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Testing newly introduced ornamental plants to the arid climate of Kuwait

(Prüfung neuer Zierpflanzen im ariden Klima Kuwaits)

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Abstract

Thirty five ornamental plants were introduced into the Ahmadi Bioremediated Soil Park to screen and closely monitor the growth performance of these new introductions under the local environmental conditions. Out of these 35 plant species, 15 were planted in both bioremediated and agricultural soils to assess their suitability for growing in bioremediated soils. Data on vegetative growth was recorded to assess the performance of newly-introduced plants, whereas, the heat stress was documented of *Bauhinia blakeana*, where no visible effects of petroleum pollutants on plant growth were observed. Performance of each plant group is discussed separately in the text. Overall, plant survival was 72.73% for all plant groups. Generally, plants that failed to grow in bioremediated soil also did not survive in the agricultural soil, indicating that they were sensitive to heat stress more than the presence of petroleum contaminants in the soil. New plant species that were able to establish and perform satisfactorily will be used in greenery projects after they are fully naturalized to the prevailing climatic conditions.

Keywords: *Ornamental plants, heat stress, plant introduction, bioremediated soil, arid climate*

Introduction

In view of the increasing demand for greenery development in the country, the Kuwait Institute for Scientific Research (KISR) formulated the National Greenery Plan (NGP) to provide an integrated framework for the present and future greenery efforts. This program covers 20,000 ha of open spaces within Kuwait City and the green belt areas. Attempts are being made to execute various medium- and long-term projects in the program. The plan also identified plant resource needs for developing the designated open spaces. To support the implementation of NGP, KISR initiated an ornamental plant testing program in 1984 and contributed to the preparation of a plant palette in 1988 (Taha et al. 1988). The ornamental

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plant introduction and testing efforts were restarted after a brief interruption during and immediately after the Iraqi invasion of Kuwait and has become an ongoing activity. A number of trees, shrubs, vines and grasses were introduced and are currently at various levels of testing in the coastal growing conditions (Basham & Al-Menaie 1996; Bhat 1997; Bhat & Al-Menaie 1998).

In Kuwait, plants are exposed to a wide variety of abiotic stresses imposed by harsh environmental conditions (Suleiman & Grina 2002; Suleiman and Bellen 2002). Although several ornamental plant species are known to survive in harsh desert conditions in other countries, only a limited number of plants are available in Kuwait. The invasion and subsequently, the detonation of oil wells before the Iraqi military forces withdrew from Kuwait in 1991, polluted a vast area with petroleum hydrocarbons. In the post war period, KISR successfully tested and standardized the bioremediation technology to rehabilitate oil polluted soils.

The bioremediated soils used in the study were produced at KISR as a result of a joint research program between KISR and Petroleum Energy Center (PEC) of Japan. The biological treatment was used to treat highly contaminated soils (top 20 cm soil following the sludge layer). The contaminated soil was initially screened to remove tarry material and stones. Then it was supplemented with urea and phosphate fertilizers to provide nutrients for microbial growth. Compost and wood chips were also added to improve water retention capacity of the soil. The soil after thorough mixing was used for field bioremediation by:

(a) Landfarming for the treatment of moderately (3 – 5% total petroleum hydrocarbons (TPH) and lightly contaminated (2 – 3% TPH) soils;
(b) Windrow composting piles fitted with an irrigation system, used for the treatment of 1,100 m^3 of moderately contaminated soils; or
(c) Static soil piles, fitted with irrigation and enforced aeration systems, for the treatment of 500 m^3 of lightly contaminated soils (Al-Daher et al 1999).

In the landfarming method, plots, each measuring $400 \times 30 \times 0.3$ m, were constructed using the processed oil polluted soil. The plots were tilled twice a week using a rototiller and irrigated by pivot irrigation system. For the windrow composting pile bioremediation, soil piles, each measuring $20 \times 3 \times 1.5$ m, were constructed and fitted with perforated pipes for irrigation. The piles were turned over every month for mixing and aeration. In the case of the static pile method, soil piles were constructed in a similar way, with the exception that the perforated plastic pipes were buried at the bottom of the piles and connected to an air compressor to supply oxygen for hydrocarbon biodegradation. The results showed excellent biodegradation of petroleum oil contaminants in soil by micro-organisms present in the soil (Balba et al. 1998). The landfarming method resulted in 85.6% biodegradation of TPH in the lightly contaminated soil and 82.7% in the moderately contaminated soil. In contrast, the windrow and static pile methods resulted in 75.2% and 72.6% biodegradation of TPH during the first 15 months, respectively (Al-Daher et al. 1999).

Although it has been possible to reduce the contaminants to environmentally safe levels, the bioremediated soils still contain varying amounts of hydrocarbons. It is proposed to use the bioremediated soils in greenery and landscape projects. In view of these facts, the study reported in this paper was undertaken to expand the ornamental plant palette by introducing and testing plants for their suitability in growing in bioremediated and agricultural soils under Kuwait's harsh climatic conditions.

Materials and methods

Climate and soil experimental site

The State of Kuwait is located between latitudes 28° 30′ and 30° 06′ to the North of the Equator and between longitudes 46° 30′ and 48° 30 to the East of Greenwich and occupies a total land area of 1,781,800 ha. Kuwait's climate is characterized by extended harsh summers and short mild winters. Mean temperature during the warmest and coolest months range between 46.2°C and 6.9°C (Annual Statistical Abstract 1998). Winter brings occasional frost. Rainfall is minimal, not exceeding 115 mm yr^{-1}, but due to low relative humidity and hot weather conditions the evaporation is very high, averaging 14.1 mm d^{-1}. Strong, dry and hot northwesterly winds prevail during summer, particularly in June and July. They often raise extensive dust storms during summer months which reduce the visibility to a few meters, especially at noon. Kuwait's native soils are sandy in texture, alkaline in reaction, low in organic matter and have high calcareous materials (mostly $CaCO_3$). Water resources in Kuwait are scarce, and the brackish water currently used is saline with total dissolved solids (TDS) concentrations ranging from 3.0–8.0 g l^{-1}.

Plant establishment

The study site was situated in the Ahmadi Bioremediated Soil Park, which represent a natural landscape setting in which a wide range of naturalized ornamental plant species were used to create desired landscape visual impacts (Al-Zalzaleh et al. 2001). Out of the 35 newly-introduced ornamental plant species belonging to different categories (11 trees, two palms, 14 shrubs and five groundcovers) 15 were grown either in agricultural or bioremediated soil, whereas the remaining 20 were grown only in agricultural soil (see Table I).

Prior to the initiation of the study, soil samples of both soil types (bioremediated and agricultural soils) were analysed for various physical and chemical characteristics (see Table II). The native soil in the bioremediated treatment was excavated and replaced by 60 cm of bioremediated soil. The added soil was then compressed uniformly by a roller to provide appropriate plant anchorage. This area was used for shrubs, groundcover and lawn grasses. In the case of large-sized plants (palms and trees), pits measuring 1 × 1 × 1 m were dug and backfilled with the bioremediated soil. In the agricultural soil treatment area, native soil was replaced with non-contaminated agricultural soil in a similar manner.

The trees and palms in 15-gallon containers and shrubs in one-gallon containers were used for planting. All plants received a complete fertilizer (15-15-15 nitrogen-phosphorus-potassium) at a rate of 10 g/plant at two-month intervals (Suleiman et al. 2002). Plant establishment was monitored for 18 months to ensure the adaptability assessment of the selected plants in two consecutive summer seasons.

Experimental approach

Plants were distributed randomly in the garden based on their growth pattern and to ensure maximum visual impacts. The experimental plants were selected from both agricultural soil and bioremediated soil; however, *Prunus cerasifera* "Thundercloud" and *Pyrus calleryana* "Aristocrat" were planted only in the Japanese garden, which contained agricultural soil. Soil samples were collected from areas where plants died to ascertain the cause for the mortality.

Table I. General information and survival of trees, shrubs and groundcover used in the study.

Category	Scientific name	Common name	Family	Origin	Survival%	
					Agricultural soil	Bioremediated soil
Palms						
	Arecastrum romanzoffianus	Queen Palm	Palmae	Brazil	0	0
	Erythea edulis	Guadalupe Palm	Palmae	Guadalupe Island	100	NA
Trees						
	Albizzia julibrissin	Silk Tree	Leguminosae	West Australia	100	NA
	Bauhinia blakeana	Hong Kong Orchid Tree	Leguminosae	China	100	0
	Cassia bicapsularis	Tropical Senna	Leguminosae	Tropical America	100	100
	Chitalpa tashkentensis	Chitalpa	Bignoniaceae	North Mexico	100	100
	Lagerstroemia faurei	Crape Myrtle	Lythraceae	Indochina	100	NA
	Photinia fraseri 'Standard'	Fraser's Photinia	Rosaceae	China/Japan	100	NA
	Pinus halapensis Brutia	Calabrian Pine	Pinaceae	East Mediterranean	100	100
	Pistacia chinensis	Chinese Pistache	Anacardiaceae	China	100	NA
	Prunus cerasifera 'Thundercloud'	Flowering Cherry Plum	Rosaceae	Central Asia	0	NA
	Pyrus calleryana 'Aristocrat'	Aristocrat Pear	Rosaceae	China	0	NA
	Robina pseudoacacia 'Purple Robe'	Purple Robe Locust	Leguminosae	North America	100	NA
Shrubs						
	Caesalpinnia mexicana	Mexican Bird of Paradise	Leguminosae	Mexico	100	100
	Camellia sasanqua 'Bonzana'	Bonzana Sun Camelia	Theaceae	Japan	0	NA
	Cyperus alternifolis gracilis	Dwarf Umbrella Plant	Cyperaceae	Madagascar	100	NA
	Eleagnus pungens	Silverberry	Eleagnaceae	China/Japan	0	0
	Escallonia langleyensis	Pink Escallonia	Saxifragaceae	South America	0	NA
	Ilex vomitora 'Stokes Dwarf'	Yaupon	Aquifoliaceae	Texas	100	100
	Lawsonia inermis	Henna	Lythraceae	Asia	100	100
	Leucophyllum frutescens	Texas Ranger	Scrophulariaceae	Mexio	100	100
	Nandina domestica	Heavenly Bamboo	Berberidaceae	India	100	NA
	Phylostachys aurea	Golden Bamboo	Rosaceae	South China	100	NA
	Raphiolepis indica 'Ballerina'	Ballerina Indian Hawthorn	Rosaceae	South China	100	NA
	Raphiolepis indica 'Clara'	Clara Indian Hawthorn	Rosaceae	South China	100	NA
	Rosa banksiae	Banksia Yellow Rose	Rosaceae	China	0	0
	Simmondsia chinensis	Jojoba	Buxaceae	Tropical America	100	100

(*continued*).

Table I. (*continued*).

Category	Scientific name	Common name	Family	Origin	Survival%	
					Agricultural soil	Bioremediated soil
Groundcover						
	Ceanothus 'Yankee Point'	Carmel Creeper	Rhamnaceae	California	0	0
	Cistus crispus	Rock Rose	Cistaceae	South Europe	0	0
	Myoporum pacifica	Pacifica Myoporum	Myopoaceae	Australia	100	100
	Ophiopogan japonicus	Mondo Grass	Liliaceae	Japan	100	NA
	Santolina chamaecyparrisus	Lavender Cotton	Compositae	South Europe	100	NA
Seed Mix						
	Atriplex canascens	Fourwing Saltbush	Chenopodiaceae	Northern Mexico	100	NA
	Encelia farinose	Brittlebush Honey	Compositae	California	100	NA
	Prosopis glandulosa		Fabaceae	Northern Mexico	100	NA

Table II. Basic characteristics of the bioremediated soil and agricultural soil used in the Ahmadi Biopark.

Parameter	Measuring unit	Bioremediated soil	Agricultural soil
ECe (1:2)	dSm^{-1}	3.34	0.30
pH (1:2)	–	7.41	8.35
$CaCO_3$	% eq	6.04	8.44
SAR	$(mmols/l)^{0.5}$	7.02	0.85
Munsell Color	dry	2.5Y 4/1 (dark grey)	2.5Y 7/2 (light grey)
Clay ($< 2\ \mu m$)	%	5.0	2.0
Sand (200–50 μm)	%	94	95.5
Silt (50–2 μm)	%	1.0	2.5
Textural Class	–	Sand	Sand
TPH (FTIR)	%	0.56	0.06
TEM (FTIR)	%	1.24	0.07
CM	%	3.77	0.79
Moisture	%	0.64	0.72

ECe = Electrical Conductivity; SAR = Sodium Adsorption Ratio; TPH = Total Petroleum; Hydrocarbons; FTIR = Fourier Transform Infrared; TEM = Total Extractable Matter; CM = Combustible Matter.

Leaves were routinely inspected for foliar injury due to the presence of petroleum hydrocarbons in the soil.

Plant survival and adaptability study. Experimental plants were monitored for survival and adaptability by measuring the height and canopy periodically. The foliage was measured for length, width, area, perimeter, shape factor and ratio factor using the leaf area meter (Model CI-202, Inc., USA). The plants that could not survive the summer heat were noted (Data not presented). The initial data-recording started in February 2001 and data were taken every two months.

Bioremediated soil study. Fifteen species (*Arecastrum romanzoffianus*, *Bauhinia blakeana*, *Caesalpinnia mexicana*, *Cassia bicapsularis*, *Ceanothus griseus* "Yankee Point", *Chitalpa tashkentensis*, *Cistus crispus*, *Eleagnus pungens*, *Ilex vomitoria* "Stokes Dwarf", *Lawsonia inermis*, *Leucophyllum frutescens*, *Myoporum pacifica*, *Pinus halapenses* "Brutia", *Rosa banksiae* and *Simmondsia chinensis*) were planted in both agricultural soil and bioremediated soil. Plant growth was compared in terms of height and width in both soils. The mortality in the bioremediated soil was recorded and compared with that in the agricultural soil. Foliar injury resulting from the effect of bioremediated soil on the plants was monitored and recorded.

Potential landscape use of the adapted plants in the greenery/landscape projects was determined and suggested. Any special treatment required to improve the visual impact of plants (need for excess irrigation, shade or plant support) were also suggested based on their growth pattern.

Results and discussion

Plants' performance evaluation

The survival percentage was calculated periodically by counting the number of live plants of each species (with live parts above the ground) in both soils. The percentage survival for the two palms was 50% with *Erythia edulis* surviving throughout the duration of the study in agricultural soil. The other palm species, *Arecastrum romanazoff*, could not thrive in either soil as a result of its sensitivity to the heat. In the tree category, five trees were planted in both agricultural and bioremediated soil. While 72.73% of all the trees planted survived in both soils, 80% of plants successfully established in bioremediated soil. *Bauhinia blakeana* was the only tree that did not withstand the petroleum hydrocarbons in the soil. Nine out of 14 shrub species were planted in both soils. The overall survival percentage for the shrubs category in the bioremediated soil was 77.78%. The two shrubs (*Rosa banksiae* and *Eleagnus pungens*) that died in the bioremediated soil could also not survive the agricultural soil, whereas the response of *Camellia sasanqua* that were affected by the neighboring *Wedelia triloba* plants needs to be investigated further. The percentage survival of the entire shrub category was found to be 78.58%. Three out of five groundcovers were planted in both soils. *Ceanothus grissii* and *Cistus crispus* did not establish in both soils, whereas *Myoporum pacifica* died in the agricultural soil. The other two groundcovers (*Ophiopogan japonicus* and *Santolina chamecyparissus*) thrived throughout the duration of the study. The percentage survival of the groundcovers in the bioremediated soil was 33.3%, whereas the overall adaptation of the groundcovers was 60%.

Soil pH and ECe near stressed plants

Soil samples were collected in the close vicinity of stressed plants and analysed for pH and electrical conductivity (ECe) to ascertain if the plant's failure to establish was related to an increase in soil salinity (see Table III). The plant species included in this study were:

Table III. Characterization for pH of the saturated soil paste* and ECe based on the soil saturation extract.

Plant species	Code	Soil/ water	pHs	pH classes*	ECe	Salinity class*
Camellia sasanqua 'Bonanza'	a	AS	6.7	Neutral	1.73	Non-saline
Ceanopthus griseus 'Yankee Point'	a	AB	7.4	Slightly alkaline	3.08	Very slightly saline
Cistus cripus	c	BB	7.4	Slightly alkaline	3.48	Slightly saline
Cistus cripus	b	AB	7.5	Slightly alkaline	10.26	Moderately saline
Cistus cripus	a	AB	7.4	Slightly alkaline	17.82	Strongly saline
Eleagnus pungens	c	BB	7.4	Slightly alkaline	37.0	Strongly saline
Eleagnus pungens	a	AB	7.5	Slightly alkaline	2.26	Very slightly saline
Eleagnus pungens	b	AS	7.2	Neutral	6.17	Slightly saline
Escallonia langleyensis	b	AS	7.2	Neutral	1.07	Non-saline
Escallonia langleyensis	a	AS	7.4	Slightly alkaline	2.93	Very slightly saline
Myoporum pacifica	c	BB	7.1	Neutral	8.25	Moderately saline
Myoporum pacifica	a	AB	7.4	Slightly alkaline	3.00	Very slightly saline
Myoporum pacifica	b	AB	7.8	Slightly alkaline	0.64	Non-saline
Nandina domestica	c	AS	7.4	Slightly alkaline	1.25	Non-saline
Ophiopogan japonicus	a	AS	7.4	Slightly alkaline	4.03	Slightly saline
Phyllostachys aurea	b	AS	7.4	Slightly alkaline	0.67	Non-saline
Rosa banksiae	c	BB	7.1	Neutral	5.75	Very slightly saline
Rosa banksiae	a	AB	7.4	Slightly alkaline	4.94	Slightly saline
Rosa banksiae	b	AB	7.5	Slightly alkaline	2.76	Very slightly saline

*Soil Survey Division Staff. Soil Survey Manual. USDA-NARC Agric. Handbook 18, US Govt Print Office, Washington, DC. pp.192;

Non-saline (0 – 2 dS/m); very slightly saline (2 – 4 dS/m); slightly saline (4 – 8 dS/m); moderately saline (8 – 16 dS/m); & strongly saline ($\geqslant$ 16dS/m). a, b, c represent replicates of the plant species; AB represents agricultural soil, brackish water; AS represents agricultural soil, sweet water; BB represents bioremediated soil, brackish water.

Table IV. Potential landscape use of introduced plants.

Category/Scientific name	Agricultural/ bioremediated soil	Landscape use	Special care/remarks
Palms			
Arecastrum romanzoffianus	Both		
Erythea edulis	Agricultural soil	As a specimen plant	
Trees			
Albizzia julibrissin	Agricultural soil	Home garden	Special care required
Bauhinia blakeana	Both	Parks/large garden	Special care required
Cassia bicapsularis	Both	Roadside/Parks	
Chitalpa tashkentensis	Both	Parks	Special care required
Lagerstroemia faurei	Agricultural soil	Roadside/Park	
Photinia fraseri "Standard"	Agricultural soil		
Pinus halapensis Brutia	Both	Parks	Special care required
Pistacia chinensis	Agricultural soil	Parks	Special care required
Prunus cerasifera "Thundercloud"	Agricultural soil		
Pyrus calleryana "Aristocrat"	Agricultural soil		
Robina pseudoacacia "Purple Robe"	Agricultural soil	Roadside	
Shrubs			
Caesalpinnia mexicana	Both	Afforestation, garden	Flowers all year
Camellia sasanqua "Bonzana"	Agricultural soil		
Cyperus alternifolis gracilis	Agricultural soil	Garden	
Eleagnus pungens	Both		
Escallonia langleyensis	Agricultural soil		
Ilex vomitora "Stokes Dwarf"	Both	Border	
Lawsonia inermis	Both	Street, garden	
Leucophyllum frutescens	Both	Street, garden	Flowers all year
Nandina domestica	Agricultural soil	Garden	Needs shade
Phyllostachys aurea	Agricultural soil	Garden	Does not take excess irrigation
Raphiolepis indica "Ballerina"	Agricultural soil	Garden	
Raphiolepis indica "Clara"	Agricultural soil	Garden	
Rosa banksiae	Both		
Simmondsia chinensis	Both		
Ground cover			
Ceanothus "Yankee Point"	Both		
Cistus crispus	Both		
Myoporum pacifica	Both	Border, bed	Does not take drought
Ophiopogan japonicus	Agricultural soil	Border, bed	Yellows in summer
Santolina chamaecyparrisus	Agricultural soil	Border, bed	
Seed mix			
Atriplex canascens	Both	Afforestation	Aggressive
Encelia farinose	Both	Garden, afforestation	
Prosopis glandulosa	Both	street, afforestation	

Camellia sasanqua 'Bonanza' 'a' (AS), *Ceanothus griseus* 'Yankee Point' 'a' (AB), *Cistus crispus* 'c' (BB), *Cistus crispus* 'a,b' (AB), *Eleagnus pungens* 'c' (BB), *Eleagnus pungens* 'a' (AB), *Eleagnus pungens* 'b' (AS), *Escallonia langleyensis* 'a,b' (AS), *Myoporum pacifica* 'c' (BB), *Myoporum pacifica* 'a,b' (AB), *Nandina domestica* 'c' (AS), *Ophiopogan japonicus* 'a' (AS), *Phyllostachys aurea* 'b' (AS), *Rosa banksiae* 'c' (BB) and *Rosa banksiae* 'a,b' (AB). Soils near the stressed plants recorded neutral to slightly alkaline except near *Eleagnus pungens* 'c', *Myoporum pacifica* 'c' and *Cistus crispus* 'a,b', where the soil was highly to moderately saline. The visual observations also showed that no signs of high salinity in

Table V. Some physical and chemical characteristics of bioremediated and agricultural soils at the end of the study. (Source: Al-Zalzaleh et al. 2001)

Parameter	Unit	Non-vegetated area		Area under trees		Area under shrubs		Area under groundcover		Area under lawn	
		Biorem. Soil	Agric. Soil	Biorem. Soil	Agric. Soil	Biorem. Soil	Agric. Soil	Biorem. Soil	Agric. Soil	Biorem. Soil	Agric. Soil
pH (1:2)	-	7.9	8.10	7.5	7.85	7.60	7.80	7.50	8.00	7.95	7.85
ECe (1:2)	dSm^{-1}	5.76	2.23	3.00	0.64	2.40	2.94	3.14	2.20	0.40	1.35
$CaCO_3$	% eq	6.64	4.18	5.33	3.63	4.43	5.68	6.38	5.12	6.07	3.68
Munsell colour	dry	2.5Y 4/3 Olive brown	2.5Y 6/3 Light yellowish brown	2.5Y 4/2 Dark greyish brown	2.5Y 6/3 Light yellowish brown	2.5Y 3/3 Dark olive brown	2.5Y 6/3 Light yellowish brown	2.5Y 4/2 Dark greyish brown	2.5Y 6/3 Light yellowish brown	2.5Y 4/2 Dark greyish brown	2.5Y 6/3 Light yellowish brown
TPH (FTIR)	%	0.22	0.04	0.13	0.03	0.27	0.03	0.20	0.04	0.24	0.04
TEM (FTIR)	%	0.41	0.04	0.22	0.04	0.61	0.04	0.48	0.05	0.48	0.04

ECe = Electrical Conductivity; TPH = Total Petroleum Hydrocarbons; FTIR = Fourier Transform Infrared; TEM = Total Extractable Matter; Tree = *Conocarpus lancifolius*, Shrub = *Bougainvillea glabra*, Groundcover = *Gazania triloba*, Lawn = *Paspalum vaginatum*.

stressed plants. These observations indicate that plant stress could have been imposed by extreme summer heat rather than high soil salinity.

In sensitive plant species, petroleum hydrocarbons adversely affect plant growth by exerting their influence on the plant's physiological processes. The mode in which petroleum molecules act on plants is a complex phenomenon involving both contact toxicity and indirect deleterious interactions with other molecules. Contact toxicity occurs mainly due to the solvent effects of low-boiling hydrocarbons on the lipid membrane structure in the root cells. The extent of toxicity depends on the type of hydrocarbons, and their polarity and molecular weight (McGill et al. 1981). These low-boiling petroleum components are readily removed from the biologically active surface layer in moist, well drained soils through evaporation and leaching (Hunt et al. 1973). Indirect effects of oil pollution on soil include oxygen deprivation due to greater microbial activity in contaminated soils, increased water repellence, disruption of soil texture, and alteration of the soil-water relationship (Guo & McNabb 1992, Li & Sawatsky 1997). Creation of anaerobic conditions in contaminated soils may lead to the generation of toxic compounds such as H_2S. Oil-degrading microorganisms also compete with plants for nutrients. These factors ultimately affect plant growth and development. See Tables IV and V.

Conclusions

A number of introduced ornamental plants showed excellent adaptability to the arid climate of Kuwait. The percentage survival was high, particularly in the tree and shrub categories. Other than the *Bauhinia blakeana*, all the plants survived and performed equally well in both bioremediated and agricultural soils. There was no foliar injury as a result of the petroleum hydrocarbon presence in the soil. The proven adapted plants can be considered for landscape/greenery projects under Kuwait's growing conditions (see Table IV). The chemical and physical characteristics of both soils at the end of the experiment are displayed in Table V.

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