JOURNAL of the ADELAIDE BOTANIC GARDENS

AN OPEN ACCESS JOURNAL FOR AUSTRALIAN SYSTEMATIC BOTANY

flora.sa.gov.au/jabg

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STATE HERBARIUM OF SOUTH AUSTRALIA
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State Herbarium of South Australia
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Government of South Australia
Department of Environment, Water and Natural Resources

Board *of the* Botanic Gardens *and* State Herbarium

J. Adelaide Bot. Gard. 7(2): 167-179 (1985)

THE PERFORMANCE OF AN AMENITY PLANTING UNDER IRRIGATION AT MONARTO, SOUTH AUSTRALIA

Anthony P. Meissner and Brendan G. Lay

S.A. Department of Agriculture, 25 Grenfell Street, Adelaide, South Australia, 5000.

Abstract

An extensive trial of forty six tree, shrub and groundcover species under various irrigation regimes and natural rainfall was used to evaluate the performance of these plants for amenity purposes. Multivariate cluster analysis was used to separate the plants into groups on overall performance under all the irrigation regimes. Nearly half of the species used grew satisfactorily under all test conditions. These plants came from areas in southern Australia which received between 350 and 500mm of annual rainfall and are tolerant of a range of acid and alkaline soils. All exotic plants in the trial performed poorly and most eventually died. Plants irrigated at the optimum rate performed best.

Introduction

The cultivation of trees, shrubs and ground cover plants specifically for the amelioration of the urban environment is accepted practice throughout the world and an integral part of town planning. In recent years there has been a greater appreciation of Australian native flora for amenity plantings. There is, however, a general misconception that native plants will thrive under all environmental conditions. Hence, the selection of native species is often in the absence of information about the local environment, the plant's own natural habitat, or its performance in similar situations elsewhere.

As specific information of plant performance under different climatic or cultural conditions is lacking, it is often difficult to recommend a range of plants for cultivation in a specific location. Little data are available on the effects of irrigation rate or method and its relationship to soil type. This is possibly because these plantings have no economic value *per se* even though it is necessary to select the right tree, shrub or ground cover species to plant.

In the early 1970's, the Government of South Australia proposed to build a new city at Monarto near Murray Bridge (35° 10'S 139° 17'E). Investigations of the soils and hydrology of the site indicated the likelihood of high soil salinity and ground water tables developing as a result of increased water application following urbanization (Schrale 1976). The Department of Agriculture collaborated with the Monarto Development Commission to evaluate the probable effects of irrigation practices in an urban environment on soil salinity, groundwater hydrology and the performance of a range of commonly grown amenity plants. The Monarto Irrigation Experiment Station was therefore established in 1976.

Overall performance of these plantings has been described in a general way by Lay (1980, 1983). This paper reports the statistical evaluation of these results and describes the effects of the different irrigation treatments on the growth of the plants.

Design of experiment

Details of the site and irrigation design are given in Schrale (1976) and Dubois (1977). Briefly, nine beds were laid out as shown in Figure 1. Eight of the beds were planted with a range of trees, shrubs and ground-covers, the ninth contained only mown grass. Each of the eight planted beds was further subdivided into three sub-beds and planted with forty six native and exotic species (Figure 2). Table 1 lists the species together with their tolerance to some soil conditions and the minimum average annual rainfall of areas of their natural occurence.

The treatments applied were (1) natural rainfall, (2) drip irrigation applied at the calculated

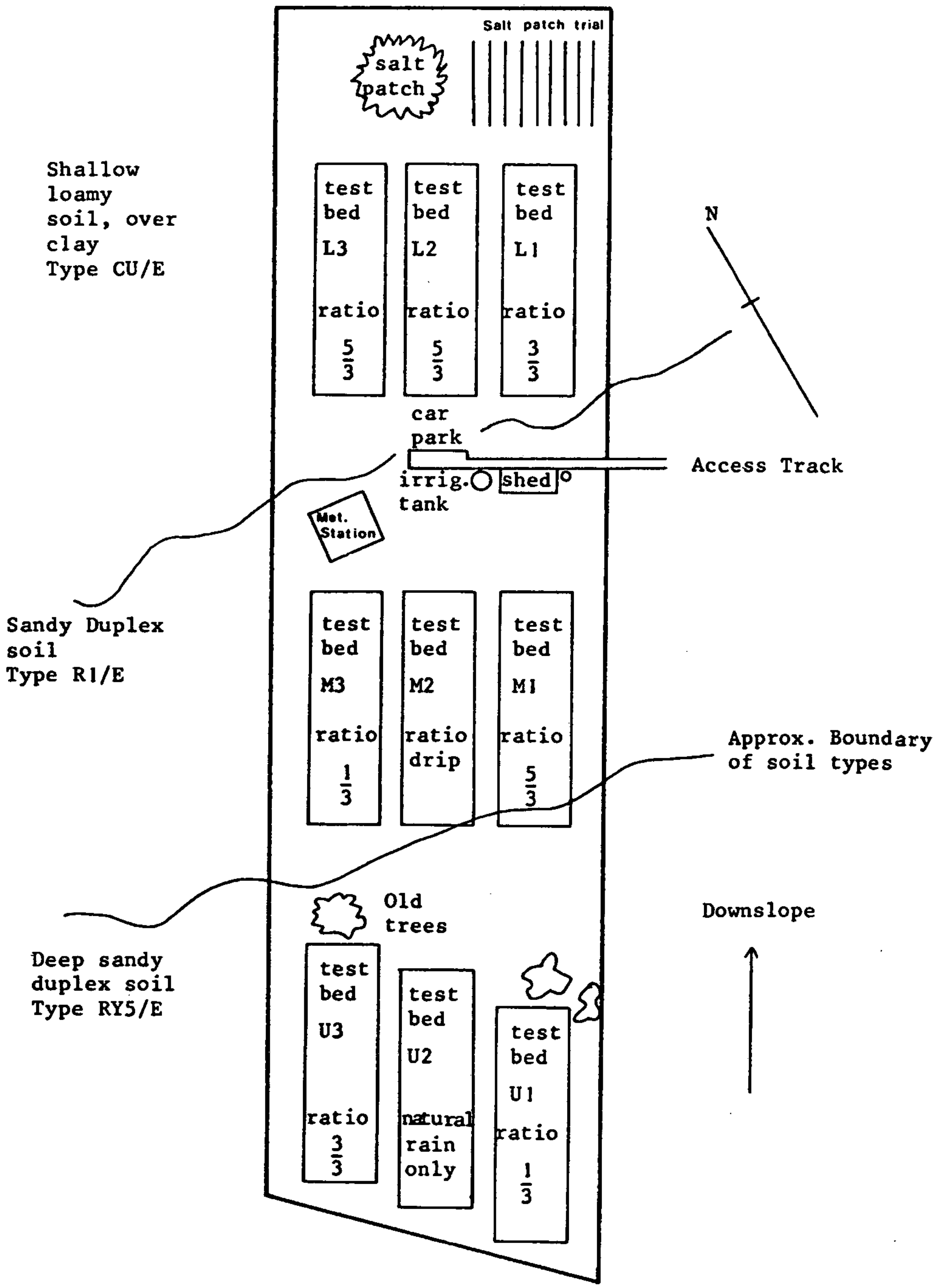
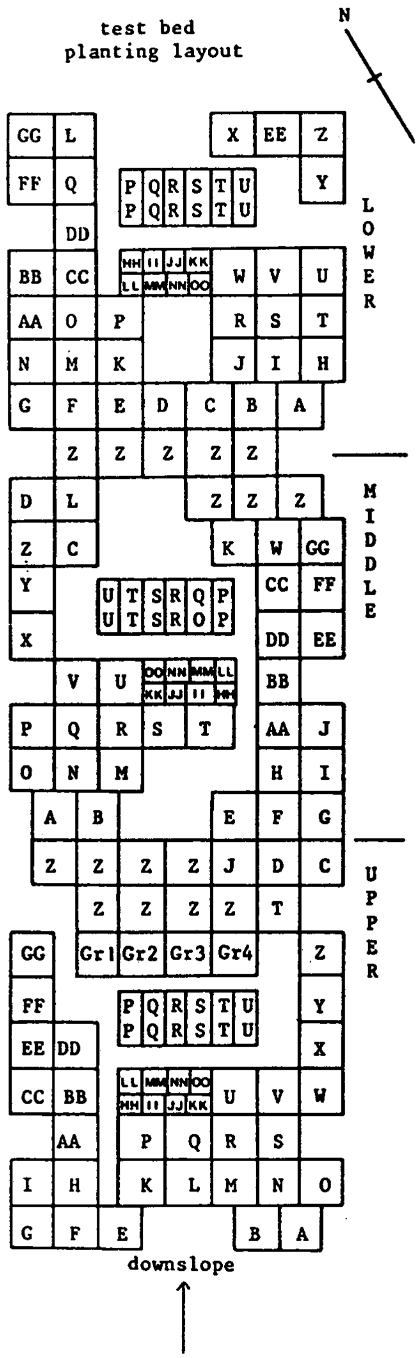


Fig. 1. Site layout details for the experimental site. Soil types refer to the Factual Key (Northcote, 1970).



Plant species

A	*Eucalyptus odorata* Schltdl.
B	*Eucalyptus salmonophloia* F. Muell.
C	*Eucalyptus ficifolia* F. Muell.
D	*Eucalyptus gomphocephela* A. Dc.
E	*Eucalyptus redunca* Schauer. var. *melanophloia* Benth.
F	*Eucalyptus melliodora* Schauer
G	*Eucalyptus leucoxylon* F. Muell. var. *rosea*
H	*Eucalyptus maculata* Hook.
I	*Eucalyptus sideroxylon* Woolls.
J	*Casuarina cunninghamiana* Mig.
K	*Acacia calamifolia* Sweet ex Lindl.
L	*Acacia iteaphylla* F. Muell. ex Benth.
M	*Acacia pendula* G. Don
N	*Acacia brachybotrya* Benth.
O	*Acacia saligna* (Labill.) H. Wendl.
P	*Agonis flexuosa* (Spreng.) Schauer
Q	*Callistemon salignus* (Sm.) DC.
R	Callistemon viminalis (Gaertn.) Loud.
S	*Hakea elliptica* (Sm.) R. Br.
T	*Eucalyptus forrestiana* Diels
U	*Hakea laurina* R. Br.
V	*Eucalyptus spathulata* Hook.
W	*Leptospermum laevigatum* (Gaertn.) F. Muell.
X	*Melaleuca armillaris* Sm.
Y	*Melaleuca halmaturorum* Mig.
Z	*Melaleuca nesophila* F. Muell.
AA	*Celtis occidentalis* L.
BB	*Bougainvillea magnifica* var. *traillii*
CC	*Lagerstroemia indica* L.
DD	*Brachychiton populneo/acerifolium*
EE	*Hibiscus* "General Cortegis"
FF	*Jacaranda mimosifolia* D. Don
GG	*Melia azedarach* L.
HH	*Cassia nemophila* J.R.T. Vogel
II	*Calocephalus brownii* F. Muell.
JJ	*Calothamnus quadrifidus* F. Br.
KK	*Eremophila maculata* (Ker.) F. Muell.
LL	*Grevillea rosmarinifolia* Cunn.
MM	*Hakea suaveolens* R. Br.
NN	*Melaleuca decussata* R. Br.
OO	*Templetonia retusa* (Vent.) R. Br.
PP	*Enchylaena tomentosa* R. Br.
QQ	*Hardenbergia comptoniana* (Andr.) Benth.
RR	*Eremophila glabra* (R. Br.) Ostenf.
SS	*Myoporum parvifolium* R. Br.
UU	*Rhagodia spinescens* R. Br.

Fig. 2. Planting layout of each test bed.

rate of potential plant water use under drip**, (3) sprinkler irrigation applied at the calculated potential plant water use (designated as ratio 3/3 in Figure 1), (4) sprinkler irrigation at five thirds (5/3). The total water applied by dripper was one third the sprinkler rate. The layout of the treatments is shown in Figure 1. The experiment began in April 1977 and irrigations ceased in June 1982. Plants which died or were damaged by equipment were replanted only until March 1978. Daily rainfall was recorded at the site from September, 1976 to August, 1982. Annual rainfall during the experiment averaged 336 mm and annual totals for 1977 to 1981 were 313, 385, 382, 317 and 322 mm. Photograph 1 shows a view over the lower and middle test beds at the end of the experiment.

Plants were chosen on the basis of species commonly available to the public and included some known for their salt tolerance. In particular, South Australian dryland and coastal species were chosen where possible (Matheson and Barwick, 1975).

The performance of the plants was evaluated on three occasions: March 1980, July 1982 and May 1983. The method of assessment used is described by Lay and Meissner (1985); each plant was rated individually on a six point scale for health and vigour.

Data analyses

As the experiment was not completely replicated conventional statistical analysis was not appropriate. The approach adopted was to use multivariate cluster analysis techniques to derive species performance groupings and to elucidate the effects of irrigation and time on plant performance. The data set contained 39,744 items made up of 46 species x 3 sub-beds x 8 beds x 3 times for each of 6 health and vigour categories.

These data were reduced to derive the species performance groupings. Contingency tables of species x health and vigour categories were drawn up for each of the three dates on which the plantings were assessed. For example, a health table had 46 rows, one for each species and six columns, one for each point of the health scale. This gave six tables of 6 columns each. These columns were then considered as 36 variables, each column (variable) containing the number of occurrences a species was assessed as having a particular health or vigour score at one of the times of assessment. A similarity matrix of performance between species was calculated using a linear quantitative measure (Gower, 1971). This similarity matrix was then used as the basis for hierarchical cluster analysis using the furthest neighbour technique. Groups were delineated by visual inspection of the resulting dendrogram. The treatment x time effect groups were derived similarly by reducing the original data set by amalgamating over species and sub-beds. The GENSTAT statistical package was used to carry out the data manupulations and analyses (Alvey *et al.* (1977)).

Results and discussion

The hierarchical nature of the analysis and the resulting dendrogram do not imply any inherent relationship between plant species or groups, but should be seen only in the context of separating plants into similar groups on their response to a particular set of environmental conditions.

**Determination of average plant water requirement was done according to Schrale (1976). He used the potential evapotranspiration from a mown, well-watered grass as a guide for the first two years. After this time, plant requirement was determined from tree lysimeter studies and included a provision that about 15% of applied water was available to leach salts beyond the root zone of the plants.

Table 1 **Species used in Monarto irrigation experiment**

Symbol	Botanical name	Common name	Native to	Height	Rainfall mm	ACF
A	Eucalyptus odorata	Peppermint Box	Monarto	6-8	450	AC
B	Eucalyptus salmonophloia	Salmon Gum	W.A.	10-15	350	C
C	Eucalyptus ficifolia	Red Flowering Gum	W.A.	6-8	550	A
D	Eucalyptus gomphocephala	Tuart	W.A.	10-30	450	ACF
E	Eucalyptus redunca v. melanophloia	Black Barked Marlock	W.A.	3-5	400	AC
F	Eucalyptus melliodora	Yellow Box	Vic.	10-20	500	
G	Eucalyptus leucoxylon rosea	Red Flowered S.A. Blue	Monarto	8-20	500	AC
H	Eucalyptus maculata	Spotted Gum	N.S.W.	8-25	600	A
I	Eucalyptus sideroxylon	Red Ironbark	S.A.	10-20	500	AC
J.	Casuarina cunninghamiana	River Oak	Qld.	10-25	550	AC
K	Acacia calamifolia	Wallowa	S.A.	2-5	250	C
L	Acacia iteaphylla	Flinders Range Wattle	S.A.	3-5	400	AC
M	Acacia pendula	Weeping Myall	S.A.	6	400	AC
N	Acacia brachybotrya	Grey Mulga	Monarto	2	350	AC
O	Acacia saligna	Golden Wreath Wattle	S.A.	6	450	ACF
P	Agonis flexuosa	Willow Myrtle	W.A.	5-8	500	ACF
Q	Callistemon salignus		S.A.	3-5	500	A
R	Callistemon viminalis	Weeping Bottlebrush	N.S.W.	4-6	550	A
S	Hakea elliptica		W.A.	2-5	330+	AC
T	Eucalyptus forrestiana	Fuchsia Gum	W.A.	3-5	350	AC
U	Hakea laurina	Pincushion Hakea	W.A.	3-5	450	ACF
V	Eucalyptus spathulata	Swamp Mallet	W.A.	6-8	400	ACS
W	Leptospermum laevigatum	Coastal Teatree	Vic.	2-4	400	ACF
X	Melaleuca armillaris	Bracelet Honey Myrtle	Vic.	3-5	450	
Y	Melaleuca halmaturorum	K.I. Swamp Paperback	S.A.	2-4	350	ACS
Z	Melaleuca nesophila	Western Honey Myrtle	W.A.	2-3	450	ACF
AA	Celtis occidentalis	Hackberry	Exotic	10-15	450	
BB	Bougainvillea magnifica var. traillii	Purple Bougainvillea	Exotic	2-3	500	
CC	Lagerstroemia indica	Crepe Myrtle	Exotic	3-4	450	F
DD	Brachychiton populneo/ acerifolium	Hybrid Flame Tree	N.S.W.	10-15	500	AC
EE	Hibiscus "General Cortegis"	Hibiscus	Exotic	1-2	550	
FF	Jacaranda mimosifolia	Jacaranda	Exotic	6-10	550	
GG	Melia azedarach	White cedar	Qld.	6-10	500	AC
HH	Cassia nemophila var.	Desert Cassia	S.A.	1-2	250	AC
II	Calocephalus brownii	Cushion Bush	S.A.	½	400	ACF
JJ	Calothamnus quadrifidus	Crimson Net Bush	W.A.	2-3	500	A
KK	Eremophila maculata	Spotted Emu Bush	Monarto	1-2	350	C
LL	Grevillea rosmarinifolia	Rosemary Grevillea	Vic.	2-3	550	A
MM	Hakea suaveolens	Sweet Hakea	W.A.	3-4	350	ACF
NN	Melaleuca decussata	Crossleaved Honey Myrtle	S.A.	1-3	450	ACS
OO	Templetonia retusa	Red Templetonia	S.A.	1-2	400	C
PP	Enchylaena tomentosa	Ruby Saltbush	Monarto	GC	300	C
QQ	Hardenbergia comptoniana	W.A. Coral Pea	W.A.	GC	600	ACS
RR	Eremophila glabra	Tar Bush	S.A.	GC	350	CS
SS	Myoporum parvifolium	Creeping Boobialla	S.A.	GC	500	ACSF
UU	Rhagodia spinescens		S.A.	GC	300	CS

* Considered tolerant of:
A = Acid neutral soils; C = Calcareous (alkaline) soils;
F = Coastal sites; S = Saline sites

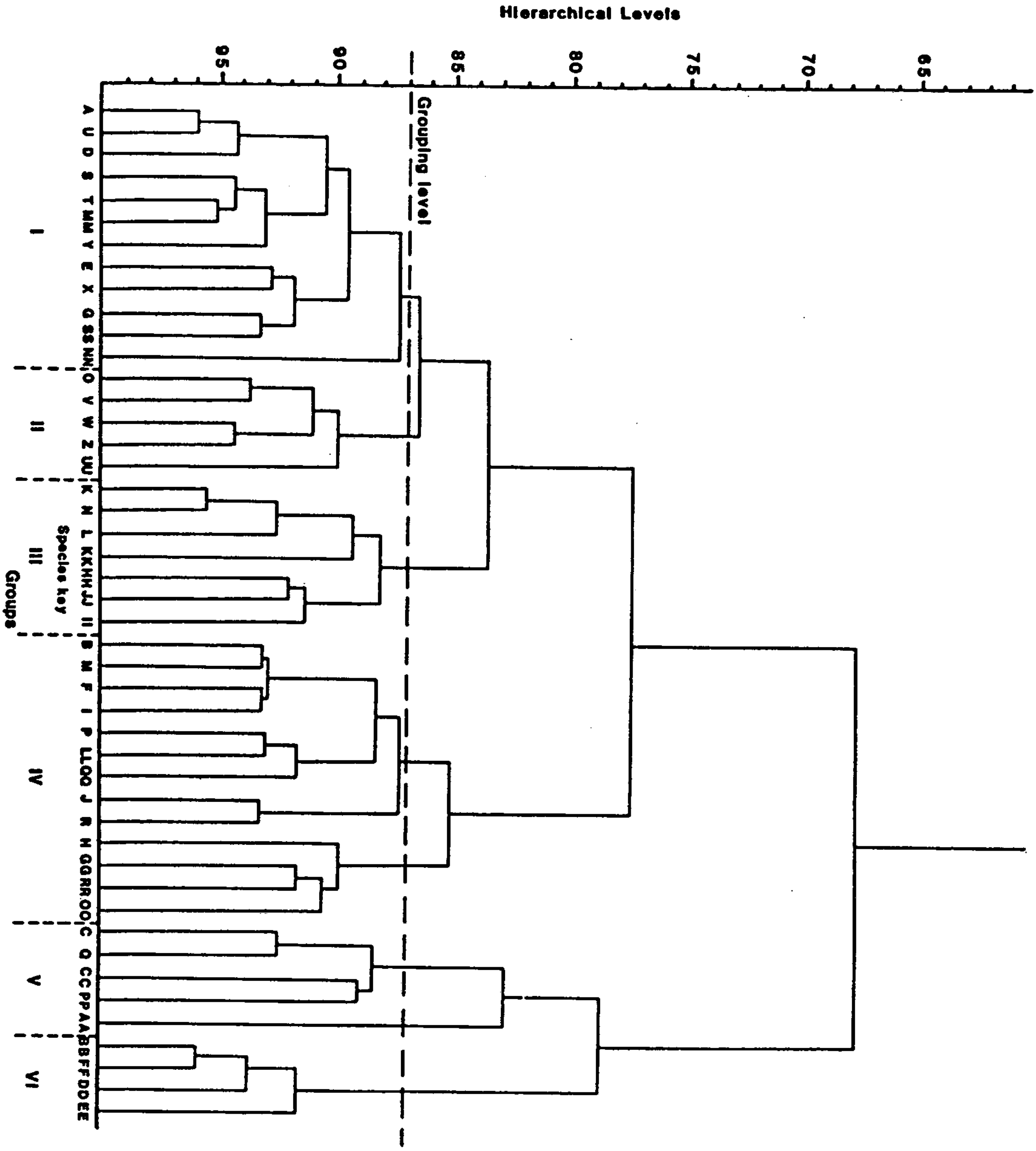


Fig. 3. Dendrogram of cluster analysis for species performance. Letters refer to species (see Table 1) and roman numerals to groups.

Table 2. Health and vigour profiles for typical members of each group. Righthand column of figures are mean performance scores from Lay (1983). A rating of 0 for health and vigour indicate a dead plant while a score of 5 indicates a healthy or vigorous plant. (Lay and Meissner, 1985).

			Health						Vigour						Perform.
Group	Species	Time	0	1	2	3	4	5	0	1	2	3	4	5	Scores
I	*Hakea elliptica*	March 1980	0	0	0	0	5	19	0	0	0	5	7	12	9.6
		July 1982	0	0	0	1	8	15	0	0	1	6	10	7	8.5
		May 1983	0	2	1	4	7	10	0	1	1	8	9	5	7.6
II	*Eucalyptus spathulata*	March 1980	1	0	0	1	8	14	1	0	2	0	8	13	8.7
		July 1982	1	0	0	1	2	20	1	0	0	2	4	17	9.0
		May 1983	2	0	1	0	0	21	2	2	0	2	4	14	8.4
III	*Cassia nemophila*	March 1980	1	0	2	3	5	12	1	1	2	7	11	2	7.6
		July 1982	5	1	2	3	7	6	5	0	2	2	8	7	6.2
		May 1983	9	0	3	1	8	3	9	1	1	3	6	4	4.7
IV	*Templetonia retusa*	March 1980	1	1	0	7	8	7	1	1	6	3	6	7	7.7
		July 1982	3	1	5	10	4	1	3	2	4	8	6	1	5.2
		May 1983	3	0	1	8	12	0	3	2	4	8	7	0	5.7
V	*Eucalyptus ficifolia*	March 1980	2	2	1	10	5	4	2	5	6	7	3	1	5.9
		July 1982	7	0	2	8	7	0	7	6	5	2	3	1	4.0
		May 1983	8	0	1	6	7	2	8	3	3	4	5	1	3.6
VI	*Brachychiton populneo-acerfolium*	March 1980	4	6	2	7	5	0	4	13	5	2	0	0	3.8
		July 1982	18	5	1	0	0	0	18	5	1	0	0	0	0.6
		May 1983	23	1	0	0	0	0	23	1	0	0	0	0	0.1

(a) Species performance groups

Six performance groups were delineated. The dendrogram derived by using furthest neighbour cluster analysis is shown in Figure 3. Groups I to IV were separated from Groups V and VI on the basis of the number of plants that died (0 score for both health and vigour). The number of species in each group were 12, 5, 7, 13, 5 and 4 for groups I and VI in that order. Mean values within group similarities ranged from 91.7% (Group I) to 88.7% (Group VI) with Groups I and II most similar (90.1%). Groups I and VI were most dissimilar (70.9%). Group I and II plants were generally healthy and grew vigorously over the duration of the experiment. Group II plants generally became more healthy and vigorous with time even though there were some deaths. Species in Group VI rapidly declined in health and vigour over the course of the experiment and these consisted exclusively of exotic plants. The performance profile of typical members of each group is shown in Table 2.

The performance of plants in all groups except Group II declined with time. The best performing groups were species that all came from areas receiving between 350 and 500 mm of average annual rainfall and tolerant of both acid and alkaline soils with some plants known to be salt tolerant. Group IV plants were generally from high rainfall areas and not tolerant of alkaline soils. Species in Groups I and II performed well over all irrigation treatments and continued to do so even when irrigation ceased in July 1982. This was despite the severe drought which occurred in that year. This group of plants can be expected to perform similarly in environments like that at the Monarto site. Even though Group VI plants are widely grown with success in some urban environments in South Australia this group could not be recommended in drier areas if irrigation is discontinued after establishment or where salinity or high water tables may occur.

Slightly different groupings may have been obtained with other methods of constructing the similarity matrix or the use of other clustering techniques such as nearest neighbour or centroid

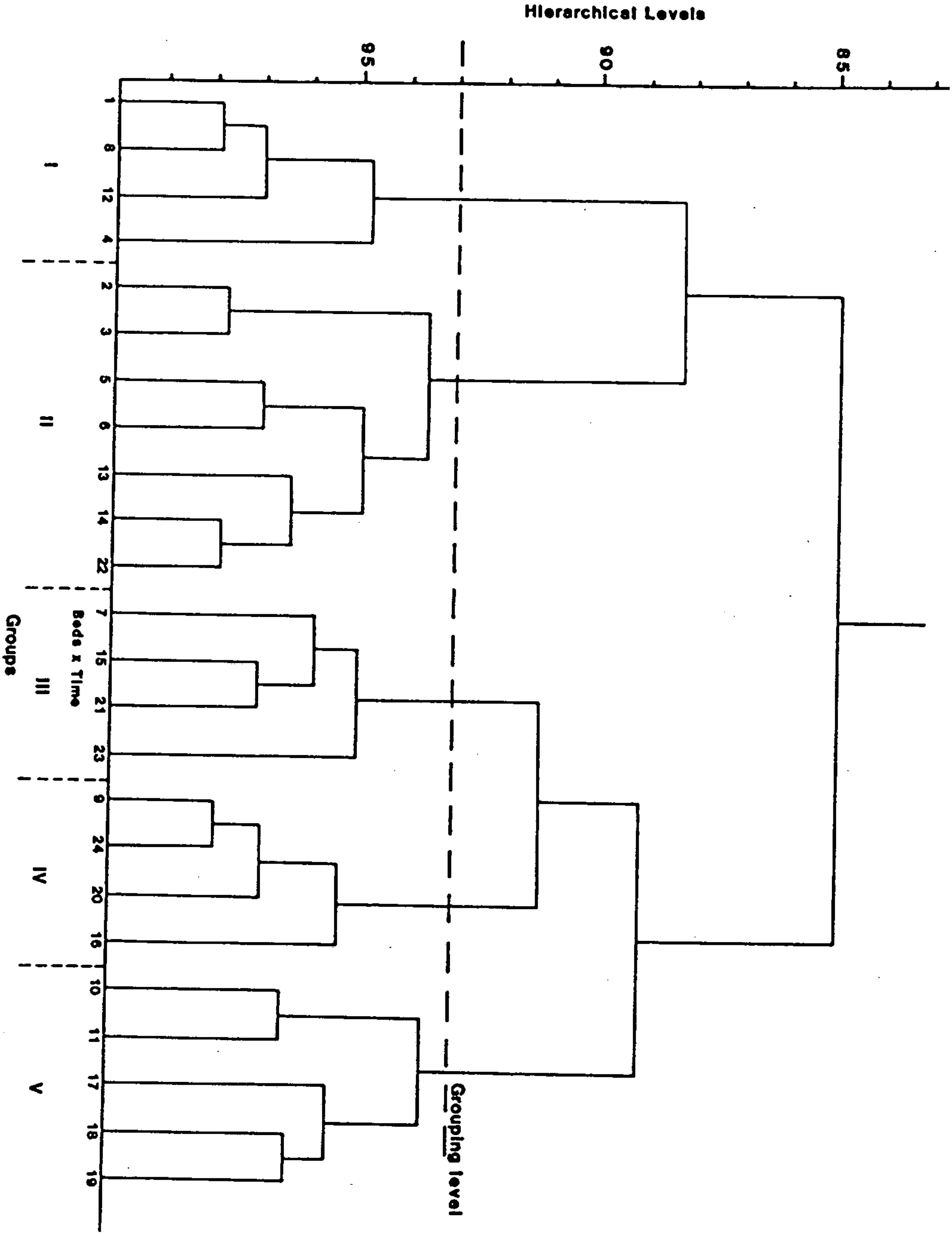


Fig. 4. Dendrogram of cluster analysis for irrigation treatments and time of evaluation. Key to numbers is given in Table 3.

Table 3. Key to numbers on the dendrogram in Figure 4.

Key	Group	Bed		Treatment	Time
1	I	Lower	1	3/3	March 1980
8		Upper	3	3/3	March 1980
4		Middle	2	Drip	March 1980
12		Middle	2	Drip	July 1982
2	II	Lower	3	5/3	March 1980
3		Middle	1	5/3	March 1980
5		Middle	3	1/3	March 1980
6		Upper	1	1/3	March 1980
13		Middle	3	1/3	July 1982
14		Upper	1	1/3	July 1982
22		Upper	1	1/3	May 1983
7	III	Upper	2	Rain	March 1980
15		Upper	2	Rain	July 1982
23		Upper	2	Rain	May 1983
21		Middle	3	1/3	May 1983
9	IV	Lower	1	3/3	July 1982
16		Upper	3	3/3	July 1982
20		Middle	2	Drip	May 1983
24		Upper	3	3/3	May 1983
10	V	Lower	3	5/3	July 1982
11		Middle	1	5/3	July 1982
17		Lower	1	3/3	May 1983
18		Lower	3	5/3	May 1983
19		Middle	3	5/3	May 1983

clustering. Clustering techniques can summarize data efficiently and show the subtle differences which give rise to the groupings. Table 2 shows the differences in the health and vigour categories for examples from the groups. If the facilities for multivariate cluster analyses are not available, groups can be derived by averaging the sum of the health and vigour scores over all treatments as described by Lay (1983) and Lay and Meissner (1985). These mean figures are shown in Table 2 for comparison with the multivariate analysis groups.

(b) Irrigation treatments and time effects

Results of the cluster analysis are shown as a dendrogram in Figure 4. The key to the number is shown in Table 3. Five groups were delineated at the 93% heirarchical level. The groupings indicate some interaction between the irrigation treatments and time. This can be seen from Table 3 where the irrigation and time treatment are shown in their derived groups. The effect of optimum irrigation treatments early in the experiment is characteristic of Group I members. In contrast Group IV members were associated with the later effects of the optimum irrigation rate. Plants which were in the optimum groups were generally healthier and grew more vigorously than those in the other clusters. Sub-optimal irrigation effects over the duration of the experiment separated out in Group II. This group was, predictably, most similar to Group III consisting mostly of the natural rainfall treatment. The under-watered groups (rain and 1/3 irrigation) were healthy but did not grow as quickly. Overwatering effects at the later stages of the experiment made up Group V and resulted in unhealthy growth and variable vigour. Common symptoms were wind throw, limb breakage, partial or complete dieback and general chlorosis caused by waterlogged soils, particularly on the middle and lower beds. Plates 2(a), (b) and (c) show the difference in the performance of the same species watered at 1/3, drip and 5/3 irrigation rates respectively.

Plate 1. Elevated view of lower and middle test beds at the end of the experiment. View looking north.
Plate 2(a). View of same set of plants in test beds middle 1 (1/3 treatment).

Plate 2(b) and (c). View of same set of plants in test beds middle 2 (drip) and middle 3 (5/3) respectively.

Table 4: Health and vigour profiles for the irrigation treatments and natural rainfall at the three evaluation times. Final column of figures from Lay (1983). Ratings scale as for Table 2.

		Health						Vigour						Perform.
March 1980	Treatment	0	1	2	3	4	5	0	1	2	3	4	5	Score
March 1980	Rain	22	1	2	20	50	43	22	13	25	32	32	14	6.6
	Drip	3	2	3	8	33	89	3	6	15	25	38	51	8.3
	1/3	12	2	5	9	54	56	12	10	17	34	43	22	7.3
	3/3	5	7	6	15	28	77	5	7	11	19	35	61	8.1
	5/3	11	9	8	34	45	31	11	14	21	25	43	24	6.5
July 1982	Rain	27	2	4	26	36	43	27	9	19	23	38	22	6.0
	Drip	13	5	5	11	27	77	13	8	9	20	24	64	7.7
	1/3	17	2	4	26	44	45	17	9	9	29	46	28	6.7
	3/3	29	2	9	14	30	54	29	9	4	20	25	21	6.5
	5/3	40	5	8	36	28	21	40	9	19	23	31	16	4.9
May 1983	Rain	29	2	5	13	31	58	29	8	24	25	30	22	6.0
	Drip	24	2	14	13	38	47	24	5	9	21	28	51	6.9
	1/3	21	5	10	14	40	48	21	11	10	30	42	24	6.3
	3/3	33	5	9	17	32	42	33	8	8	15	31	43	6.2
	5/3	40	4	12	18	33	31	40	15	10	26	25	22	5.1

The effect of cessation of irrigation was most noticeable with the drip irrigation treatment (Table 4). There was a rapid decline in health and vigour from July 1982 to May 1983. This was during a period of severe drought. This rapid deterioration may have been due to the more confined root distribution of some species because of the restricted zone of soil wetting around each water source (Lay 1983) compared with the sprinkler treatments. When watering ceased, the plants were not able to draw moisture from a larger volume of soil as would be the case for the sprinkler irrigation treatments. The plants in the 5/3 irrigation rate improved when irrigation ceased as excess water was able to drain away and soil aeration improved as a result.

Conclusion

Most of the species planted at Monarto were chosen as being hardy or salt tolerant plants commonly under cultivation. Group I and particularly Group II species proved suitable for amenity plantings at Monarto. These plants are recommended in environments similar to that at Monarto and are tolerant of a wide range of soil and climatic conditions as experienced at the experimental site. Drip irrigation gave by far the best results in terms of amount of water used to establish healthy and vigorous plants. A significant point revealed by the experiment is that many species are able to perform well without any irrigation even on this exposed site.

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