



Evaluation of shrub performance under arid conditions

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Abstract

The climate of Kuwait is characterized by very hot, dry summers and cool rainy winters. Although a large number of ornamental plants had proved to endure such environmental conditions, Kuwait is dependent on limited species previously introduced to the country. A greater diversification is required to increase the plant list in developing landscape projects. Developing plants that have attractive characteristics during all four seasons help gardeners reach their goal of a well-planned landscape. Careful plant selection is the key first step in developing a balanced and self-perpetuating landscape. The purpose of this study was to test and evaluate a list of ornamental shrubs that had not been previously tested for their suitability to Kuwait. This study was conducted on twenty six shrub species in an inland and a coastal site. These plants were obtained from Australia and India. The shrubs were tested for their suitability to withstand the adverse climatic conditions of Kuwait. It was observed that in summer *Bambusa vulgaris* Aureo-variegata, *Hakea laurina*, *Calliandra haematocephala* and *Justicia aurea* were not able to survive the intense heat during the months of July and August. Some shrubs like *Cestrum diurnum*, *Eucalyptus websteriana*, *Hamelia patens*, *Holmskioldia sanguinea* etc. were moderately sensitive to the heat and *Acacia sclerophylla*, *Acacia wilhelmina*, *Hibiscus rosasinensis* variegata, *Banksia ashbyi*, *Gossypium sturtianum*, *Callistemon viminalis* 'Captain Cook', *Nyctanthes arboretum* and *Russelia equisetiformis* were found to have excellent growth in summer. The survival percentages of plants like *Geijera parviflora*, *Gossypium sturtianum*, *Cestrum diurnum*, *Holmskioldia sanguinea*, *Brachychiton rupestris*, *Nyctanthes arboretum* and *Euphorbia characias* were hundred percent.

Key words: Ornamental plants, diversification, gardeners, landscape, shrub, inland site, coastal site, intense heat.

Introduction

With the rapid development of the urban and suburban areas in Kuwait, including residential and commercial areas, the demand for greenery and beautification is increasing massively. This increase demands vast amounts of diversified plant materials. For proper implementation of the various landscape projects, including public parks, streetscapes and home gardens, an efficient ornamental plant list should be developed. This can only be accomplished by plant introduction and screening under the prevailing weather conditions of Kuwait. The success of a site-suitable landscaping trend depends on appropriate plant selection⁶⁻⁸.

The development of a greenery plan for Kuwait requires intensive water management. This goal can be achieved through manpower training in landscape development, selection of plants tolerant to arid environments and usage of appropriate irrigation systems⁹. Low water use plantings may enhance water conservation in dry landscapes. Therefore, the demand for landscape plantings that has a low water requirement is increasing. In arid landscapes, where nutrients are concentrated in biophilic profiles under patches vegetated with either shrubs or perennial grasses¹, the presence of these vegetated patches may moderate effects of wind and water on movement of plant nutrients, organic matter and litter around landscape^{2,10}.

Residential landscape constitutes a significant portion of the urban environment. With the increasing mobility of the society,

many people come to reside in environments with unfamiliar plant communities and environmental conditions⁴. Promotion of ornamental plants will improve the quality of the environment and the increase in the diversity of plants. For the above mentioned reasons this study was conducted in two locations, inland and coastal site.

Shrubs are one of the main components of the landscape. Shrubs range from approximately 3 to 10 feet height, are defined as woody plants and are multi-stemmed and low branching. Low growing shrubs can be arranged to divide space at ground level, a physical separation rather than a visual one. Larger shrubs growing above eye level will define space. Shrubs can be grown in their natural form or on the other hand may be clipped or pruned into shape³. Selecting plants that have attractive characteristics during all four seasons helps gardeners reach their goal of a well planned landscape⁵. Some plants have several attributes that exhibit ornamental qualities during each season of the year. A properly planted tree or shrub will be tolerant of adverse conditions and require much less management than one planted incorrectly. The plant should be specifically appropriate to the site or the site should be amended to specifically fit the plant. In this study twenty six species of ornamental shrubs, that had not been previously tested in Kuwait, were evaluated for their adaptability to extreme conditions and their visual impact on the greenery.

Methodology

A total of 26 plant species listed in Table 1 were selected for their performance in the extreme climate of Kuwait. These plant species were procured from Australia and India, where the climatic conditions match with those in Kuwait. These plants were allowed to harden in the greenhouse. Before the start of the experiment the site was developed, land was cleared of weeds, trash, rocks, dirt and other debris. The soil was analyzed for the presence of nutrients. Chemical analysis of water was also done prior to planting. In the planting holes in both sites 30 cm of the top layer was back filled with agricultural soil and peat moss. The sites were fine graded and leveled. Soil was disinfected and weed treated. Soil was irrigated before planting to leach salts, followed by a drying period of two days. The hardened plants were then transplanted in the field and a complete randomized block design was used. The transplanted plants were medium in size and had a healthy green appearance.

Table 1. Survival percentage of experimental shrubs in the inland and coastal site.

Plant species	Survival (%)	
	Inland site	Coastal site
<i>Eucalyptus torwood</i>	80	100
<i>Acacia sclerophylla</i>	60	100
<i>Acacia wilhelmina</i>	60	100
<i>Geijera parviflora</i>	100	100
<i>Hibiscus rosasinensis variegata</i>	0	100
<i>Bambusa vulgaris Aureovariegata</i>	40	80
<i>Banksia ashbyi</i>	40	100
<i>Gossypium sturtianum</i>	100	100
<i>Calliandra haematocephala</i>	20	60
<i>Callistemon viminalis 'Captain Cook'</i>	0	100
<i>Cestrum diurnum</i>	100	100
<i>Eucalyptus nutans</i>	100	60
<i>Eucalyptus websteriana</i>	40	20
<i>Leptospermum coriaceum</i>	0	20
<i>Hakea laurina</i>	0	0
<i>Hamelia patens</i>	60	0
<i>Holmskioldia sanguinea</i>	100	100
<i>Brachychiton rupestris</i>	100	100
<i>Justicia aurea</i>	0	0
<i>Nyctanthes arboretum</i>	100	100
<i>Murraya exotica</i>	80	60
<i>Phyllanthus nivosus</i>	100	60
<i>Thryptomene baeckeacea</i>	0	0
<i>Russelia equisetiformis</i>	80	100
<i>Tecoma argentina</i>	80	100
<i>Euphorbia characias</i>	100	100

DAP=Days after planting, SD=Standard deviation.

A complete randomized block design with five replications of all experimental plant species in both sites was used. Optimum cultural practices were carried out for the transplanted plants. For shrubs, 60 cm diameter basin was prepared around the plant and a six inch pot full of peat moss was applied. A teaspoon full of complex fertilizer 15-15-15 was also applied to the base of the plant after raking the soil. Subsequent doses of fertilizer were applied at monthly intervals. Mealy bug infestation was noticed in some of the shrubs and the pest was controlled by spraying Diazinon at the rate of 0.01% at weekly intervals. Experimental plant species were covered with shade net to protect the plants from high temperature and hot winds. Irrigation water amounts were regulated to meet the plants requirements according to the season. Old, unhealthy and dried branches were removed and the shrubs were pruned at a desired height and the shapes of the plant were maintained. Weeding was also done at regular intervals. Data on survival, plant height, stem diameter and phenological observations were documented on bi-monthly basis.

Results and Discussion

The data collected were tabulated and their means, standard deviation, survival percentages and growth rates were calculated. The survival percentages of the plants in both inland and coastal site are presented in Table 1, and Fig. 1 is its graphical representation. It was observed that by the middle of the experimental period 16 species out of the 26 experimental shrubs in the inland site recorded 100% survival. Only one shrub recorded 0%. The remaining shrub survival percentages recorded 20-80%, but by the end of the study it was observed that only 9 species out of the 26 recorded 100% survival. Six shrubs recorded 0% survival and the remaining shrub survival percentages ranged from 20 to 80%. In the coastal site, 21 species of the experimental shrubs recorded 100% survival during the first half of the experiment. Again only one shrub died during that period. The survival percentages of remaining shrubs recorded 60-80%. Towards the end of the project 15 species recorded 100% survival. There was 0% survival for four shrubs, 20-80% survival was recorded for remaining shrubs.

Tables 2 and 3 indicate the mean, standard deviation and growth rates of the experimental shrubs in the inland and coastal site respectively. Fig. 2 shows the comparison of growth rates of the experimental plants in both sites. It was observed that in the inland site, towards the middle of the experimental period the species *Hakea laurina* died. This was due to the extreme temperatures prevailed in Kuwait during the months of June, July and August. The plant species *Russelia equisetiformis* showed the maximum growth rate of 246.54%. The lowest growth rate of -37.18% was observed in *Bambusa vulgaris Aureo-variegata*. By the end of the experiment the plants *Callistemon viminalis 'Captain Cook'*, *Leptospermum coriaceum*, *Hakea laurina*, *Justicia aurea* and *Thryptomene baeckeacea* died as they were not able to withstand the extreme climatic conditions. Some plants like *Acacia wilhelmina*, *Hibiscus rosasinensis variegata*, *Banksia ashbyi* and *Gossypium sturtianum* showed more than 200% growth rate. The plant species *Justicia aurea* died in the coastal site, when the experiment was half way through, as it could not withstand variable climatic conditions. The highest growth rate of 250.97% was recorded for *Acacia wilhelmina*. Only three plant species, namely

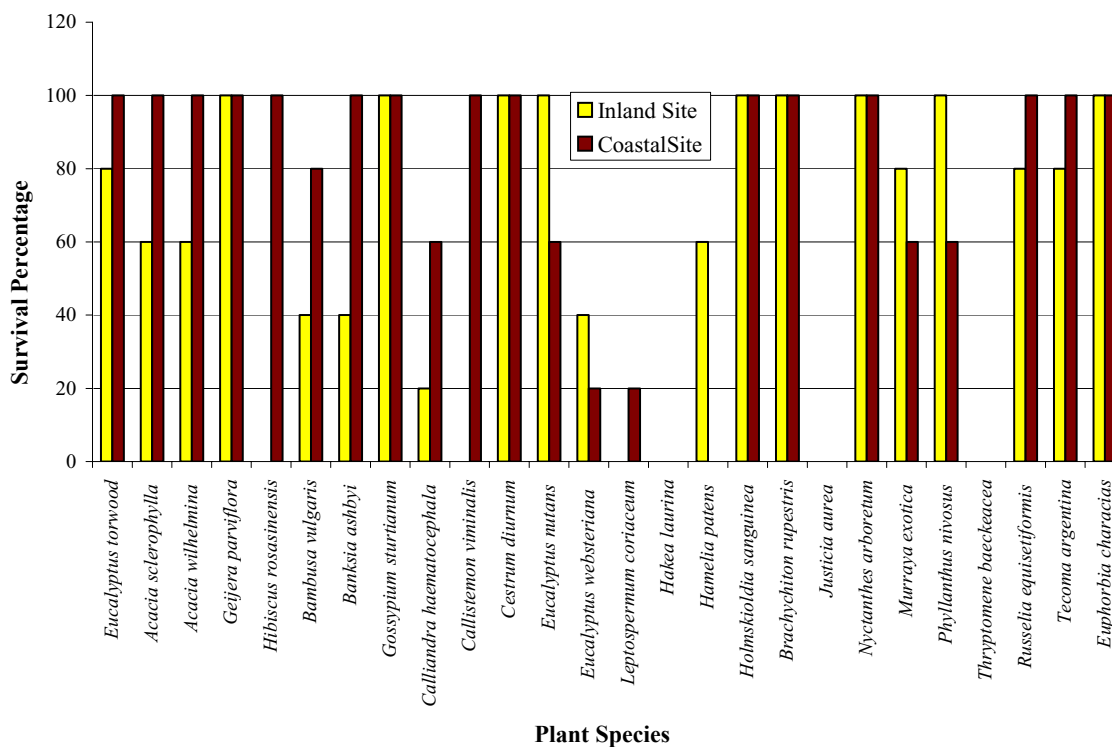


Figure 1. Survival percentages of experimental shrubs in inland and coastal sites.

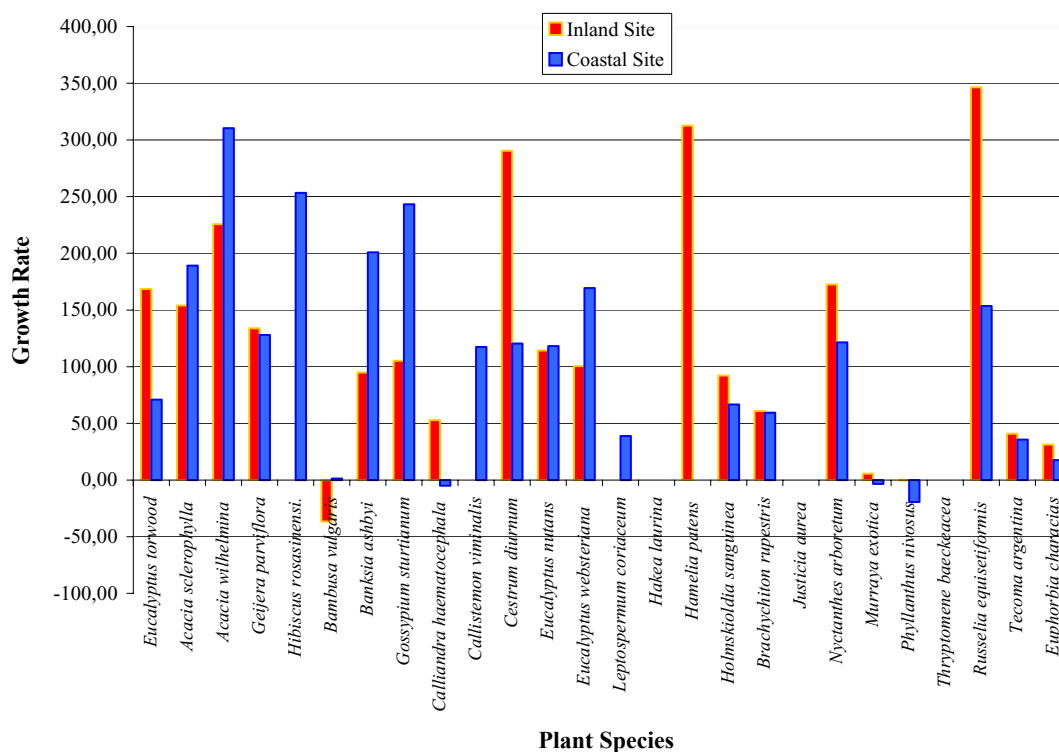


Figure 2. Growth rate of experimental shrubs in inland and coastal sites.

Calliandra haematocephala, *Murraya exotica* and *Phyllanthus nivosus*, had negative growth rates. When compared to the growth rates of the plants in the inland site the plants in the coastal site did well even under extreme climatic conditions.

The means and standard deviations of plant caliper of the experimental shrubs in the inland and coastal site are presented in

Tables 4 and 5 respectively. Tables 6 and 7 respectively, represent the plant cover of the shrubs under study in the inland and coastal site. The effect of high temperature and low temperature on the growth of plants is explained in Tables 8 and 9, respectively.

Table 2. Periodical means and standard deviations of plant height (cm) of the experimental plants in the inland site.

Plant species	Initial		120 DAP		240 DAP		360 DAP		Final		Growth rate (%)
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
<i>Eucalyptus torwood</i>	45.80	15.30	56.80	12.64	99.20	16.66	148.25	35.52	152.50	35.52	168.49
<i>Acacia sclerophylla</i>	30.00	4.74	41.00	6.82	65.25	20.43	73.00	3.61	74.67	5.13	153.97
<i>Acacia wilhelmiana</i>	31.00	12.71	37.60	13.01	87.60	24.47	100.67	21.59	101.00	23.26	225.81
<i>Geijera parviflora</i>	39.20	14.48	32.40	2.07	56.80	4.82	73.80	16.42	75.80	19.66	133.95
<i>Hibiscus rosasinensis variegata</i>	33.40	3.05	18.40	5.68	28.67	10.02	Dead	Dead	Dead	Dead	Dead
<i>Bambusa vulgaris Aureo-variegata</i>	109.20	20.66	82.60	8.85	68.60	11.50	65.50	10.61	61.50	12.02	-36.73
<i>Banksia ashbyi</i>	24.80	3.27	32.00	3.67	39.75	10.72	49.00	12.73	46.00	14.14	94.92
<i>Gossypium sturtianum</i>	48.60	8.41	80.00	2.92	116.40	17.11	108.80	53.84	111.20	11.08	105.17
<i>Calliandra haematocephala</i>	84.40	8.99	81.25	16.94	90.67	13.58	92.50	43.13	140.00	0.00	52.84
<i>Callistemon viminalis 'Captain Cook'</i>	93.40	34.00	135.40	23.14	183.60	36.57	258.80	20.63	Dead	Dead	Dead
<i>Cestrum diurnum</i>	30.80	5.81	67.20	18.81	111.60	18.37	62.40	6.27	262.40	19.09	290.48
<i>Eucalyptus nutans</i>	35.40	7.02	54.20	5.36	84.20	8.38	92.60	8.65	77.60	14.54	114.36
<i>Eucalyptus websteriana</i>	31.50	6.61	47.60	10.78	74.25	4.79	84.50	13.44	73.00	2.83	100.55
<i>Leptospermum coriaceum</i>	31.33	1.15	26.40	3.21	19.50	0.71	Dead	Dead	Dead	Dead	Dead
<i>Hakea laurina</i>	54.20	9.31	61.40	13.03	Dead	Dead	Dead	Dead	Dead	Dead	Dead
<i>Hamelia patens</i>	28.20	3.83	32.80	4.76	42.40	9.07	103.00	9.00	104.00	9.17	312.70
<i>Holmskioldia sanguinea</i>	33.80	4.49	27.00	4.24	41.40	4.72	58.80	6.18	63.40	5.77	92.12
<i>Brachychiton rupestris</i>	56.60	32.10	43.40	9.45	65.60	16.15	70.00	22.51	69.80	24.58	60.83
<i>Justicia aurea</i>	20.20	13.05	26.33	20.55	39.00	0.00	Dead	Dead	Dead	Dead	Dead
<i>Nyctanthes arboretum</i>	44.60	11.65	50.80	8.70	82.60	22.41	128.60	31.09	132.40	31.44	172.43
<i>Murraya exotica</i>	67.20	15.27	74.00	14.67	67.75	10.78	74.25	8.66	67.75	17.21	5.53
<i>Phyllanthus nivosus</i>	62.20	5.89	64.80	6.14	62.80	5.17	71.00	4.47	61.00	25.08	-0.33
<i>Thryptomene baeckeacea</i>	60.60	12.95	57.60	5.41	47.50	17.82	Dead	Dead	Dead	Dead	Dead
<i>Russelia equisetiformis</i>	24.60	8.26	60.50	30.58	85.25	13.74	126.00	12.52	143.75	35.20	346.43
<i>Tecoma argentina</i>	112.80	15.66	118.00	16.67	111.40	16.32	142.60	54.48	149.00	65.43	40.83
<i>Euphorbia characias</i>	30.00	9.77	33.20	5.81	42.80	3.56	45.80	5.07	43.60	6.35	31.33

DAP=Days after planting, SD=Standard deviation, Growth rate={(Final height-Initial height)/Initial height}x100.

Table 3. Periodical means and standard deviations of plant height (cm) of the experimental plants in the coastal site.

Plant species	Initial		120 DAP		240 DAP		360 DAP		Final		Growth rate (%)
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
<i>Eucalyptus torwood</i>	52.60	10.01	66.80	13.22	93.40	13.35	112.80	24.02	114.20	24.49	70.96
<i>Acacia sclerophylla</i>	29.40	3.58	49.20	7.79	77.60	9.21	83.80	9.98	85.00	10.56	189.12
<i>Acacia wilhelmiana</i>	31.00	8.31	48.60	8.71	108.80	20.00	123.00	23.70	127.20	25.02	310.32
<i>Geijera parviflora</i>	27.40	13.52	30.00	2.00	57.80	7.01	66.80	8.41	68.40	7.77	128.00
<i>Hibiscus rosasinensis variegata</i>	35.60	2.61	15.00	1.58	37.00	15.23	50.40	23.72	53.00	22.99	253.33
<i>Bambusa vulgaris Aureo-variegata</i>	97.20	13.27	83.60	7.60	78.50	38.24	98.50	47.14	98.50	47.87	1.34
<i>Banksia ashbyi</i>	23.60	6.66	31.40	4.34	61.00	17.86	69.80	20.27	71.00	22.51	200.85
<i>Gossypium sturtianum</i>	54.20	4.66	66.80	5.89	122.60	9.91	179.20	24.35	186.00	24.67	243.17
<i>Calliandra haematocephala</i>	91.60	21.26	102.40	8.08	92.33	3.21	99.33	31.56	87.00	36.37	-5.02
<i>Callistemon viminalis 'Captain Cook'</i>	100.80	13.88	131.40	19.03	168.00	24.65	215.00	21.78	219.00	20.29	117.26
<i>Cestrum diurnum</i>	50.60	11.26	43.20	11.08	88.40	10.09	93.80	9.52	95.20	8.90	120.37
<i>Eucalyptus nutans</i>	36.20	7.98	43.80	4.49	64.75	9.00	78.00	4.58	79.00	5.29	118.23
<i>Eucalyptus websteriana</i>	36.40	5.86	44.00	8.80	69.67	10.21	91.00	0.00	98.00	0.00	169.23
<i>Leptospermum coriaceum</i>	33.00	4.85	34.60	10.19	46.75	15.52	52.00	0.00	48.00	0.00	38.73
<i>Hakea laurina</i>	51.00	10.65	67.60	9.45	93.60	12.82	Dead	Dead	Dead	Dead	Dead
<i>Hamelia patens</i>	25.20	8.01	28.40	5.37	31.80	2.39	Dead	Dead	Dead	Dead	Dead
<i>Holmskioldia sanguinea</i>	33.00	4.30	36.00	4.24	42.80	3.19	54.00	7.87	55.00	7.84	66.67
<i>Brachychiton rupestris</i>	41.00	13.21	42.40	6.43	63.40	11.28	66.60	8.32	67.60	9.71	59.43
<i>Justicia aurea</i>	28.40	28.43	15.00	6.32	Dead	Dead	Dead	Dead	Dead	Dead	Dead
<i>Nyctanthes arboretum</i>	48.60	8.53	41.40	7.13	69.20	14.48	92.20	13.81	107.60	8.82	121.40
<i>Murraya exotica</i>	64.20	12.70	68.60	9.84	59.00	8.19	62.33	19.55	62.00	20.66	-3.43
<i>Phyllanthus nivosus</i>	61.20	7.29	64.60	7.50	56.20	4.49	49.33	5.69	49.33	6.03	-19.39
<i>Thryptomene baeckeacea</i>	64.00	7.81	58.20	9.47	76.33	25.58	Dead	Dead	Dead	Dead	Dead
<i>Russelia equisetiformis</i>	32.20	5.93	42.20	9.71	71.00	24.53	78.80	15.48	81.60	16.64	153.42
<i>Tecoma argentina</i>	105.80	8.58	116.00	11.14	122.00	17.44	143.20	14.82	143.60	13.58	35.73
<i>Euphorbia characias</i>	36.60	8.44	31.80	5.45	37.80	3.70	36.00	8.60	37.40	6.58	17.61

DAP=Days after planting, SD=Standard deviation, Growth rate={(Final height-Initial height)/Initial height}x100.

Table 4. Periodic stem diameter (mm) means and standard deviations of experimental shrubs in the inland site.

Plant species	Initial		120 DAP		240 DAP		360 DAP		Final	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Eucalyptus torwood</i>	4.00	0.00	4.80	0.84	8.80	1.48	16.50	3.11	17.00	2.71
<i>Acacia sclerophylla</i>	3.20	1.30	4.40	1.14	7.50	2.52	14.00	1.00	14.00	1.00
<i>Acacia wilhelmina</i>	2.20	0.84	6.20	2.05	12.20	3.96	20.33	2.31	20.67	2.08
<i>Geijera parviflora</i>	5.40	0.89	5.00	0.71	10.20	1.30	14.60	1.95	14.80	1.92
<i>Hibiscus rosinensis variegata</i>	4.00	0.00	5.20	0.84	8.00	1.73	Dead	Dead	Dead	Dead
<i>Bambusa vulgaris Aureo-variegata</i>	10.80	1.30	10.80	1.30	10.80	1.30	13.00	2.83	13.00	2.83
<i>Banksia ashbyi</i>	3.60	0.55	5.80	0.45	6.50	0.58	8.50	2.12	9.00	1.41
<i>Gossypium sturtianum</i>	4.80	0.84	9.00	0.00	11.60	1.14	16.00	1.22	16.00	1.22
<i>Calliandra haematocephala</i>	5.80	0.45	8.25	0.96	11.00	1.73	15.00	1.41	24.00	0.00
<i>Callistemon viminalis 'Captain Cook'</i>	6.80	1.10	14.40	2.51	21.60	2.07	31.00	5.34	Dead	Dead
<i>Cestrum diurnum</i>	2.80	1.30	6.00	0.71	10.40	2.07	14.00	0.71	31.60	4.51
<i>Eucalyptus nutans</i>	3.00	0.71	7.40	0.89	11.40	1.52	14.60	0.89	14.60	0.89
<i>Eucalyptus websteriana</i>	2.50	0.58	4.40	0.89	7.50	1.29	13.50	0.71	13.50	0.71
<i>Leptospermum coriaceum</i>	3.67	0.58	3.00	0.00	3.00	0.00	Dead	Dead	Dead	Dead
<i>Hakea laurina</i>	4.60	0.89	7.40	1.14	Dead	Dead	Dead	Dead	Dead	Dead
<i>Hamelia patens</i>	5.20	0.84	7.60	0.55	11.20	1.10	19.33	1.53	21.67	1.15
<i>Holmskioldia sanguinea</i>	3.20	0.45	3.80	0.45	4.40	0.55	6.20	0.84	6.80	0.45
<i>Brachychiton rupestris</i>	8.00	3.46	6.60	0.89	10.60	1.95	15.40	3.91	15.40	3.91
<i>Justicia aurea</i>	5.20	1.30	8.00	1.00	9.00	0.00	Dead	Dead	Dead	Dead
<i>Nyctanthes arboretum</i>	4.00	1.00	5.60	0.55	9.20	1.92	16.00	3.32	16.20	3.27
<i>Murraya exotica</i>	4.60	0.55	5.25	0.50	8.00	0.82	12.00	1.15	13.50	2.52
<i>Phyllanthus nivosus</i>	5.80	0.45	9.40	0.89	11.40	1.52	33.60	43.84	14.80	2.95
<i>Thryptomene baeckeacea</i>	6.00	0.71	5.00	0.00	5.00	2.58	Dead	Dead	Dead	Dead
<i>Russelia equisetiformis</i>	3.20	1.30	4.50	1.29	5.50	1.29	11.75	1.71	11.75	1.71
<i>Tecoma argentina</i>	9.40	0.89	12.40	1.67	13.40	1.52	16.40	2.51	14.50	3.32
<i>Euphorbia characias</i>	4.00	0.71	18.60	0.55	21.20	0.84	23.00	1.00	24.80	1.79

DAP=Days after planting, SD=Standard deviation.

Table 5. Periodic stem diameter (mm) means and standard deviations of experimental shrubs in the coastal site.

Plant species	Initial		120 DAP		240 DAP		360 DAP		Final	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Eucalyptus torwood</i>	4.00	1.00	4.40	0.89	8.00	1.22	10.60	1.82	11.00	2.35
<i>Acacia sclerophylla</i>	3.80	1.64	6.00	1.00	10.00	0.71	15.00	1.00	15.00	1.00
<i>Acacia wilhelmina</i>	3.60	0.55	6.60	0.89	15.40	2.61	22.20	4.49	22.40	4.39
<i>Geijera parviflora</i>	6.40	1.82	5.80	0.45	10.80	1.10	11.80	0.84	12.60	0.55
<i>Hibiscus rosinensis variegata</i>	5.20	0.45	4.60	0.55	5.60	0.89	7.60	1.34	7.80	1.10
<i>Bambusa vulgaris Aureo-variegata</i>	12.60	0.89	12.20	1.48	9.75	3.20	9.50	3.11	9.50	3.11
<i>Banksia ashbyi</i>	3.60	0.55	6.00	1.22	7.80	1.64	10.40	2.70	10.80	2.95
<i>Gossypium sturtianum</i>	5.60	0.55	7.20	0.45	20.60	1.52	29.40	2.70	31.60	3.91
<i>Calliandra haematocephala</i>	6.60	2.19	9.40	1.82	10.00	1.00	12.33	1.53	13.67	3.79
<i>Callistemon viminalis 'Captain Cook'</i>	7.20	0.84	13.80	1.30	21.80	2.17	30.20	1.48	30.40	1.52
<i>Cestrum diurnum</i>	4.00	0.71	6.00	1.41	11.20	1.30	13.20	1.48	13.60	1.52
<i>Eucalyptus nutans</i>	3.40	0.55	6.20	0.84	11.00	2.00	14.00	1.00	14.33	0.58
<i>Eucalyptus websteriana</i>	2.80	0.45	3.80	0.84	9.00	1.73	14.00	0.00	14.00	0.00
<i>Leptospermum coriaceum</i>	3.60	1.14	3.40	0.55	4.25	0.50	5.00	0.00	5.00	0.00
<i>Hakea laurina</i>	5.00	0.71	8.40	1.14	14.40	1.95	Dead	Dead	Dead	Dead
<i>Hamelia patens</i>	5.00	0.71	5.20	0.45	6.00	0.00	Dead	Dead	Dead	Dead
<i>Holmskioldia sanguinea</i>	4.20	0.45	4.60	0.55	5.40	0.55	5.80	0.45	6.20	0.45
<i>Brachychiton rupestris</i>	8.40	2.30	6.40	0.55	12.80	1.92	16.80	3.96	17.40	4.51
<i>Justicia aurea</i>	7.60	1.52	5.60	1.52	Dead	Dead	Dead	Dead	Dead	Dead
<i>Nyctanthes arboretum</i>	4.80	1.10	5.00	0.71	8.00	2.35	10.60	2.07	12.00	1.58
<i>Murraya exotica</i>	5.80	0.45	5.80	0.45	8.33	0.58	9.33	0.58	9.33	0.58
<i>Phyllanthus nivosus</i>	6.20	1.64	6.80	1.30	8.20	0.45	9.67	0.58	9.67	0.58
<i>Thryptomene baeckeacea</i>	7.20	1.10	5.80	0.84	7.33	1.53	Dead	Dead	Dead	Dead
<i>Russelia equisetiformis</i>	3.00	0.71	4.20	0.84	5.60	1.14	7.20	2.05	8.00	1.58
<i>Tecoma argentina</i>	11.40	0.89	11.80	0.84	14.40	1.95	16.00	2.55	17.20	3.56
<i>Euphorbia characias</i>	5.00	1.41	18.20	0.84	20.80	1.30	22.80	1.79	22.80	1.79

DAP=Days after planting, SD=Standard deviation.

Table 6. Periodic plant canopy diameter (mm) means and standard deviations of experimental shrubs in the inland site.

Plant species	120 DAP		240 DAP		360 DAP		Final	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Eucalyptus torwood</i>	16.60	5.55	43.00	7.91	72.75	26.13	69.75	31.46
<i>Acacia sclerophylla</i>	26.80	6.76	52.75	1.89	57.67	6.11	84.33	15.89
<i>Acacia wilhelmiana</i>	34.40	6.02	58.40	15.90	97.33	13.05	99.33	13.80
<i>Geijera parviflora</i>	12.00	2.92	28.60	2.79	54.80	10.66	56.20	13.26
<i>Hibiscus rosasinensis</i> variegata	12.60	3.58	32.33	3.06	Dead	Dead	Dead	Dead
<i>Bambusa vulgaris</i> Aureo-variegata	17.40	5.08	16.40	9.61	30.50	34.65	26.00	28.28
<i>Banksia ashbyi</i>	24.80	6.30	33.75	6.90	51.50	24.75	55.50	24.75
<i>Gossypium sturtianum</i>	17.20	3.63	57.00	5.96	87.80	7.46	64.00	13.58
<i>Calliandra haematocephala</i>	21.50	8.35	38.33	20.26	56.00	11.31	129.00	0.00
<i>Callistemon viminalis</i> 'Captain Cook'	61.40	18.15	81.40	6.23	144.60	18.23	Dead	Dead
<i>Cestrum diurnum</i>	21.00	7.68	37.60	6.84	24.20	7.40	149.80	18.62
<i>Eucalyptus nutans</i>	43.80	10.38	63.80	6.10	77.40	5.98	70.60	17.42
<i>Eucalyptus websteriana</i>	23.60	12.70	34.00	2.16	40.50	0.71	51.50	4.95
<i>Leptospermum coriaceum</i>	12.80	2.28	26.00	1.41	Dead	Dead	Dead	Dead
<i>Hakea laurina</i>	13.80	2.59	Dead	Dead	Dead	Dead	Dead	Dead
<i>Hamelia patens</i>	32.60	4.04	45.00	4.90	132.67	12.01	134.00	12.12
<i>Holmskioldia sanguinea</i>	24.80	4.09	36.60	7.99	40.40	8.85	56.20	7.76
<i>Brachychiton rupestris</i>	27.60	5.55	32.20	7.40	27.80	13.79	32.80	14.50
<i>Justicia aurea</i>	12.00	9.54	2.00	0.00	Dead	Dead	Dead	Dead
<i>Nyctanthes arboretum</i>	21.60	5.03	45.40	4.56	81.00	18.26	83.00	20.45
<i>Murraya exotica</i>	13.75	2.75	15.50	2.52	27.75	2.06	43.75	9.03
<i>Phyllanthus nivosus</i>	22.00	2.35	22.40	5.18	37.40	4.62	37.20	10.80
<i>Thryptomene baeckeacea</i>	17.60	1.82	16.00	4.69	Dead	Dead	Dead	Dead
<i>Russelia equisetiformis</i>	53.50	21.49	67.75	2.36	88.00	11.22	115.50	27.74
<i>Tecoma argentina</i>	34.00	15.05	24.20	6.83	53.20	23.93	58.50	31.43
<i>Euphorbia characias</i>	23.00	2.74	36.60	4.28	38.80	2.49	41.40	5.03

DAP=Days after planting, SD=Standard deviation.

Table 7. Periodic plant canopy diameter (mm) means and standard deviations of experimental shrubs in the coastal site.

Plant species	120 DAP		240 DAP		360 DAP		Final	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Eucalyptus torwood</i>	26.20	2.86	40.00	8.63	52.20	12.07	59.80	9.42
<i>Acacia sclerophylla</i>	44.40	3.21	54.60	2.79	82.40	17.02	83.60	17.01
<i>Acacia wilhelmiana</i>	34.00	3.39	90.00	17.82	129.40	14.84	134.00	16.51
<i>Geijera parviflora</i>	18.20	3.03	27.60	3.36	53.00	15.62	56.60	15.37
<i>Hibiscus rosasinensis</i> variegata	9.60	2.41	37.60	23.56	50.80	24.08	52.60	22.63
<i>Bambusa vulgaris</i> Aureo-variegata	26.40	2.97	25.50	14.73	52.25	15.54	50.25	12.09
<i>Banksia ashbyi</i>	25.80	2.17	31.20	3.11	45.60	4.72	47.60	6.54
<i>Gossypium sturtianum</i>	23.40	5.98	76.00	6.04	121.80	14.97	144.20	21.05
<i>Calliandra haematocephala</i>	12.80	5.07	18.33	4.04	56.33	35.23	69.00	72.81
<i>Callistemon viminalis</i> 'Captain Cook'	63.40	12.10	80.80	9.47	122.20	6.06	124.60	6.84
<i>Cestrum diurnum</i>	26.00	0.71	50.20	4.02	66.00	8.69	66.20	8.14
<i>Eucalyptus nutans</i>	23.60	3.58	59.00	9.35	90.67	27.06	94.67	30.66
<i>Eucalyptus websteriana</i>	20.40	5.86	35.67	1.53	65.00	0.00	69.00	0.00
<i>Leptospermum coriaceum</i>	14.80	4.09	29.25	9.71	29.00	0.00	26.00	0.00
<i>Hakea laurina</i>	25.80	3.63	44.80	6.72	Dead	Dead	Dead	Dead
<i>Hamelia patens</i>	15.20	4.87	35.80	2.86	Dead	Dead	Dead	Dead
<i>Holmskioldia sanguinea</i>	36.20	3.96	39.40	3.97	54.60	6.43	54.60	5.59
<i>Brachychiton rupestris</i>	42.40	5.03	24.00	5.52	23.20	16.89	24.00	17.94
<i>Justicia aurea</i>	12.40	2.70	Dead	Dead	Dead	Dead	Dead	Dead
<i>Nyctanthes arboretum</i>	7.80	1.10	41.60	9.18	51.00	12.41	57.60	8.05
<i>Murraya exotica</i>	5.40	2.07	11.00	7.81	16.33	3.79	17.33	4.04
<i>Phyllanthus nivosus</i>	8.20	2.39	18.00	2.12	24.33	7.09	18.67	1.53
<i>Thryptomene baeckeacea</i>	36.00	5.52	35.67	4.51	Dead	Dead	Dead	Dead
<i>Russelia equisetiformis</i>	26.40	6.69	55.20	19.74	78.00	24.57	80.60	24.85
<i>Tecoma argentina</i>	34.80	5.81	44.80	2.28	53.60	5.64	50.80	6.98
<i>Euphorbia characias</i>	8.60	1.14	34.60	5.03	33.60	1.95	34.40	5.32

DAP=Days after planting, SD=Standard deviation.

Table 8. The effect of high temperature on the growth of experimental shrubs.

Plant species	Effects of temperature
<i>Eucalyptus torwood</i>	Not affected by heat.
<i>Acacia sclerophylla</i>	Good growth. More branches had developed and grew laterally covering more area. Effect of heat on plants not noticeable.
<i>Acacia wilhelmiana</i>	Excellent growth. More lateral growth and the leaves are good and green in color.
<i>Geijera parviflora</i>	No drying. Some leaves which are directly exposed to sunlight were affected. More branches were formed and newly formed leaves were greener.
<i>Hibiscus rosasinensis variegata</i>	Good bushy green growth. More branches. Not affected by heat.
<i>Bambusa vulgaris Aureo-variegata</i>	Total loss of plants.
<i>Banksia ashbyi</i>	Very good growth when compared with the winter season. Increase in height of the plants. Have developed more branches. A slight discoloration of the leaves was noticed.
<i>Gossypium sturtianum</i>	Excellent growth. There was no effect of heat. Increase in the stem thickness was noticed.
<i>Calliandra haematocephala</i>	Affected by heat. Two plants were dead. The upper leaves had dried. Drying starts from leaf margins.
<i>Callistemon viminalis 'Captain Cook'</i>	Excellent growth. More branches.
<i>Cestrum diurnum</i>	Yellowing of leaves was noticed. New sprouts can be seen from the base of the plants. Leaves show wrinkling which in later stages turn into a cup like structure.
<i>Eucalyptus nutans</i>	Not much affected by high temperature. Slight burning of leaves due to heat, but normal canopy development was good.
<i>Eucalyptus websteriana</i>	Some leaves were dried. Loss of vigor of plant was noticed.
<i>Leptospermum coriaceum</i>	Total drying of leaves and stem. Drying starts from the top of the plant.
<i>Hakea laurina</i>	Total loss of plant.
<i>Hamelia patens</i>	Leaves dried. But the flowers were still in the plant. The shape and structure of the plant was lost. New sprouts can be seen in the axils.
<i>Holmskoldia sanguinea</i>	Dried leaf tips. New healthy shoots are coming. Dark discoloration of the leaves was due to burning.
<i>Brachychiton rupestris</i>	All the leaves were dried, but the stem remains green. The drying starts from margins of leaves leading to total drying of leaf lamina, leaving only the veins of leaves on plant.
<i>Justicia aurea</i>	Total drying of the plant.
<i>Nyctanthes arboretum</i>	Good growth of the plants. Bushy green growth was noticed. Old leaves show senescence without drying. Fully expanded leaf lamina was seen.
<i>Murraya exotica</i>	Retarded growth of the plants. Leaves show partial drying and shedding. Only the main stem remains.
<i>Phyllanthus nivosus</i>	No leaf on the plants, but the stem remains healthy.
<i>Thryptomene baeckeacea</i>	Stem and leaves were dried. Stem shows dark discoloration.
<i>Russelia equisetiformis</i>	Good growth. Increase in the height of the plant. More shoots were emerging from the base of the plant. Increase in the length of the inter-nodal region.
<i>Tecoma argentina</i>	No increase in stem growth was noticed. But there was an increase in the stem thickness in the upper part of the main stem.
<i>Euphorbia characias</i>	Partial drying of leaves. Numerous new shoots are coming from the base giving the plants a bushy appearance. Leaves turned to pale green. Loss of vigor of plants.

Table 9. The effect of low temperature on the growth of experimental shrubs.

Plant species	Effects of low temperature
<i>Eucalyptus torwood</i>	Good growth. Characteristic green leaves were developed. Increase in height of the plant was noticed
<i>Acacia sclerophylla</i>	Good growth. The branches were well developing and spread. No effect of cold on the growth.
<i>Acacia wilhelmiana</i>	Excellent growth. Branches spread to more area. Well developed greenish leaves noticed.
<i>Geijera parviflora</i>	Very good growth. Branches were well developing from the entire stem. Healthy leaves.
<i>Hibiscus rosasinensis variegata</i>	Characteristic variegated leaves were formed. No effect of cold on the growth and development. Increase in height of the plant was noticed.
<i>Bambusa vulgaris Aureo-variegata</i>	Numerous suckers were developed from the base. The suckers were actively growing.
<i>Banksia ashbyi</i>	Greener leaves compared to summer. Increase in height of the plants was noticed.
<i>Gossypium sturtianum</i>	Excellent growth. Increase in height of the plants was noticed. Well development of the trunk. Numerous sprouts were formed from the basal region.
<i>Calliandra haematocephala</i>	No prominent growth. Stem tips were dried. Branches were produced from entire region gave the plant a bushy appearance.
<i>Callistemon viminalis 'Captain Cook'</i>	Good growth. No effect of cold on the growth of the plant. Well developed trunk and branches.
<i>Cestrum diurnum</i>	Normal growth.
<i>Eucalyptus nutans</i>	The margins of leaves were dried. Development of lateral branches gave a wider canopy to the plant.
<i>Eucalyptus websteriana</i>	No effect. The leaves were greener.
<i>Leptospermum coriaceum</i>	Plants lost vigor. Almost stunted growth throughout the period.
<i>Hakea laurina</i>	Total loss of plant.
<i>Hamelia patens</i>	Good growth.
<i>Holmskoldia sanguinea</i>	Excellent growth. The leaves were more greenish than that in the summer.
<i>Brachychiton rupestris</i>	Very good growth. Well developed stem and leaves. Good young leaves were coming from axils.
<i>Justicia aurea</i>	Total loss during summer.
<i>Nyctanthes arboretum</i>	Even though the plants flowered, as the season progressed the leaves started drying. The drying started from the margins and then covered the entire area. New leaves were produced. The stem was also healthy.
<i>Murraya exotica</i>	Almost retarded growth. The leaves showed chlorosis. The dried leaves were seen hanging on the plant
<i>Phyllanthus nivosus</i>	Good growth. The tip of the stems was dried. The leaves showed characteristic mosaic pattern.
<i>Thryptomene baeckeacea</i>	Total loss during summer.
<i>Russelia equisetiformis</i>	Excellent growth. Additional suckers were produced from the base. The stems extended upwards. The plants were flowered.
<i>Tecoma argentina</i>	The plants were healthy but the rate of growth was very slow. Additional branches were produced from the middle part of the stem.
<i>Euphorbia characias</i>	Excellent growth. Additional production of flowers during this season. More branches were produced and all the branches bore flowers.

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