	TOTAL I.F.F. WEIGHT /tree	TOTAL FLESH WEIGHT /tree	TOTAL KERNEL & SHELL WEIGHT /tree
71 1	37	9	0	0	14	[illegible]
60 1	913	167	63	125	331	[illegible]
60 2	5207	1244	109	185	2109	[illegible]
60 3	125	31	2	4.5	55	[illegible]
60 4	2394.5	650	28	50	1032	[illegible]
GN 1	136	11	46	91	14	[illegible]
GN 3	440	107	75	90	105	[illegible]

APPENDIX 9.: PROPORTION OF TREES BEARING FRUIT AT EACH POPULATION FOR 1990/91

SITE #	PROPORTION OF TREES FRUITING	SITE #	PROPORTION OF TREES FRUITING
1	0	37	1
2	0	38	0.5
3	1	39	0.25
4	0	40	0.5
5	0.29	41	0.67
6	1	42	0.17
7	0.67	43	0.33
8	0	44	1
9	1	45	1
10	0	46	0.25
11	0.6	47	1
12	0.85	48	1
13	1	49	0.38
14	0.25	50	1
15	0.36	51	0.67
16	0.75	52	1
17	1	53	0.6
18	1	54	0.4
19	0.67	55	0.5
20	0.2	56	0.33
21	0	57	1
22	0	58	0.25
23	0	59	0.67
24	*	60	1
25	0	61	0.5
26	0	62	1
27	0.29	63	0.33
28	0.83	64	0
29	0	65	0.5
30	1	66	0
31	0.22	67	0
32	0.4	68	0
33	1	69	0
34	0.44	70	0
35	0.07	71	0
36	0.67	72	0

APPENDIX 10 : SITE NUMBERS, SITE NAMES AND LAND STATUS.

SITE #	NAME	LAND STATUS	
1	Borden	Private	
2	Woodanilling	Private	
3	Robinson Road	Road verge	
4	Sunter Road Reserve	Shire	
5	Sunter Road Reserve	Shire	
6	Kalbarri Nat. Park	CALM	
7	Kalbarri Nat. Park	CALM	
8	Geralton	Private	
9	Mullewa	Private	
10	Coalseam "Nat. Park"	Shire	
11	Ajana	Private	
12	Morawa	Private	
13	South Meenar Reserve	CALM	^29977
14	Lundy Reserve	CALM	^ 4667
15	Yorkrakine Rock Reserve	CALM	^23586
16	Yorkrakine Rock Reserve	CALM	^23586
17	Durokoppin Reserve	CALM	^22921
18	Mooranoppin Reserve	CALM	^21153
19	Totagin	CALM	^ 1313
20	Cox Road Reserve	CALM	^ 9754
21	Cox Road Reserve	CALM	^ 9754
22	Cox Road Reserve	CALM	^ 9754
23	Oldfield River	VCL	
24	Peak Charles Nat. Park	CALM	
25	Ravensthorpe Ranges	VCL/Shire	
26	Ravensthorpe Ranges	VCL/Shire	
27	Dingo Rock Reserve	CALM	^13494
28	Dingo Rock Reserve	CALM	^13494
29	Reserve near Dingo Rock	CALM	^25984
30	Reserve near Dingo Rock	CALM	^25984
31	Wyalkatchem Golf Course	Shire	
32	Wyalkatchem Golf Course	Shire	
33	Wyalkatchem Golf Course	Shire	
34	Elabbin Reserve	CALM	^16932
35	Elabbin Reserve	CALM	^16932
36	Lake Brown Reserve	CALM	^24789

APPENDIX 10.: SITE NUMBERS, SITE NAMES AND LAND STATUS.

SITE #	NAME	LAND STATUS	
37	Lake Campion Reserve	CALM	^24789
38	Sandford Rocks Reserve	CALM	^ 1432
39	Sandford Rocks Reserve	CALM	^ 1432
40	Sandford Rocks Reserve	CALM	^ 1432
41	Sandford Rocks Reserve	CALM	^ 1432
42	Sandford Rocks Reserve	CALM	^ 1432
43	Westonia Township	Shire?VCL	
44	Kangaroo Rock	VCL	
45	Lake Deborah	Pastoral	
46	Lake Deborah	Pastoral	
47	Vermin-proof fence	CALM	
48	Vermin-proof fence	CALM	
49	Kulyaling Reserve	CALM	^39379
50	Kulyaling Reserve	CALM	^39379
51	Alderside Reserve	CALM	^13797
52	Alderside Reserve	CALM	^13797
53	Yealering Roadside	Shire	
54	Gillimaning Road	Private	
55	Yealering Township	Shire	^14694
56	Yealering Township	Shire	^14694
57	Yealering Township	Shire	^14694
58	Yealering Township	Shire	^14694
59	Yealering Township	Shire	^14694
60	Lake Toolibin Reserve	CALM	^ 9617
61	Sewell Rock Reserve	CALM	^ 9426
62	Sewell Rock Reserve	CALM	^ 9426
63	Sewell Rock Reserve	CALM	^ 9426
64	Sewell Rock Reserve	CALM	^ 9426
65	Jilakin Rock Reserve	CALM	^15385
66	Bendering Reserve	CALM	^25681
67	Bendering Reserve	CALM	^25681
68	Bendering Reserve	CALM	^25681
69	Bendering Reserve	CALM	^25681
70	Wave Rock	Shire	
71	Wave Rock	Shire	
72	Wave Rock	Shire	

APPENDIX 11 : EXTREMES OF TEMPERATURE FROM SEPTEMBER 1990 TO MARCH 1991 IN THE WHEATBELT (TOWNS ARE PLACED IN THEIR RELATIVE NORTH-SOUTH AND EAST-WEST POSTIONS).

DAYS PER YEAR AT OR OVER 30 oC

Kalbarri	114				
Geraldton	61			Mullewa	124
				Morawa	121
Wongan Hills	114			Southern Cross	115
Brookton	84			Hyden	99
Katanning	52	Ongerup	46	Ravensthorpe	44

DAYS PER YEAR AT OR UNDER 5 oC

Kalbarri	16				
Geraldton	25			Mullewa	58
Morawa		52			
Wongan Hills	39			Southern Cross	69
Brookton	88			Hyden	88
Katanning	72	Ongerup	64	Ravensthorpe	47

APPENDIX 12 : GROUPING OF STUDY SITES BY SHALLOW SOIL PARAMETERS

The figures in this appendix were produced by multivariate analysis of 16 of the shallow soil parameters by two techniques. The Bray-Curtis measure (which is exactly equivalent to the Sorensen analysis (Legendre and Legendre, 1983)) and cosine theta. Both methods are outlined on page 24.

Program em420 (03.01.A)- Test Date of run : 14 Oct 1991

E M Mattiske & Associates

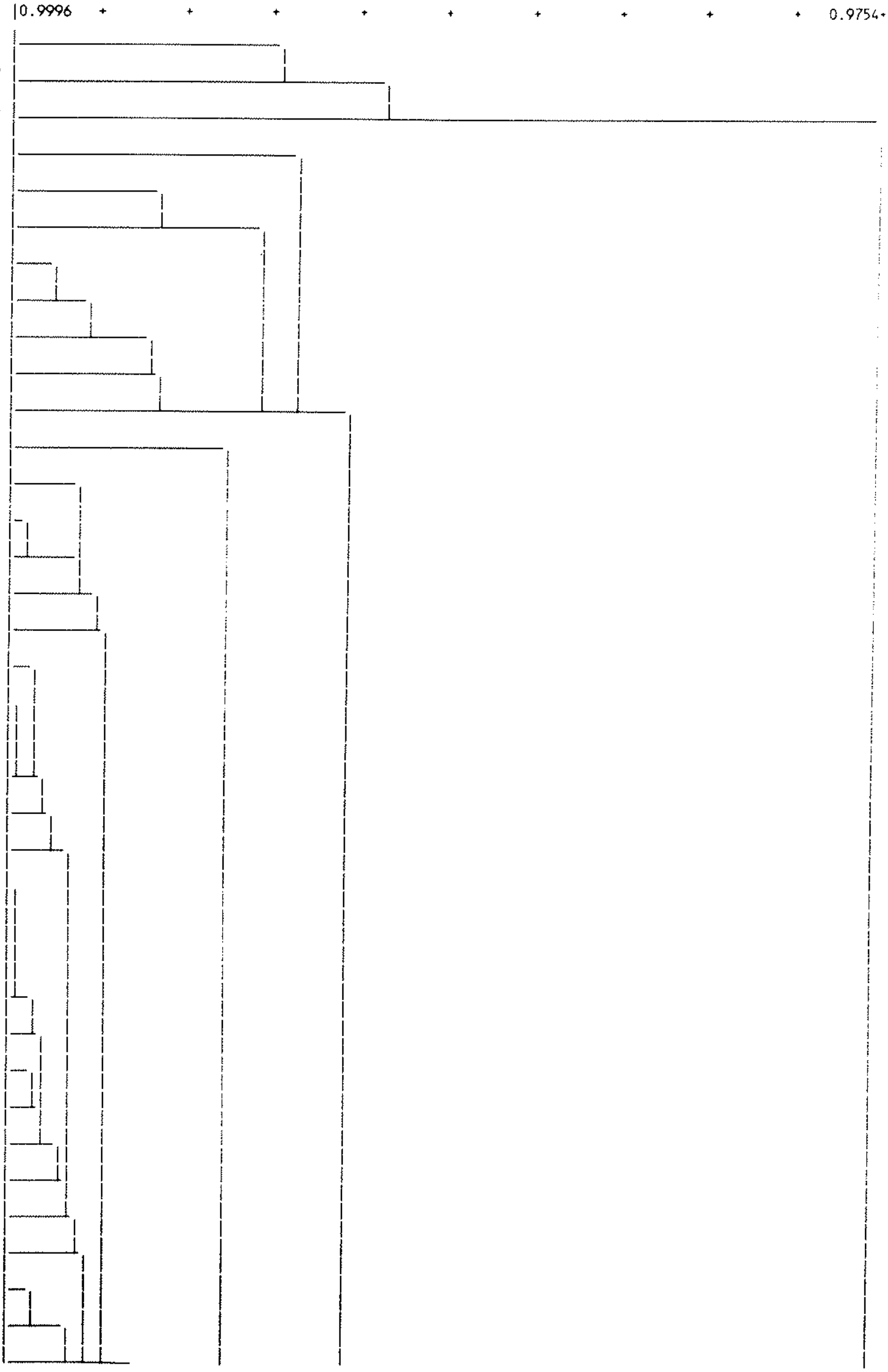
ALAMUNDA 6076 WA

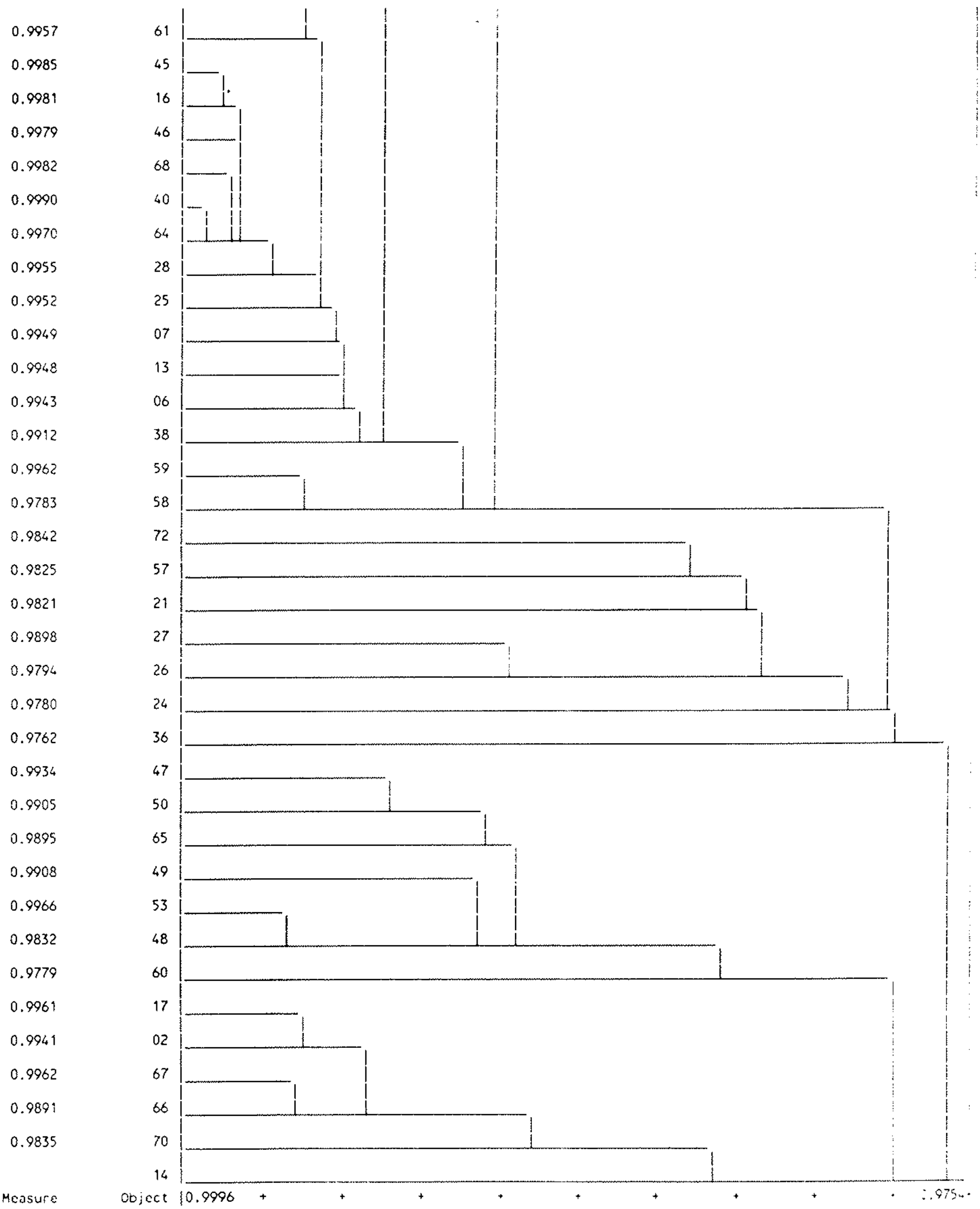
MINIMUM SPANNING TREE

Association measure is Coefficient of proportional similarity (cosine theta)

Single Linkage Dendrogram

Measure	Object
0.9922	01
0.9893	69
0.9754	18
0.9916	20
0.9957	63
0.9928	56
0.9984	33
0.9976	71
0.9957	37
0.9955	08
0.9903	62
0.9935	44
0.9979	39
0.9993	42
0.9977	41
0.9974	34
0.9969	29
0.9989	31
0.9994	30
0.9996	35
0.9987	22
0.9984	51
0.9980	15
0.9995	32
0.9995	19
0.9994	52
0.9991	03
0.9987	09
0.9990	05
0.9988	04
0.9983	23
0.9979	10
0.9977	43
0.9974	11
0.9989	54
0.9979	55
0.9961	12




0.9957 61
0.9985 45
0.9981 16
0.9979 46
0.9982 68
0.9990 40
0.9970 64
0.9955 28
0.9952 25
0.9949 07
0.9948 13
0.9943 06
0.9912 38
0.9962 59
0.9783 58
0.9842 72
0.9825 57
0.9821 21
0.9898 27
0.9794 26
0.9780 24
0.9762 36
0.9934 47
0.9905 50
0.9895 65
0.9908 49
0.9966 53
0.9832 48
0.9779 60
0.9961 17
0.9941 02
0.9962 67
0.9891 66
0.9835 70
14
Measure Object 0.9996 + + + + + + + + + 0.975

Program cm420 (03.01.A) Sandlewood Soils Date of run : 14 Oct 1991

E M Mattiske & Associates

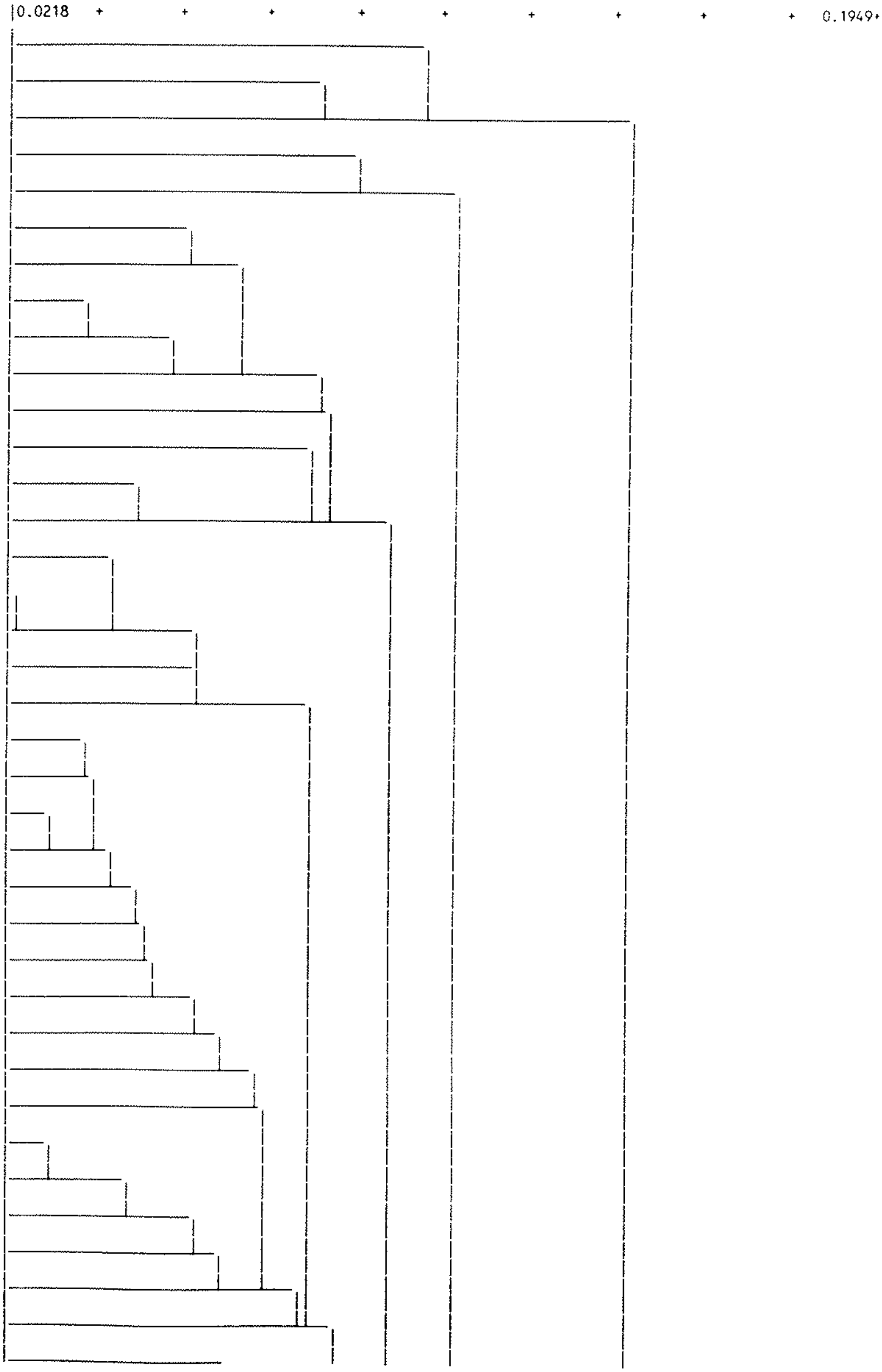
KALAMUNDA 6076 WA

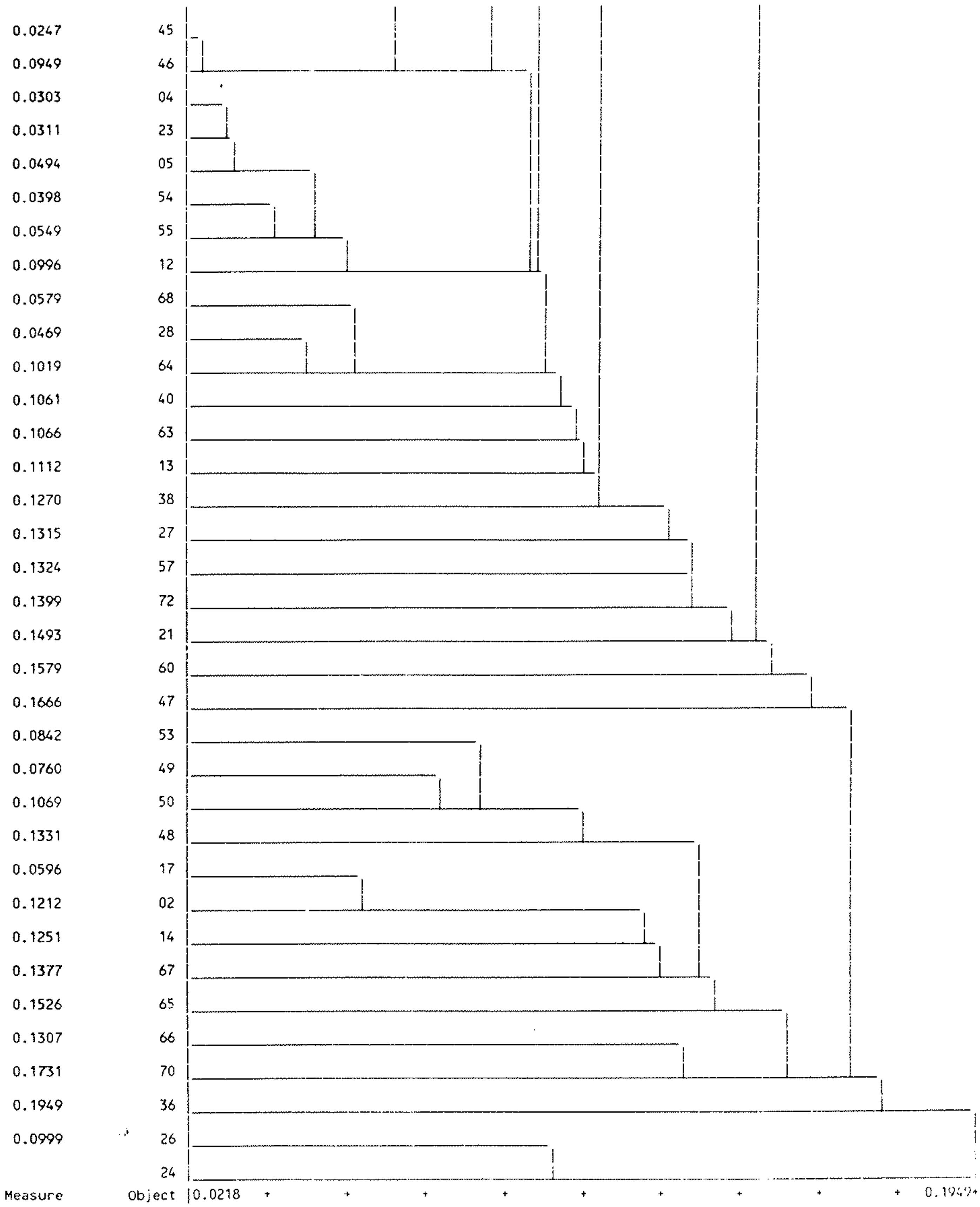
M I N I M U M S P A N N I N G T R E E

Association measure is Bray-Curtis measure

Single Linkage Dendrogram

Measure	Object
0.1040	01
0.0829	69
0.1459	18
0.0910	20
0.1111	56
0.0575	62
0.0677	08
0.0366	71
0.0530	33
0.0832	37
0.0844	44
0.0808	34
0.0476	59
0.0977	58
0.0417	39
0.0218	42
0.0584	41
0.0594	35
0.0814	22
0.0361	32
0.0376	09
0.0288	31
0.0420	30
0.0462	15
0.0494	61
0.0497	11
0.0590	29
0.0636	43
0.0717	06
0.0731	25
0.0292	19
0.0453	52
0.0590	10
0.0647	51
0.0793	03
0.0866	07
0.0659	16





0.0247 45
0.0949 46
0.0303 04
0.0311 23
0.0494 05
0.0398 54
0.0549 55
0.0996 12
0.0579 68
0.0469 28
0.1019 64
0.1061 40
0.1066 63
0.1112 13
0.1270 38
0.1315 27
0.1324 57
0.1399 72
0.1493 21
0.1579 60
0.1666 47
0.0842 53
0.0760 49
0.1069 50
0.1331 48
0.0596 17
0.1212 02
0.1251 14
0.1377 67
0.1526 65
0.1307 66
0.1731 70
0.1949 36
0.0999 26
24
Measure
Object
0.0218
0.1949+