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VARIOUS ATTEMPTS IN GREENING THE STATE OF KUWAIT

MANNIFALTIG VERSUCHE DAS ERGRÜNEN DER STAAT AUS KUWAIT

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Kuwait is a desert country characterized by harsh climate, poor soils, and scarce water resources. Several attempts have been undertaken to combat desertification in the arid country of Kuwait. These include the emphasis on the native plants through the mass planting of local plants to be further used in the desert rehabilitation, where seeds from the desert are being collected to be used for the natural re-vegetation process. Other attempts include the introduction of exotic ornamental plants that can endure similar harsh climatic conditions. Several studies are being conducted to enhance the greenery and beautification of the country. Xeriscaping is a recent approach used in Kuwait's desert landscapes. It is a low-water landscape concept especially developed to be used in countries with low rainfall and scarce water resources. More than 150 ornamental plants have been introduced and naturalized within Kuwait and yet around 200 more species are being examined for further introductions. A new study was also conducted to enhance the re-vegetation of the country was the remediation of the oil-contaminated soil that resulted form the Iraqi invasion on Kuwait. In attempts to retain the soil's productivity, physical, chemical and biological methods of remediation were studied earlier. The biological method was recommended for agricultural purposes. Local and newly introduced ornamental plants were experimented using bio-remediated soil. After a thorough study of the plants' performance the results proved that there were no major differences in the plants' survival and vegetative growth in either soil types.

Keywords: Kuwait; Desertification; Desert rehabilitation; Re-vegetation; Ornamental plants; bio-remediated

INTRODUCTION

Kuwait is situated at the northwestern corner of the Arabian Gulf Region between latitudes 28° 45′ N and 30° 06′ N and longitudes 46° 33′ E and 48° 35′ E. The total land area is 14 818 km^2. Kuwait's climate is characterized by harsh summers and mild winters. Temperature extremes are high with means ranging between 44.7°C in summer and 8°C in winter. Winter is encountered occasionally with frost. The rainfall is minimal, not exceeding 115 mm/year. Evaporation is very high averaging 14.1 mm per day. The relative humidity is low and winds are strong. Winds blow from the north-west

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and the south-east. Kuwait's soils are high in calcareous materials, especially calcium carbonate. The soil is sandy in texture and alkaline and low in plant nutrient material. Water resources in Kuwait are scarce and the brackish water currently used is saline.

Native vegetation

Kuwait has a unique desert ecosystem comprising of 314 plants, 28 mammals, 300 birds and 40 reptiles (Omar, 1982). It is composed of open scrub under-shrubs, perennial herbs and ephimarals. The vegetation in Kuwait was described under four ecosystems: sand dune ecosystem, salt marsh and saline depression ecosystem, desert plain ecosystem and desert plateau ecosystem (Halwagy and Halwagy, 1974).

Desertification causes and desert rehabilitation

The rate of urban development in the 80s that was due to rapid increase in the population in Kuwait resulted in an increase of human activity in the desert, adversely affected the desert ecosystem. The major causes of desertification include overgrazing, sand and gravel quarrying, off road traffic and finally oil pollution. Desert rehabilitation and biodiversity conservation in Kuwait is essential. In attempts to increase and conserve the native vegetation, KISR conducted several studies in an effort to sustain the desert vegetation. The studies included the following:

Rehabilitation of war damaged areas in the National Park of Kuwait

To preserve diverse native flora and fauna, the State of Kuwait established a National Park on an area of 330 km^2 in the north of the country (Omar *et al*, 2000). Recovery of the native species was evident and the future results were expected to conserve Kuwait's biodiversity. After the Iraqi invasion and the liberation war, severe damage occurred to the park. Park assessment revealed the loss of the recovered vegetation cover due to the war activities and the effect of grazing of the exposed land. Moreover, the wildlife habitats in the park were severely damaged due to the loss of energy. Human intervention was necessary to fix the damage in the park and re-vegetate the area. A study was made to reintroduce native and acclimatized plant species that are heat- and drought tolerant. Hardy trees and shrubs, from seeds or stock, were used to re-vegetate the area to give the proper environment to allow native plant recovery. Plants included *Acacia bivenosa, Acacia burketii, Acacia cuthertsoni, Acacia ligulata, Acacia pachycerus, Acacia sudanii, Azadirach indica, Chilopsis linearis, Dalbergia sissoo, Kegelia pinnata, Leucaenia sp., Prosopis juliflora, Prosopis spicigera, Prosopis chilensis, Susbenia formos, Ziziphus spina-christi, Atriplex lentiformis, Atriplex halimus, Atriplex nummularia, Senna artemesoides, Olea sp.* and *Convolvulus sp.*

Rehabilitation and management of Kuwait's rangelands for sustainable yield

Work has been done in terms of developing a method to rehabilitate Kuwait's rangelands resulting in appropriate vegetation cover and soil erosion prevention. The method should also be adequate to be used on a large scale. It was essential to develop vegetation of mixed species and structural diversity to protect soil surface, support a range of endemic fauna, and support judicious grazing management. The vegetation mix included endemic and acclimatized foreign plant species from similar ecologies to compensate for the poor availability of native plant species. Potential plants for this study included *Acacia burkitti, Acacia victoriae, Acacia saligna, Atriplex semibaccata, Atriplex semilunaris, Atriplex vesicaria, Maireana triptera, Eragrostis dieslii, Senna artemisoides, Cenchrus ciliaris, Rhanterium epapposum, Haloxylon salicornicum* and *Stipa capensis*.

Utilization of Kuwait's native flora for sustainable greenery

According to the native plant society in Virginia, USA, the use of native flora benefits wildlife, horticulture and landscaping, and conservation and restoration or domestic livestock forage. Xeriscaping with desert native and naturalized plants is one of the goals to sustain greenery in the country. By using the native desert landscape, natural vegetation within Kuwait will be conserved, as the native plants are adapted to drought, heat, and the local soil. Native plants potential for landscape use include *Acacia pachyceras, Atriplex leucooclada, Calligonum conglomerates, Farsetia aegyptica, Haloxylon salicornicum, Horwoodia dicksoniae, Lycium shawii, Nitraria retusa, Ochradenus baccaus, Pennisetum divisum* and *Rhanterium epapposum*.

Urban greenery

In a response to the high demand of greenery within Kuwait, KISR initiated the work in providing an integrated framework for the present and future greenery efforts. Successive studies occurred to increase Kuwait ornamental plant palette by introducing, selecting and screening, heat and drought tolerant plants. The studies included the following:

National greenery plan (NGP)

Several attempts have been undertaken to green and beautify Kuwait, especially after the war period. KISR developed the NGP, which was developed to cover 20 000 hectares of open spaces within Kuwait city and the green belt areas. The plan identified the need of 141 000 palms, 3.9 million afforestation trees, 270 ornamental trees, 3.0 million shrubs, 3.0 million m^2 of groundcover plants, 12.4 million m^2 of seeded lawn (KISR, 1996). Fifty ornamental plants were selected for the execution of the NGP according to an assessment of the war-neglected plants. Realizing the shortage of the diversity of the ornamental plant palette, the NGP identified a task of amassing germplasm pools and establishing appropriate information on them. This called for long-term continuous programme of introducing new ornamental plants that evolved from similar climates. Some of the plants identified for landscape use included *Acacia arabica, Acacia salicina, Acacia saligna, Agave americana, Caesalpinnia pulcherrima, Caesalpinnia gillsii, Catharanthus roseus, Carpobrotus edulis, Carissa grandiflora, Cericidium floridum, Clerodendrum inerme, Conocarpus lancifolius, Cynodon dactylon, Eucalyptus camaldulensis, Ficus infectoria, Ficus retusa, Ipomea palmate, Jasminum sabac, Lantana camara, Leucophyllum frutescens, Melia azaderach, Phyla nodiflora, Ziziphus jujube* and *Ziziphus spina-christi*.

New plant introductions

Work in screening and selecting additional plant introduction was initiated in 1984. A number of plants were introduced and tested against the climatic constraints. The main focus of the project was to collect and initiate preliminary testing of a number of trees, shrubs, vines and grasses for determining their potential landscape values (Taha *et al.*, 1988, Houkal *et al.*, 1988). Fifty plants were selected due to their adaptability under coastal conditions to be incorporated in the plant palette for the greenery plan.

Further introductions of 200 seeds of plants are being tested since 1996. The seeds were introduced from various resources in Australia. Eighty plants in the plant-testing center have proved adaptation to the local climate, and are still under study for assessing long-term growth performance under coastal conditions.

Mangrove, a distinct plant, is being reintroduced to Kuwait to be further used in the local coastline that is estimated to be 290 km. Mangrove species from different resources such as *Avicennia marina, Avicennia germinans, Ceriops tagal* and *Rhizophora mucronata* were tested in appropriate testing sites. *Avicennia marina* and *A. germinans* proved to be suitable to be used in Kuwait.

Soil bioremediation

Efforts were made at KISR to assess the extent of soil contamination and to propose the best methods for rehabilitating the soil. Three bioremediation approaches were proposed. KISR and the Petroleum Energy Center of Japan (PEC) demonstrated through studies remediation of the soil in the Burgan Oil Field. The Ahmadi Bioremediated Soil Park was then established with the Kuwait Oil Company (KOC) to test the survival of plants in bioremediated soil.

Several local and newly introduced ornamental plants were used for the study in the Ahmadi Bioremediated Soil Park. Two soil types were used: agricultural and bioremediated. Plants will be mentioned for their survival and adaptability, and comparisons between plant performances in different soil types will be made.

The plants in the study were selected based on their heat- and drought-tolerance. Various parameters are being measured to verify the adaptability and survival of the plants. The Ahmadi Bioremediated Soil Park adds an extra condition, that is, the utilization of bioremediated soil. This is another parameter in the study of ornamental plant growth and development. Plant survival in bioremediated soil will be recorded and documented. This will produce new input that can enhance plant development in polluted areas.

MATERIALS AND METHODS

Application of bioremediated soil

The top 60 cm layer, in areas used for grasses and groundcover was replaced with bioremediated soil and compacted uniformly to provide adequate anchorage for plants. However, in the case of trees, 1 × 1 × 1 m planting holes were dug and backfilled with bioremediated soil. The top 60 cm layer in the remaining area was replaced with agricultural soil.

Plant materials

A broad range of plant material was selected to test the suitability of bioremediated soil for survival. Plants were grouped into trees, shrubs and ground covers. Irrigation water was applied through drip lines. The experiment was arranged in a split-plot design with soil type as the main block and species as subplots. Plant height and canopy were recorded at 2-month intervals.

RESULTS

The periodic data on height and canopy of the test plants in bioremediated and agricultural soil are presented in Tables I and II. *Chitalpa tashkentensis* plants remained dormant until February, The leaves started to emerge in March 2001. *Cassia bicapsularis*, *Chitalpa tashkentensis* and *Caesalpinia mexixana* plants grew taller and

TABLE I Periodic plant height of selected plant species in bioremediated and agricultural soil

	Plant height on month (cm)									
	Agricultural Soil					*Bioremediated Soil*				
Plant species	*Feb.*	*Apr.*	*Jun.*	*Jul.*	*Aug.*	*Feb.*	*Apr.*	*Jun.*	*Jul.*	*Aug.*
Trees										
Cassia bicapsularis	175	166	Dead			190	210	210	210	210
Chitalpa tashkentensis	240	250	300	350	350	370	375	370	380	400
Shrubs										
Caesalpinia mexicana	112	127	150	160	170	130	94	160	180	210
Ilex vomitoria	23	30	30	30	25	22	25	25	26	25
Groundcovers										
Myoporum pacifia	12	12	Dead			12	12	Dead		
Santolina chamaecyparrissus	17	20	29	35	20	28	47	38	40	20

TABLE II Periodic plant canopy of selected plant species in bioremediated and agricultural soil

	Plant Canopy (cm)									
	Agricultural Soil					*Bioremediated Soil*				
Plant species	*Feb.*	*Apr.*	*Jun.*	*Jul.*	*Aug.*	*Feb.*	*Apr.*	*Jun.*	*Jul.*	*Aug.*
Trees										
Cassia bicapsularis	195	168	Dead			190	200	Cut		
Chitalpa tashkentensis	120	125	120	115	115	93	97	100	140	180
Shrubs										
Caesalpinia mexicana	103	133	180	200	225	100	74	120	150	170
Ilex vomitoria	35	43	40	45	40	30	45	40	47	50
Groundcovers										
Myoporum pacifia	65	73	Dead			45	74	Dead		
Santolina chamaecyparrissus	24	29	43	45	40	33	84	43	45	46

had larger canopies in the bioremediated soil than in the agricultural soil. In contrast, the growth of *Ilex vomitoria, Myoporum pacifica* and *Santolina chmaecyparicuss* was the same in both soil types However, *Myoporum pacifica* could not survive the heat in either soil, whereas *Santolina chmaecyparicuss* partially dried out during June and July, and recovered towards the end of August.

DISCUSSION

The initial data clearly suggest that plant responses to bioremediated soil varied according to plant species. Based on their responses, the species studied in the project could be grouped into two categories. The first category includes plants that benefited from replacement of native soil with bioremediated soil. Species such as are included in this category *Cassia bicapsularis, Chitalpa tasketentasis* and *Caesalpinia maxicana.*

Growth promotory by weathered petroleum hydrocarbons has also been reported in mangrove plants (Snedaker *et al.*, 2001). The second group, in which the growth was same in the two both soil types, included species such as Ilex vomitoria, Myoporum pacifia and Santolina chamaecyparrisus. However, during the initial stages, the growth of Santolina chamaecyparrisus was poor in bioremediated soil, although they recovered later.

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 and McNabb 1992; Sawatsky and Li, 1997). Creation of anaerobic conditions in contaminated soils may lead to the generation of toxic compounds such as H_2S. Oil-degrading micro-organisms also compete with plants for nutrients. These factors ultimately affect plant growth and development.

According to McNabb *et al.* (1992), water repellency in hydrocarbon-contaminated soils is influenced by the soils water content and becomes problematic only under low moisture regimes. Other researchers have made similar observations (i.e., Dekker and Ritsema 1994; Ritsema *et al.*, 1997). Dekker and Ritsema (1994) introduced the concept of critical soil moisture levels to describe the water content at which soils are no longer water repellent. Sawatsky and Li (1997) suggested critical soil water contents of 20% for contaminated soils and 18% for bioremediated soils, above which the sorpivity of contaminated soil was near that of control soils. Below this value, there was a strong divergence in sorpivity between contaminated soils and bioremediated or control soils. The negative effects became more pronounced as the water potential approached the permanent wilting point (i.e., -1.5 MPa matrix potential).

CONCLUSION

Kuwait's environmental conditions are harsh and extreme. The environmental setting enhances the development of plants tolerant of hot climatic conditions, dry and saline soil and drought. Various plants are available internationally that can survive such conditions. Although several ornamental plant species proved to survive harsh desert climatic conditions, a limited number of ornamental plants are available in Kuwait. New ornamental plant introduction will increase Kuwait's plant palette (Suleiman and Grina, 2002). Introduction of new ornamental plants will improve the landscape and greenery of the country. Promotion of ornamental plants will improve the quality of the environment, and increasing the diversity of plants will encourage better selection for the landscape design for the National Greenery Plan which covers 20 000 ha of open spaces within Kuwait City and the green belt areas. The plan identified the needs for 141 000 palms, 3.9 million afforestation trees, 270 ornamental trees, 3.0 million shrubs, 3.0 million m^2 of groundcover plants, and 12.4 million m^2 of seeded lawn (KISR, 1996). Based on a preliminary assessment during 1984–88, a plant palette comprising of fifty ornamental plant species was recommended for the execution of the NGP (Taha and Houkal, 1988). Ornamental testing facilities were severely damaged and these studies were interrupted during the 1990 Iraqi occupation. However, efforts to increase Kuwait's ornamental plant resources base were reinitiated after the infrastructure facilities was renovated after liberation. A number of trees, shrubs, vines and grasses were introduced and tested under the coastal climatic conditions. One of the major problems faced during the implementation of these projects was maintaining genetic consistency as most plants were raised from seeds and were one-time plantings only. There was also not enough time to repeat the plantings. This made it difficult to determine weather the plant mortality was from genetic incompatibility or sensitivity to harsh weather conditions. These problems can be overcome by procuring seeds from various resources and testing them.

A vast area of the country was heavily polluted with oil after the Iraqi aggression. Oil pollution in soil deprives plants of oxygen by occupying the empty pore space as well as by increasing the microbial activity in the soil. Thus, it will create conditions that make it hard for plants to live in the absence of sufficient oxygen. KISR estimated the volume of the oil gushed into the soil and the total area that got polluted. Studies also identified heavily and lightly contaminated soil. Efforts were made to assess the extent of contamination, the effects of oil pollution on vegetation and to propose the best methods of rehabilitating the soil. Three bioremediation approaches were proposed. KISR and PEC (Petroleum Energy Center of Japan) demonstrated studies on bioremediation the contaminated soil in the Burgan oil field. The Ahmadi Park was, then, established in cooperation with KOC to test the survival of greenery plants in the bioremediated soil. Bioremediation approach was selected for its ability to significantly reduce the total petroleum hydrocarbons and for the bioremediated soil's ability to support plant growth with no indication of accumulation of toxic organic constituents in plant tissues (Al-Zalzaleh *et al.*, 2001a,b).

Several ornamental plants were introduced in the Ahmadi Biopark to be studied for their adaptability to Kuwait's environmental conditions and some were also studied for their performance in the bioremediated soil. Because the plants were carefully selected from areas of similar environments to Kuwait's, the percentage of survival was high, particularly in the tree and shrub categories. Other than the *Bauhinia blakeana* tree that was sensitive to the hydrocarbons, all the plants that were planted in both soil types, agricultural and bioremediated, survived equally. There was no adverse effect of the hydrocarbons in the soil on the plant growth and development. There was no foliar injury on the plants as a result of the hydrocarbons in the soil. The bioremediated soil supported the newly-introduced plant growth in the biopark.

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