جامعة قطر
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المجلس الوطني للثقافة والفنون والتراث

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Prosopis cineraria in Qatar

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لا يسمح بإعادة إصدار هذا الكتاب أو أي جزء منه أو تخزينه في نطاق استعادة المعلومات أو نقله بأي شكل من الأشكال ، دون إذن خطي مسبق من الناشر.

Dedication
to
H.H. Sheikha Mozah Bint Nasser Al-Missned
The Consort of
H.H. Sheikh Hamad Bin Khalifa Al-Thani
The Emir of the State of Qatar

Blessed be those who contribute by moral support, financial support or the power within their means.

No other official has drawn their country's attention to the appreciation of their nature heritage be it plants or animals.

No other has launched programmes focusing on the education of future generations on environmental issues, the balance of the ecosystem and the importance of recycling.

No other had the vision of launching a programme targeting beauty and knowledge of the local flora.

"A Flower Each Spring" is now in its seventh spring. The spring of 2005 exceeded all expectations with the selection of a rare species not only of interest to Qatar where it is represented by relic localized populations but of interest worldwide as one of the tree species selected as a solution for arid land.

We thank you and wish you health and prosperity.

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THIS BOOK

This book comes out as the fruit of cooperation between The University of Qatar and The National Council for Culture, Arts and Heritage. The content of the work was prepared by a hard working team of researchers at The University, while publishing procedures and arrangements were performed by the Translation Center at the National Council with close cooperation with the research team represented by Dr. Noora Jabor Al Thani.

The work is hoped to be of substantial benefit to research in different fields of agriculture and environment studies in the arid areas. It also serves as a basic reference in the narrower field of the Ghaf Tree *(Prosopis cineraria)*.

The work has also an additional message in the field of humane and cultural efforts to strengthen man's attachment to his environment.

Further more, this initiative of cooperation between a research group from the field of academia and the Translation Center at The National Council for Culture is hoped to be a step forward towards joining the international intellectual tendency to bridge the gap between science and literature. We certainly know that our initiative is just a tiny step simply hoped to draw attention to the importance of the idea and probably to remind the reader of the well established tradition of Classical Arab scholars in encompassing both science and literature, based on conscious belief in the integrity of human knowledge.

Doha
January 2007

Prof. Hussam Al Khateeb
Cultural Expert
Supervisor of Translation Center
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CHAPTER - 1

INTRODUCTION

By
Professor Ekhlas M. M. Abdel Bari

1.1 Introduction

The Ghaf (Ar.) plant ***Prosopis cineraria*** belongs to the genus *Prosopis* which is a genus in the family Mimosaceae, a legume family of woody taxa of trees and shrubs.

The Mimosaceae is represented in the flora of Qatar by two genera: *Acacia* and ***Prosopis***. The former is represented by two local species *A. ehrenbergiana* and *A. tortilis* while the latter is represented by one local species *P. cineraria* and two introduced species *P. farcta* (Yanbout, Ar.) and *P. juliflora* (Ghuweif, Ar.).

The local representatives of the two genera *Acacia* and *Prosopis* can be differentiated from each other by their type of inflorescence. *Prosopis* has spicate infloresecences while *Acacia* has capitate inflorescences.

In recent years there has been much research focusing on species of both genera as well as other taxa including *Moringa* and Neem (*Azadirachta indica*) in search of trees and shrubs tolerant to stresses of aridity [high termperatures and scanty rains and salinity] and with multi- purpose uses in arid lands.

Prosopis, commonly known as Mesquite comprises 44 species mainly distributed in the dry regions of North, Central and S. America, and in N. Africa, S.W. Asia and Arabia (N.W. India to E. Pakistan, Iran, Iraq, and Afghanistan). *Prosopis* is native to many countries and occurs in arid areas in Asia and Arabia. It has been introduced in many parts of the world for various purposes and has been successful in combating sand movement but has become a problem in some parts of the world as an invasive species and by hybridizing with other species causing taxonomis confusion.

Prosopis cineraria is of particular interest because it is a tree and it is native to the State of Qatar. The species has been chosen as "the spring flower for 2005"- a program now in its seventh year.*

Search for the tree in the local flora proved that it is on the decline and all the individuals encountered are less than 50 in number and sporadically dispersed. Seedlings or saplings were never encountered and all extant individuals are mature trees with an estimated age of 90-150 years or more. The maximum number of trees is located at a place named after it (Al Ghafat (Ar.)).

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*Her Highness Sheikha Mozah inaugurated the program *A Flower Each Spring* in 1998.

1.2 Importance of *Prosopis cineraria*

Interest in *P.cineraria* worldwide has been due to 5 out of its apparent many merits. These are:

- Long living tree
- A multi-purpose tree (fuel, wood, fodder, food and medicine, land use, silviculture, etc.)
- Tolerant of drought
- Tolerant of extreme temperature (-6°C to 50°C under maximum shade)
- Tolerant of infestation (desert locusts and beetles on foliage, brucid beetles on seeds, termites on wood).

Though not much has been investigated in its value in soil fertility, it is apparent that being a shade tree and one on which animals browse, the organic matter will with time improve soil fertility. In India and Pakistan crops are grown under the trees' canopy where soil fertility is improved from litter. Historically, *P. cineraria* distribution and conservation has been in areas where it is linked to silviculture - agroforesetry. Equally, the ash has been found to contain 31% soluble potassium salts and can therefore be used as a source of potash.

According to *Le Houe'rou (2003), the species originated in North West India and East Pakistan where it is still a part of their agro-forestry production system (with millet). The link of *P.cineraria* with Rajasthan is of importance when seeking a beneficial tree. It has been reported that during the India's Rajputana famine of 1868-69 many survived because they used the sweet bark of the tree as a food substitute.

The tree is known to have many uses beside its local use as animal fodder and feed (pods, leaves and twigs).

Prosopis koelziana has been reported as the species occurring in the Arabian Peninsula (S.E. Saudi Arabia, U.A. Emirates, Oman) and equally in S. Iraq, S. Iran and coastlines of the Persian Gulf and Oman Sea.

P. cineraria has hard and heavy heartwood with innumerable uses including its use as firewood, charcoal production, timber production for building houses, poles, furniture, frames and boats, tools handles. Medicinally, it is reported as of value in folks medicine and has been used as an astringent, demulcent and pectoral, anthelmintic, refrigerant and a tonic; also in the treatment of bronchitis and dysentery. The bark is rich with tannins that are recommended for tanning. The gum produced though reputed as of high quality, is not commercially utilized.

At present, worldwide focus is on the use of this species, as well as others, in drought stricken areas in Asia and in Africa. This is because of its known tolerance to aridity and salinity and for other multipurpose uses.

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*Le Houe'rou, H.N. (2003). *Prosopis cineraria* (L.) Druce. FAO [G BASE/ DATA/ PF 003].

CHAPTER - 2

THE SYSTEMATIC POSITION AND THE IDENTITY OF THE GENUS *PROSOPIS*

By

Professor Ekhlas M. M. Abdel Bari

2.1 Introduction

Studies on the *Prosopis* species are numerous covering all aspects of their systematics, biology and economic potentials. Meskeet species in the Gulf States have been studied in some projects sponsored by USDA Forest Service, HDRA (Henry Doubleday Research Association) overseas projects, FAO, NFTA, Ahmad & Ismail (1996), and Brown (1989).

The genus *Prosopis* has been studied in detail by Burkart (1976) who classified the 44 extant species of *Prosopis* under 5 sections:

Section Prosopis	with 3 species including *P. cineraria* and *P. farcta* (Solander ex Russell) MacBride
Section Anonychium	with one species i.e., *P. africana* (Guill,Perr&Rich) Taubert
Section Strombocarpa	with 9 species
Section Monilicarpa	with one species ie. *P. argentina* Burkart
Section Algarobia	with a total of 30 species including the two usually confused species *P. chilensis* (Molina) Stuntz emend. Burkart and *P. juliflora* (Sw) DC.

Hybridization has been reported to take place easily among all taxa causing much confusion as to the identity of the species, in particular much closely allied taxa such as *P. cineraria* and *P. juliflora*.

A summary of the main characteristics of common *Prosopis* species under study for their suitability as multi-purpose trees for arid land is given in Table 1.

Table 1. Main features of common *Prosopis* trees.

Species	Height (m)	Girth (m)	Sapwood colour	Heartwood Colour
P. alba	24	2	Light yellow	Reddish brown
P. affinis	26	0.6	Yellow	Reddish brown
P. glandulosa	16	0.25 -1.2	Lemon yellow	Deep reddish brown
P. juliflora	16	1.2	Pale yellow	Yellowish brown to dark brown
P. kuntzei	11	0.6	Light yellow	Chestnut brown
P. nanduba	6	-	-	-
P. nigra	10-16	0.4-1.2	Yellow -ochre	Chestnut brown
P. ruscifolia	15	0.5	Light yellow	Yellow brown to reddish brown

P. cineraria is known as Ghaf in Arabic but has many common names in all parts of the world: Jand (Punjab), Jandi/ Jhand (Pakistan), Shum/ Shumi/ Kandi/ Jambu (India). *P. juliflora* used to be referred to as Ghaf but recently the arabic name Ghuweif, a deminitive of the name Ghaf, has been applied to *P. juliflora*. Because of the program " A Flower Each Spring", the local species of *P. cineraria* has been given its due attention.

In a study by Ahmad and Ismail (1996), on the distribution of *Prosopis* species in the Gulf States, *P. cineraria* has been reported as occurring only in Saudi Arabia and Oman.

In most of the Gulf States *Prosopis* species were reported as introductions as avenue or shade trees or for ornamental purposes or as wind breakers or sand stabilizers. However, it is also mentioned that in Oman and Kuwait the species may be used as fodder (Table 2).

Table 2. *Prosopis* species recorded in the Arabian Gulf States.

Gulf States	*Prosopis cineraria*	*Prosopis juliflora*	*Prosopis gland ulosa*	*Prosopis alba*	*Prosopis chilensis*	*Prosopis farcta*	*Prosopis koelziana*
K.S.A	+	+	-	+	+	+	+
Gulf States	*Prosopis cineraria*	*Prosopis juliflora*	*Prosopis gland ulosa*	*Prosopis alba*	*Prosopis chilensis*	*Prosopis farcta*	*Prosopis koelziana*
Kuwait	-	+	+	+	+	-	-
Bahrain	-	+	+	-	-	-	-
U.A.E	-	+	+	-	-	-	-
Qatar	-	+	+	-	-	-	-
Oman*	+	-	-	-	-	-	-

Source: Ahmed & Ismail (1996)

* Wahiba Sands Desert of Oman [HDRA project, 1990].

According to Ahmed & Ismail (1996), *Prosopis* was introduced into Indo-Pakistan area around 1878 and has since spread to other countries. The *Prosopis* species: *P. juliflora* and *P. chilensis* were introduced into the Gulf States around 1950 as avenue trees, sand stabilizers and as hedge plants mainly in farms. One specific tree of *P. juliflora* of 30 m height in Bahrain is regarded as of much older age and possibly introduced by early traders. The introduction of *P. alba* is relatively recent.

Prosopis juliflora was introduced to Sudan from Egypt and S. Africa in 1917 at Shambat, Khartoum N. and in 1928 it was planted on a plot near the Airport and in 1938 at Kilo 5 and in subsequence years at a number of sites of Khartoum Province. Six species in all where introduced but 2 species *P. chilensis* and *P. juliflora* are now beyond control. When the Green Belt was established (1962-64), the meskeet has spread all over the area. Meskeet is now a noxious weed in the Sudan and has invaded all farms of agricultural lands, hafeer pools, roadsides and elsewhere. At present much research focuses on its irradication.

P. farcta is reported as native in Saudi Arabia as it occurs in Wadi Sirhan, Al Qatif and Al Hasa desert and is known locally as Awsay and Yanbout (Ar.). Equally, the two species *P. cineraria* and *P. koelziana* are considered as indigenous trees of Saudi Arabia. *P. farcta*, known as Syrian meskeet is an invasive species. It is widespread locally in many agricultural farms.

There is no mention of *P. cineraria* in the State of Qatar, and the locations now known where it occurs are a few and of isolated individuals which are so far apart and set inland, hence they were not previously encountered by those who studied the flora and the ecology of the country.

Much of the recent interest in *Prosopis* spp. lies in the possibility of their cultivation on barren areas using saline water (Khan *et al.* (1986); Ahmad *et al.* (1994)) and as a multipurpose tree that can withstand aridity [Leakey and Last (1980), Mann and Shankarnaray, (1980), Addison (1990), Sandison and Harison (1991), NETA (1991)].

The population at Al Ghafat (in the vicinity of Rawdat Rashid) is of 8 living individuals and one dead stunt (Plate 1). The trees are apparently quite old and are possibly a relic of a population that existed many years ago. According to the locals at Al Ghafat and Rawdat Rashid, the estimated age of the population is of over 150 years. The trees are apparently not massive. However, the size of a tree is not indicative of its age.

The number of animals in the area can not be given since none were seen resting at the site. However, the amount of droppings of goats, sheep and camels indicate large herds frequent the area. The number of animals resting under the canopy is directly correlated to the crown size of the individual tree. Crown sizes and height are reduced by browsing, shedding, lopping, axing, etc. Camels can reach the crown of medium trees. The neat trim of the trees at Al Ghafat indicate the maximum level of the stretch for the camels' necks. The root/crown ratio of desert trees is large because their crown cover balances their uptake of water. Cutting branches (fodder harvesting) reduces evapo-transpiration by increasing the root-shoot ratio.

Though all the trees are apparently healthy, there was not a single sign that they produce flowers or fruits and not a single fruit or even a seed was encountered even with an intensive search by many.

Attempts to propagate Al Ghaf locally are limited but highly successful. The species can be propagated easily by seeds. Root suckering has also been reported in the species. The trees planted by Sheikh Falah Al Thani in his private farm, vicinity of Al Shahaneya, are younger trees and much smaller in girth, as compared to the mature population at Al Ghafat. The plantation of a large number of trees by the Agricultural Sector was fruitful and many saplings were used in the 2005 progamme trees plantation in schools and colleges.

2.2 Description of Al Ghaf: *Prosopis cineraria* (L.) Druce

Syn: *P. spicigera* L., *P. spicata* Burm.f.; *Mimosa cineraria* L.
Ghaf (Ar.); Plates 2- 5

Erect, single-stemmed tree up to 25 m high with deep penetrating tap root system and few subsurface radiating roots occasionally exposed. Bark dark greyish brown, fissured. Fissures longitudinally set, deep of 1-2 cm depth. Crown wide. New branches reddish with 2-5 small prickles (cf Rose bush), reduced and/or lost with aging. Internodes in young branches 1.4-1.6 cm long. Galls protruding and large, present on some trees. Extra floral nectaries present. Leaves petiolate, stipulate, dull green, alternate, compound bipinnate, of 1-2 pinnae pairs, upper pair usually longer; pinna of 7-12 pairs of leaflets; leaflets ovate oblong, very slightly mucronate, variable in size, 4-14mm long, 2-6 mm wide; petioles short, 7-13 mm long; stipules leafy about 2-3 mm x 2mm, deciduous. Inflorescences spicate, about 10 cm long; flowers small, pale yellow. Fruit slender, cylindrical, slightly torulose / falcate pods, dark reddish brown (turning grey and black with maturity possibly due to fungal infection). Seeds ovoid, oblong, or diamond-shaped, dark brown, about 1/2 cm long, weighing about 0.078gms each (Total weight of 50 seeds =1.78gm). Flowering and fruiting in spring to early summer.

The trees at a private farm were watered by drip irrigation and some carried immature inflorescences with varying lengths and flower buds of up to 120 buds (on April 22nd, 2005). It is unlikely that all these flower buds end in mature pods. However, the ground was covered with old blackened pods.

Habitat and Distribution:

Rare, found as isolated individuals in north and central Qatar; also reported in S. Qatar near the borders with Saudi Arabia. The largest population of only 8 individuals is in a small depression mid a hezoom area at Al Ghafat in the vicinity of Rawdat Rashid. This population ranks as a relic population. The depression at Al Ghafat was covered with a seasonal growth (22/04/05) of a number of species (Most common were : *Aizoon canariense, Stipa capensis, Mollugo cerviana, Eragrostis* sp. *Malva parviflora, Cynodon dactylon, Convolvulus* sp. *Zygophyllum simplex, Chenopodium murale*). There has been at least 8 other locations reported to contain from 1 to 6 trees each. The population at Al Ghafat has the highest number of individuals.

The plant is known to tolerate high temperatures and soil alkalinity. It occurs in sandy depressions and resists drought, heat, grazing, lopping (removal of branches by man to feed his animal stock) but it coppices easily. It is also a refuge to desert birds (wood pigeons, desert larks and sparrows were seen at Al Ghafat and the former with nests) and a resting place mid-day for goats, sheep and camels and other grazing animals. The plants at Al Ghafat harbored many insect species as well as spiders.

There was an obvious heavy infestation of bruchid beetles, ants and termites. The ants are probably attracted to the extra floral nectaries, common on the young vegetative parts. The tree is also reported to contain large amounts of carbohydrates particularly in its bark.

2.3 Similarities and differences between Al Ghaf and other trees or shrubs in the State of Qatar

There is more than a dozen trees and large shrubs in the State of Qatar which are encountered in the wild (Table 3). Five of these belong to the family Mimosaceae and include the two genera *Acacia* and

Prosopis both of which include indigenous and exotic species. The genus *Acacia* is represented by 3 species in the flora of Qatar: *Acacia ehrenbergiana* [Sallam Ar.], *Acacia tortilis* subsp. *tortilis* [Samar Ar.] and *Acacia nilotica* subsp. *indica* [Sunt Ar.; Gard for fruit Ar.].

The genus *Prosopis* is represented by 3 species only: *Prosopis cineraria* (Ghaf Ar.), *Prosopis farcta* (Yanbout Ar.) and *Prosopis juliflora* (Ghuweif Ar.).

Leucaena leucocephala, from the same family, Mimocaceae is an exotic but has now been naturalized. However, as yet, it has not been reported in the wild unlike *Prosopis juliflora*. (Plates 6-8).

Only *Acacia nilotica* subspecies *indica*, *Prosopis juliflora* and *P. farcta* occur in farms either planted or as invasive species. There are only 2 local species of *Ziziphus* and a number of other species have been introduced as avenue and shade trees.

Table 3. Woody taxa in the State of Qatar.

No.	Species	Family	Habit	Distribution
1	*Avicennia marina*	Avicenniaceae	evergreen mangrove	north-eastern coastline
2	*Ephedra foliata*	Ehphedraceae (gymnosperm)	liane	Rawdah depressions (localized)
3	*Cocculus pendulus*	Menispermaceae	liane	Rawdah depressions (localized)
4	*Acacia ehrenbergiana*	Mimosaceae	tree	Rawdah depressions (common)
5	*Acacia tortilis*	Mimosaceae	tree	widespread
6	*Prosopis cineraria*	Mimosaceae	tree	relic (localized)
7.	*Prosopis juliflora*	Mimosaceae	tree	Invasive (widespread)
8	*Prosopis farcta*	Mimosaceae	bush	Invasive (farms)
9	*Lycium shawii*	Solanaceae	bush	Widespread

Table 3. Contd.

No.	Species	Family	Habit	Distribution
10	*Ochradenus baccatus*	Resedaceae	evergreen bush	Disturbed areas
11	*Ziziphus nummularia*	Rhamnaceae	tree	Rawdah depressions (common)
12	*Ziziphus spina-christi*	Rhamnaceae	tree	Rawdah depressions (less common)
13	*Tamarix* spp.	Tamaricaceae	tree	Localized depressions (saline or brackish) ground water
14	*Leucaena leucophylla*	Mimosaceae	tree	Exotic
15	*Pitheclobium dulce*	Mimosaceae	tree	Exotic

2.4 Key to the main genera of trees and shrubs in the State of Qatar (including differences between *Acacia* and *Prosopis*):

Leaves simple:

- Evergreen mangrove trees... *Avicennia*
- Terrestrial trees and shrubs:
  - * Armed plants with spines prickles or thorns:
    - • Leaves palmately- veined, spines one straight and the other recurved.. *Ziziphus*
    - • Leaves pinnately- veined; spines modified branches (with leaves).. *Lycium*
  - * Unarmed lianes or bushes or shrubs:
    - • Bush and shrub:
    - • Bushes; leaves deciduous; flowers yellow .... *Ochradenus*
      - • Manny shrubs; leaves minute; flowers white or pink.. *Tamarix*
    - • Lianes:
    - * Flowering plant .... *Cocculus*
      - * Gymnosperm .... *Ephedra*

Leaves compound:

- Fruit a legume or a lomentum, spines stipular; Inflorescence capitate .... *Acacia*
- Fruit a pod, spines leafy or stipular; inflorescences spicate.. *Prosopis*

2.5 Similarities and differences between the *Prosopis* species occurring locally:

Characters	*Prosopis farcta*	P. *juliflora*	P. *cineraria*
Trunk	Multi- stemmed	Multi - stemmed	Main stem
Height	30-300 cm	3 -8 m	More than 12 m
Leaves	Compound, 3-5 pairs of pinnae 2-6 cm long 8-12 pairs of leaflets	Compound, 1-2 pairs of pinnae	Compound, 1-2 pairs of pinnae, 7-12 pairs of leaflets
Stipules	Stipules leafy, deciduous; prickles present	Stipular spine and no internode prickles	Stipules leafy, deciduous; prickles present
Inflorescences	Spicate, 4-10 cm long	Spicate, 5-10 cm long	Spicate
Fruit	Pods gibbous, stout, dark brown, 5 x 205	Pods long +/-flat, pale yellow 8-24 x 0.8-1.2 cm	Pods long falcate, cylindrical. reddish brown
Soils	Deep alluvial soils	All types of soils including saline soils	Sandy soils
Ranking	Invasive, in farms and arable fields	Invasive, everywhere	Indigenous, localized, rare, relic
Arabic names	Shouk, Kharnoub, Astri, Temour Al Fageera, Yanbout, Shalshlawi	Ghewif, Mesquite, Tamr Abuna, Biskeet	Ghaf

Plate 1. General view of the stand of *Prosopis cineraria* at Al Ghafat.
Courtesy A. Abdel Aziz, 2005.

Plate 2. *Prosopis cineraria* tree at Al Ghafat; note inclination due to wind action
Courtesy A. Abdel Aziz, 2005.

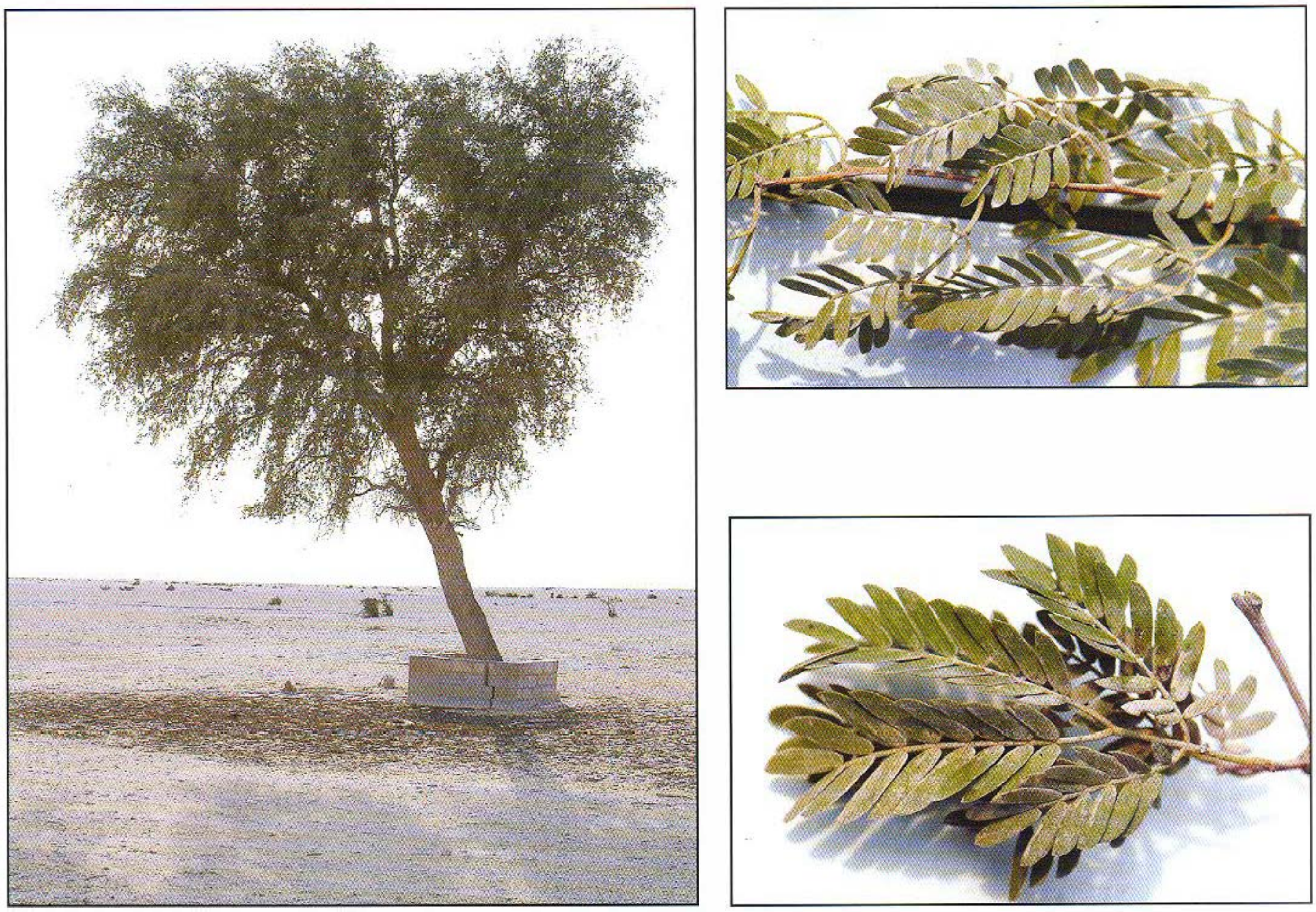

Plate 3. *Prosopis cineraria* at Al Ghafat (left); compound leaves (right).

Pate 4. *Prosopis cineraria* spicate inflorescence (above); fruit pods (below).

Plate 5. *Prosopis cineraria*: above branches with prickles; below bark with fissures.
Courtesy of Amina Al Malki (2005).

Plate 6. *Acacia tortilis* subsp. *tortilis* (short); A. *ehrenbergiana* (tall); in a desert wadi near Saudi Arabia borders.

Plate 7. *Acacia tortilis* subsp. *tortilis* tree (above); capitate inflorescences and twisted pods (below).
Courtesy Dhabia Tamir Al Thani (2005).

Plate 8. Twig of *Acacia nilotica* subsp. *indica* (right) with stipular spines and compound leaves of 2 pairs (left); *Leucaena leucocephala* twig, pod and capitate inflorescence.

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CHAPTER - 3

AUTECOLOGY OF PROSOPIS CINERARIA (L.) DRUCE AT AL GHAFAT AREA, THE STATE OF QATAR

By
Professor Gamal M. Fahmy

3.1 INTRODUCTION

Deserts occupy about 20% of the land surface of the earth (Molles, 1999). The Sahara is a hot desert straddling the Tropic of Cancer. This area, within which the mean annual precipitation is 100 mm or less and the mean annual temperature exceeds 30°C, is one of the hottest regions of the world (Cloudsley-Thompson, 1984). The State of Qatar lies within this vast belt of the Sahara. As in the majority of arid lands, the survival of desert organisms depends on their capacity to maintain a favourable balance between water uptake and water loss under conditions of severe climatic and atmospheric drought (Kassas and Batanouny, 1984). Plants growing and surviving in regions with very limited amounts of precipitation, high temperatures, in soils which are usually poor in organic matter and often saline (sodic) are called xerophytes (Greek *xeros*= dry and *phyton*=a plant) (Fahn and Cutler, 1992).

Clearly, non-succulent perennial dicotyledons constitute the permanent framework of vegetation in the Sahara Desert (Kassas and Batanouny, 1984). Among the non-succulent perennials which are common in the State of Qatar are the shrubs and trees of *Acacia tortilis* and *Ziziphus nummularia* which dominate communities with wide ecological and sociological ranges (Batanouny, 1981). The communities of the above mentioned species abounds and flourish in depressions commonly known as *rawdat*. Such species are also known as phreatophytes (Gibson, 1996), which directly tap abundant surface and subsurface water supplies or moist soils. These species occur along perennial watercourses and in depressions where stored water or the water table is near the surface (Batanouny, 1981; Abulfatih *et al*., 2001). Although, *Prosopis cineraria* is another phreatophyte native to the Gulf States, it is rare and/or in decline in the State of Qatar. It has been selected as the plant of the year 2005 by the programme "a flower each spring" under the auspices of H.H. Shaikha Mozah Bint Nasser Al-Missned, The Consort of H.H. The Emir of the State of Qatar. The programme aims at increasing knowledge of the general public of local plants and enhancing the decision makers about the conservation of endangered species and their habitats.

For a rare species like *Prosopis cineraria* of the present study, the correlation between the biology and the nature of the environment where it lives, as well as, the interrelationships with other living and non-living components, constitute the main themes of the autecological studies. Such knowledge, will determine how the peculiar biology of the species will match the characteristic features of the environment where it lives. Melding the information obtained from natural sciences, including ecology, with the social sciences such as sociology, anthropology, economics, etc., constitute the main focus of the conservation biology (Meffe and Carroll, 1997). Therefore, identification of the conservation measures and the design of management strategies, require enough data and information gained from ecology.

This investigation reports on five different subjects related to the autecology of *P. cineraria*. The study includes the geographical distribution, the tree characteristics, climatic and soil conditions in the specific habitats of *P. cineraria* and finally the structure of the leaflets and its relationship to drought resistance.

3.2 Materials and Methods

3.2.1 Geographical distribution of *Prosopis cineraria*

This was based on the examination of the relevant plant material of *P. cineraria* deposited in the herbarium of the Department of Biological Sciences, Qatar University in addition to the specimens collected from various habitats by Prof. Ekhlas M. Abdel-Bari and the members of the research team of the present biological study. The distribution of the species was further examined in the books of flora, as well as, the vegetation of Qatar (Batanouny, 1981; The Arab Organization for Agricultural Development, 1983; Abulfatih *et al.* 2001). Information provided by the elderly was considered as an additional source on its distribution. Identification of *P. cineraria* was kindly confirmed by Prof. Ekhlas M. Abdel-Bari according to the monograph of Burkart (1976). Identification of the species associated with *P. cineraria* in the study area was according to Batanouny (1981).

3.2.2 The characteristics of *P. cineraria* trees

• Tree height and the angle of slope of the trunk

The height of trees is the sum of crown height and trunk height. The height was measured from photographs of each tree and a scale of a known length. The circumference of the trunk was measured at breast height by a tape measure. The angle of the slope of the trunk to the horizontal position was measured by placing a protractor on the photograph of each tree and measuring the angle of slope of the trunk.

• The crown dimensions and cover

A tape measure was laid down on the ground below the crown of each tree. The length as well as the width across which the crown of each tree extended were used to calculate the crown cover on the ground. The cover was calculated as the product of crown length by the crown width.

3.2.3 Soil characteristics and surface matter of plant litter and animal droppings

• Soil collection and analysis

On the 12th March 2005, five trees of *Prosopis cineraria* at Rawdat Rashid were selected. After the removal of the surface deposits covering the soil, samples of surface soil to 5-cm depth were collected concentrically under each tree. The selection of the sampling locations was similar to the procedure of

Moro *et al.* (1997) and was as follows: (1) around the centre of the subcanopy near the basal insertion of the trunk of each tree (centre canopy soil, CS); (2) half-way between the centre and the edge of the canopy (intermediate canopy soil, IS) and (3) just outside the edge of the canopy (outer canopy soil, OS). All samples were passed through 2-mm sieve to remove stones, litter and animal droppings. Six soil samples were obtained from each site and stored in air tight polyethylene bags. The samples were sent immediately to the laboratories of the ESC (Environment Study Center, Qatar University), for the following soil analyses:

> soil moisture, soil texture (sand, silt and clay fractions), pH, electrical conductivity (EC), organic matter, potassium and phosphorus.

The analyses were performed according to the standard routine procedures followed by the ESC.

• Litter and animal droppings collection

Samples of litter and animal droppings on the soil of the subcaopy of *Prosopis cineraria* trees were collected from the uppermost 1 cm layer covering the soil from an area of 50x50 cm quadrates placed near the centre, halfway between the centre and the edge and just outside the edge of the canopy. The plant material as well as the animal droppings were separated from the other soil components by flotation method. Each collected layer was mixed thoroughly with 2 l distilled water in 5 l glass beaker for 5 min. The material which floated on the water surface consisted of organic matter which has a low density, while the soil components settled down at the bottom of the beaker. The organic fractions were then separated from the water by passing the whole mixture through a 0.5 mm mesh sieve. The separated material was oven dried at 70° C for 48 h till a constant weight was obtained. The dried matter was weighed and separated into fractions as follows: (a) leaflets, (b) rachis of leaves and leafless branches, (c) camels, dung and (d) droppings of other animals. The dry weights of the litter and animal droppings fractions were expressed per 50x50 cm quadrates (0.25 m^2) and per square meter of ground area in each location.

3.2.4 Effects of *Prosopis cineraria* trees on the microclimate and the composition of vegetation

• Microclimate

The microclimatic measurements were conducted on the 19th March 2005 under clear sky conditions starting from 8.00h and ending at 15.00h. On a second field excursion carried on 23rd of April 2005, measurements were conducted at 13.00h. The measurements of soil temperature at 1 cm depth and air temperature at 150 cm height were carried out using an electronic thermometer. The total radiation intensity at ground level was carried out using a luxmeter. The readings of the luxmeter (in lux) were converted to W m^{-2} by dividing by 50 (cf. Williams, 1994). The microclimatic measurements were taken at the three locations from which the soil samples and other studies were performed. The locations were: (1) around the centre of the subcanopy near the basal insertion of the trunk of each tree (centre canopy, C); (2) half-way between the centre and the edge of the canopy (intermediate canopy, I) and (3) just outside the edge of the canopy (outer canopy, O).

• Composition of vegetation

The composition of vegetation in the subcanopy and outside the edge of the canopy was studied by applying the line intercept method (Williams, 1994). Line transects (each 10 m in length) were laid down at the different locations below the trees. The species associated with the trees were collected and identified according to Batanouny (1981). The absolute cover of each species which was present at each location was calculated according to the following formula:

% absolute cover =[total intercept of the species/total length of line]x 100

3.2.5 Structure-Function relationships of the leaflets of *Prosopis cineraria*

3.2.5.1 Investigated species

In order to identify the structural features of the leaves of *P. cineraria* which contribute to their adaptation to the desert conditions, a comparison with *Acacia tortilis*, another leguminous, local drought resistant desert tree was carried out. *Acacia tortilis* was the selected species for "a flower each spring" in 2004. *A. tortilis* is one of the widespread trees in the dry regions of Africa and the Middle East. The structural features of the leaflets of both species characterizing them as drought resistant were further compared to those of *Lens esculenta*, a leguminous plant belonging to a different ecological group (a mesophyte and a crop plant).

3.2.5.2 Sampling and preparations

Ten mature fully sun-exposed leaves were collected at random from five different individuals (two leaves from each individual plant) of each species. The leaves of *P. cineraria* and *A. tortilis* were collected on March 12th , 2005 from the trees growing naturally at Al Ghafat (in the vicinity of Rawdat Rashid). The leaves of *L. esculenta* were obtained form non-flowering individuals which were growing naturally in a garden. Small segments of the leaflets were fixed in glutaraldehyde (4% buffered at pH 7.3 with 0.1 phosphate buffer for 2 hours at room temperature) and postfixed in buffered 2% osmium tetroxide (O'Brien and McCully, 1981) .

For light microscopy, sectioning was carried out with a cryostat; sections were stained with 0.05% Toluidine Blue O in distilled water (Sakai, 1973).

For scanning electron microscopy (SEM), the postfixed samples, were dehydrated in a graded series of acetone, critical point dried and coated with 200 Å of gold-palladium in a Sputter Coater.

For examination of the epidermal cells, the epicuticular wax was removed from leaflets of *P. cineraria* (fixed in glutaraldehyde 4% buffered at pH 7.3 with 0.1 phosphate buffer) by washing in chloroform for 1 min (Reicosky and Hanover, 1978). The leaflets were then postfixed in osmium tetroxide and processed as indicated before.

The samples were viewed with a Philips XL-30 scanning electron microscope at 10 kv at the Laboratory of Electron Microscopy, Unit of Central Laboratories at Qatar University.

3.2.5.3 Measurements

The area of leaflets and leaf (one side only) was obtained by weighing their tracings on high quality paper, and comparing them with a paper of known area and weight. Optical micrometers (linear and square) were used to measure the densities (number per mm^2) of stomata and the length of guard cells in epidermal strips. The number of palisade cells per unit area was obtained from paradermal sections of leaflets at adaxial (upper) and abaxial (lower) sides. The ratio of palisade cell area/leaflet area ($=A_{pal}/A$) was determined from paradermal sections (obtained for light microscopy and for SEM) taken from both sides (adaxial and abaxial) of the leaflets of *P. cineraria* and *A. tortilis* (leaflets of *L. esculenta* have only adaxial palisade). Cell surface area of palisade (A_{pal}) was calculated assuming that the cells are cylindrical (Nobel *et al.*, 1975; Fahmy, 1997). The thickness of epidermis, palisade and spongy tissues, as well as, the depth of stomatal pores were measured from transactions. The surface features of the cuticle were obtained from examinations of SEM photomicrographs.

The data collected includes means and the standard deviations of five replicates obtained from measurements performed on five leaflets sampled at random from the ten collected leaves of each species.

3.3 Results and Discussion

3.3.1 Climate

The climate of Qatar is characterized by scanty rainfall, high temperatures, hot dry summer winds and high relative humidity for the greater part of the year. Several studies (FAO, 1981; Halcrow-Balfour, 1981; El Majid, 1983; Babikir, 1986) estimate that the northern part of Qatar, where most depressions are located, receives an average of about 30-60% more rainfall than southern Qatar. The climate diagrams (Babikir, 1986), indicate that the extent of the rainy season, as well as rainfall amounts, decrease southwards. The soil moisture, which is a reflection of both soil texture and climate (particularly rainfall and evaporation), is probably the major factor causing spatial variations in the vegetation patterns in the northern, central and southern depressions in Qatar.

3.3.2 Geographical distribution of *Prosopis cineraria*

The only citation that *Prosopis cineraria* is included in the flora of Qatar is in a book published by the Arab Organization for Agricultural Development (AOAD, 1983). Batanouny (1981) reported *P. juliflora* as a cultivated tree in Doha streets. Recently, Al-Easa *et al.* (2003) reported that the genus *Prosopis* is not indigenous to Qatar. Based on field observations in the different habitats in Qatar and on the botanical collections, as well as, the local information provided by the elderly, it is now clear that *Prosopis cineraria* is a rare tree.

P. cineraria trees are found as small populations of few individuals at Rawdat Rashid-not more than 8 trees- and fewer individuals in north, central, as well as in the southern part of Qatar near Abu Samra (Plate 1).

All *Prosopis* species survive in areas with low annual rainfall or very lengthy dry periods. The existence of two root systems: a tap root to reach groundwater and lateral subsurface roots to make use of the scanty infrequent precipitation, puts *Prosopis* species firmly in the category of phreatophytes. These plants are non-succulent trees that require deep roots to tap moist soil the year whole round (Mooney *et al.*, 1977).

The specific habitats occupied by the small populations of *P. cineraria* are depressions referred to as *rawdat* (sing. *rawdah*). Two thirds of the land surface of the state of Qatar is made up of 850 depressions which lie below the surrounding land surface (Figure. 1) at a depth ranging from few meters to as much as 20 m (Batanouny, 1981; Alsharhan *et al.*, 2001). A *rawdah* ranges from few hundred meters to two to three kilometers in diameter. The depressions are surface expressions of shallow collapse structures at depth. Direct recharge of water to the depressions may occur during some particularly heavy storms, but most recharge is indirect through runoff, from surrounding catchment areas. The most important source of fresh and potable water, is obtained from freshwater lens floating on brackish and saline water.

The groundwater supply to the depressions in Qatar depends on three hydrogeological zones: northern, southern and southwestern (Al-Hajari, 1990; Alsharhan *et al.*, 2001). The northern hydrogeological zone or province has an area of 2,180 km^2 and is the most important source of fresh and potable groundwater in the State of Qatar (Figure 1).

The total dissolved solids of the groundwater is relatively low in the north central part of the country, and accordingly large number of farms which depend on such water were successfully developed. The southern hydrogeological zone occurs beneath more than half of Qatar and it is somewhat of less importance than the one to the north. The second low content of soluble salts is encountered in the south central region of Qatar, where second degree farms were developed (Abulfatih *et al.*, 2001).

The groundwater is 15-35 m deep in the north central region and 15-70 m deep in the south central region.

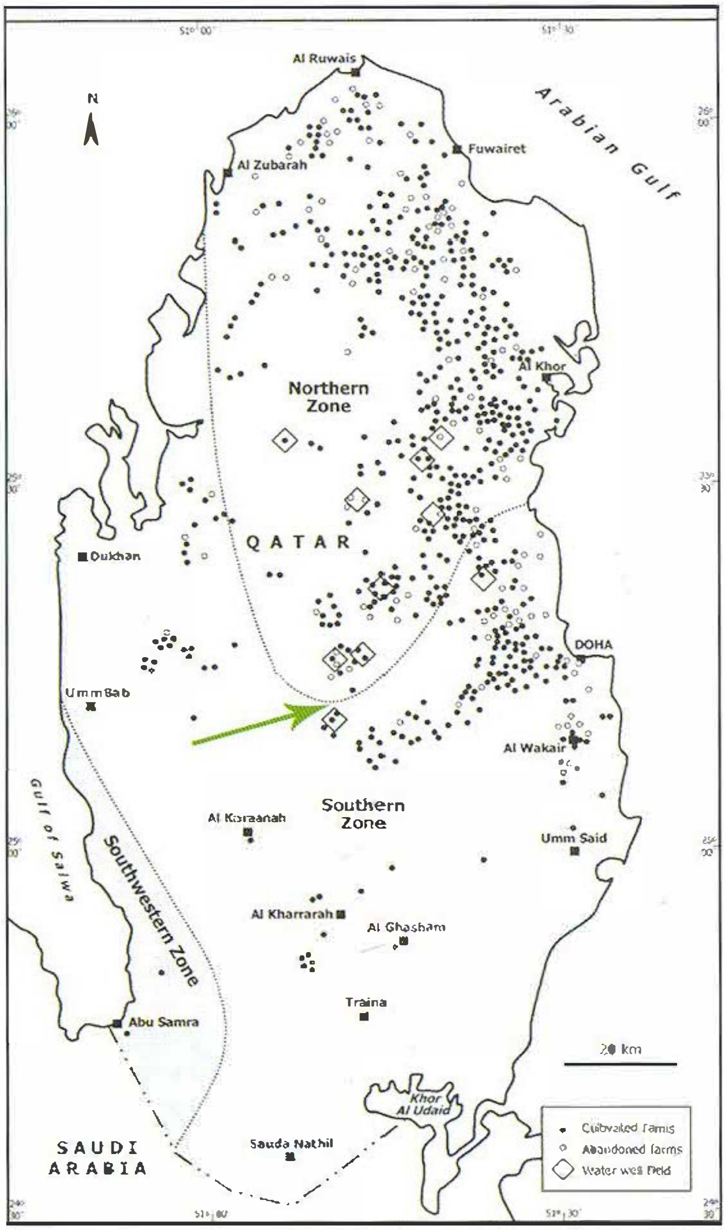
High salinity in groundwater is attributed in part to the intrusion of the underlying saline water as a result of over-extraction of the ground water for agriculture and industry.

Figure 1 indicates that Rawdat Rashid lies within the southern periphery of the northern hydrogeological zone - a location suitable for the growth of phreatophytes- where the ground water is less saline and is available to the deep vertical roots of *P. cineraria* and other trees and shurbs such as *Acacia tortilis* (Samr) and *Lycium shawii* (Awsaj).

3.3.3 *Prosopis cineraria* population in the study area of Rawdat Rashid

Plate 1. shows a population of *P. cineraria* growing at Al Ghafat. It is evident that the population is of 8 individual trees only. The area is a slight depression with some large rock fragments scattered on the surface soil deposits. The green patches seen on Plate 1 are dense growth of annuals growing in this small depression. The dwarf under-shrubs in the foreground and in the background of the photo are *Lycium shawii* (Awsaj) heavily browsed by camels.

Exploitation of groundwater for agricultural and domestic uses resulted in the decline of the water levels in the earlier wells and increased the salinity of water. An abandoned well in the vicinity of the population of *P. cineraria* trees at Al Ghafat has an estimated depth of about 50 m (Plate 2).



Source : Modified by Alsharhan *et al.* 2001 from Alhajari, 1990

Figure 1 The hydrogeologic zones, farms, and water wells in Qatar. The green arrow indicates the location of Rawdat Rashid where *Prosopis cineraria* population (Ghafat) grows [April 23, 2005].

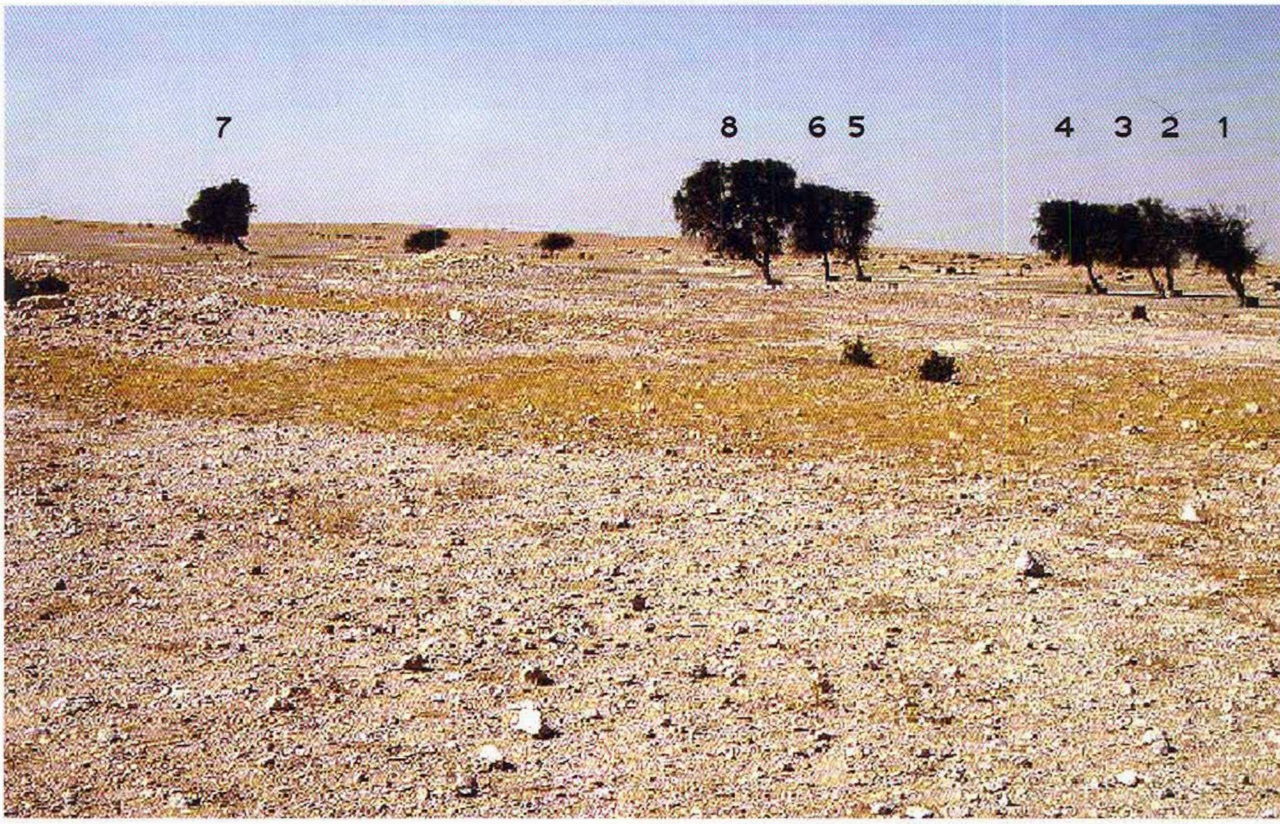


Plate 1. An overview of the population of 8 individual trees of *Prosopis cineraria* at Al Ghafat area at Rawdat Rashid. [April 23, 2005]. The number of each individual is shown above the tree.

3.3.4 Soil

The soil at Rawdat Rashid occupies a natural depression which is nearly flat and filled with younger sediments. These sediments have been washed down from the surrounding areas and include fine soil such as calcareous loam, clay loam, sandy loam, sandy and clay loam, overlain by limestone boulders of various sizes or outcrops of limestone beds. Generally rawdahs are occupied by alluvial soils and are found scattered mainly in the northern and central parts of Qatar. *Rawdat* soils are hardly less than 30 cm deep but may reach 150 cm depth and are considered the most suitable for agriculture. Naturally, they support trees, shrubs, perennial grasses and other seasonal and ephemeral species.

3.3.5 The Characteristics of *Prosopis cineraria* Trees

3.3.5.1 Tree Size

The tree sizes vary within the eight individuals of the population. The tree height ranges from 8.47 m (tree 2) to 14.6 m (tree 7). The trunk is relatively short and ranges from 2.57 m (tree 7) to 3.37

Plate 2. Prof. Ekhlas M. M. Abdel-Bari, Dr. Mahmoud Saleh Abdel-Dayem (left) and Mr. Soud Helmy (right) attempting to determine the depth of an abandoned well in the vicinity of *Prosopis cineraria* population at Rawdat Rashid. [April 23, 2005].

m (tree 1) and in four trees it was directed laterally forming flagging. The heights of *P. cineraria* trees reported in the present investigation are consistent with the heights reported for other *Prosopis* species. For example, on favourable sites with adequate moisture, *P. pallida* trees may attain a height of 20 m (Burkart, 1976; Little and Skolmen, 1989) while *P. juliflora* may normally reach a maximum height of 12 m (Burkart, 1976). Trees of 20 m height have also been reported for trees growing in favourable conditions (Singh and Singh, 1993). Table 1 summerizes the measured parameters of the 8 trees of *P. cineraria* population at Al Ghafat.

Table 1. Dimensions of the 8 trees which constitute the entire population of *Prosopis cineraria* at Rawdat Rashid. All parameters are in meters except crown cover which is in m^2. T1:T8 are the numbers of trees from 1 to 8. Each value is an average of 3 determinations. April 23, 2005.

Parameter	T1	T2	T3	T4	T5	T6	T7	T8
Height	9.42	8.47	11.24	12.62	10.21	10.00	14.62	13.47
Trunk length	3.37	3.11	3.22	3.41	2.92	3.06	2.57	2.70
Trunk Circumference	2.35	1.40	1.60	1.63	1.80	1.58	2.30	2.20
Crown Heigh	6.06	5.36	8.29	9.20	7.29	6.93	12.04	10.79
Crown Width	8.80	7.80	9.50	10.40	10.90	10.6	12.20	12.70
Crown Length	9.70	8.40	10.70	12.30	12.10	12.60	16.50	15.10
Crown Cover (m^2)	85.36	65.52	101.55	127.92	131.89	133.56	201.3	191.77

The lateral extension or flagging of the crown results in a quadrangular shadow on the ground which has a definite area. This area depends on the length and width of each crown outline. This feature, together with the obliqueness of the trunk possibly creates significant shade in the subcanopy area below each tree. This subcanopy zone is called "the intermediate zone" since it is located between the tree trunk zone and the outer zone, i.e the area not covered by the crown (Plate 3).

The crown cover varies considerably among the individuals of the population. It ranged from 83.36 to 201.30 m^2 in trees 1 and 7, respectively (Table 1).

Information gathered from the locals residing Rawdat Rashid gave an estimated age of 100-150 years for the *P. cineraria* population. The observed variations of the sizes of trees are possibly induced by environmental variables prevailing in the Al Ghafat area. Studies have indicated that thin soils, presence of hard pan, persistent wind, browsing and insect infestations induce the formation of smaller trees. Similar conclusions have been drawn by Pasiecznik *et al.* (2001).

Plate 3. *Prosopis cineraria* tree number 7 at Rawdat Rashid. [April 23, 2005]. Tree height is 14.62 m and the crown covers 201.3 m^2 of the ground surface. Note the large shaded area in the subcanopy and the lower branches which originate from the basal part of the crown are leafless, dry and were found heavily infested by boring insects.

3.3.5.2 Tree form

The slope of the trunk of each tree to the horizontal position of the ground level revealed that the angles of slope of the trunks of trees 3, 4, 5 and 6 ranged between 80 to 90° to the horizontal position. On the contrary, the trunks of the trees 1, 2, 7 and 8 had low angles to the horizontal position . The most oblique trunk was that of tree 7 which had an angle of 50° to the horizontal (Plate 3).The branches of such trees are permanently swept to the leeward side. This deformity possibly indicates that the crowns and trunks of the trees are affected by the action and the speed of wind. This permanent shape of the crowns and trunks is known as flagging. Such trees are called "flag trees" (Nobel, 1981).

The obliqueness of the trunks of the flag trees made their crown more closer to the ground. Such a feature makes the trees more accessible to browsing camels. This is supported from the data of the high amount of litter fall, as well as, camels dung which were observed on the subcanopy.

It is assumed that when *P. cineraria* trees were young, the continuous browsing by camels and goats may have resulted in the deformation and obliqueness of their trunks which now appear in the present flag form (Plate 3). This assumption may explain that the formation of flag trees may not only be caused by wind action, but also by browsing.

3.3.6 Soil characteristics and surface matter of plant litter and animal droppings

The soil supporting *Prosopis cineraria* trees consists of fine textured deposits which may be shallow or deep. On the other hand, in depressions distant from the subcanopy, the surface deposits are shallow and large rock fragments of the bedrock usually outcrop on the surface. In such locations, trees of *Acacia tortilis* and shrubs of *Lycium shawii* are common associates.

The surface soil from the three locations (CS, IS and OS see 3.2.3 for abbreviation) were coarse-textured and had a pH of approximately neutral and low electrical conductivity (Table 2).

The percentages of soil moisture and total organic carbon were as expected, higher in soils from the centre and intermediate locations than from the outer locations. The electrical conductivity of the soil extract from the outer location was higher (2.64 mS cm^{-1}) than in the intermediate (0.72 mS cm^{-1}) and centre positions (0.30 mS cm^{-1}). The same pattern occurred in the case of phosphorus. However, the potassium content in the intermediate position (13.3 mg% oven dry soil) was much higher than in both the outer and the centre positions. The clay content of the soil from the centre location was much higher (6 % oven dry soil) than in the other two locations (2.5% oven dry soil). The observed high content of organic matter, soil nutrients, clay and moisture in the subcanopy locations (centre and intermediate positions) of *Prosopis cineraria* trees of this investigation clearly affect the richness of the below canopy sites. Such richness of locations possibly created fertility patches. Organic matter, N and other soil chemical variables are often higher under tree and shrub canopies than in the gaps in semiarid and arid zones such as African savannahs (Bernhard-Reversat, 1982) and North American grasslands and deserts (Halvorson *et al.*, 1994).

At the intermediate locations of the subcanopy of *Prosopis cineraria*, the dry weights of litter as well as the camels' dung and droppings of other animals (Plate 4) were higher than in the other two locations (Figure.2). An order of magnitude of the decrease in the organic surface deposits covering the soil was as follows: intermediate location> centre location> outer location.

Table 2. Characteristics of the soil (0-5 cm depth) collected from three positions in the subcanopy of *P. cineraria* trees at Rawdat Rashid. Each value is the average of three samples obtained from three trees. The standard deviations are between brackets. March 2005.

Characters	Positions		
	Centre	Intermediate	Outer
Moisture (%)	2.28 (0.5)	1.41 (0.1)	1.3 (0.07)
pH	8 (0.3)	7.94 (0.4)	7.93 (0.2)
EC (mS cm^{-1})	0.3 (0.01)	0.72 (0.02)	2.64 (0.12)
Phosphorus (mg 100 g^{-1} dry soil)	5.2 (0.3)	4.9 (0.4)	6.45 (0.4)
Potassium (mg 100 g^{-1} dry soil)	3.35 (0.21)	13.3 (0.8)	4.1 (0.3)
Sand (%)	87.5 (6.1)	90.5 (8.2)	91 (7.9)
Silt (%)	6.5 (0.4)	7 (0.5)	6.5 (0.7)
Clay (%)	6 (0.5)	2.5 (0.1)	2.5 (0.2)
Total organic carbon (%)	1.02 (0.01)	0.74 (0.05)	0.43 (0.03)

(%) Expressed as g per 100 g oven dry soil

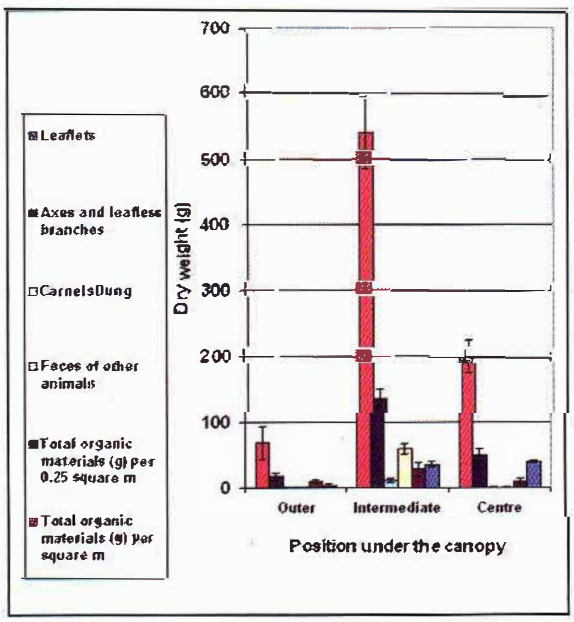


Figure 2. Dry weight (g) of litter fractions, camels' dung and droppings of other animals collected from 50x50 cm quadrates at three positions under *Prosopis cineraria* trees.[Each value is an average of four determinations]. The vertical lines are the standard deviations of the means.

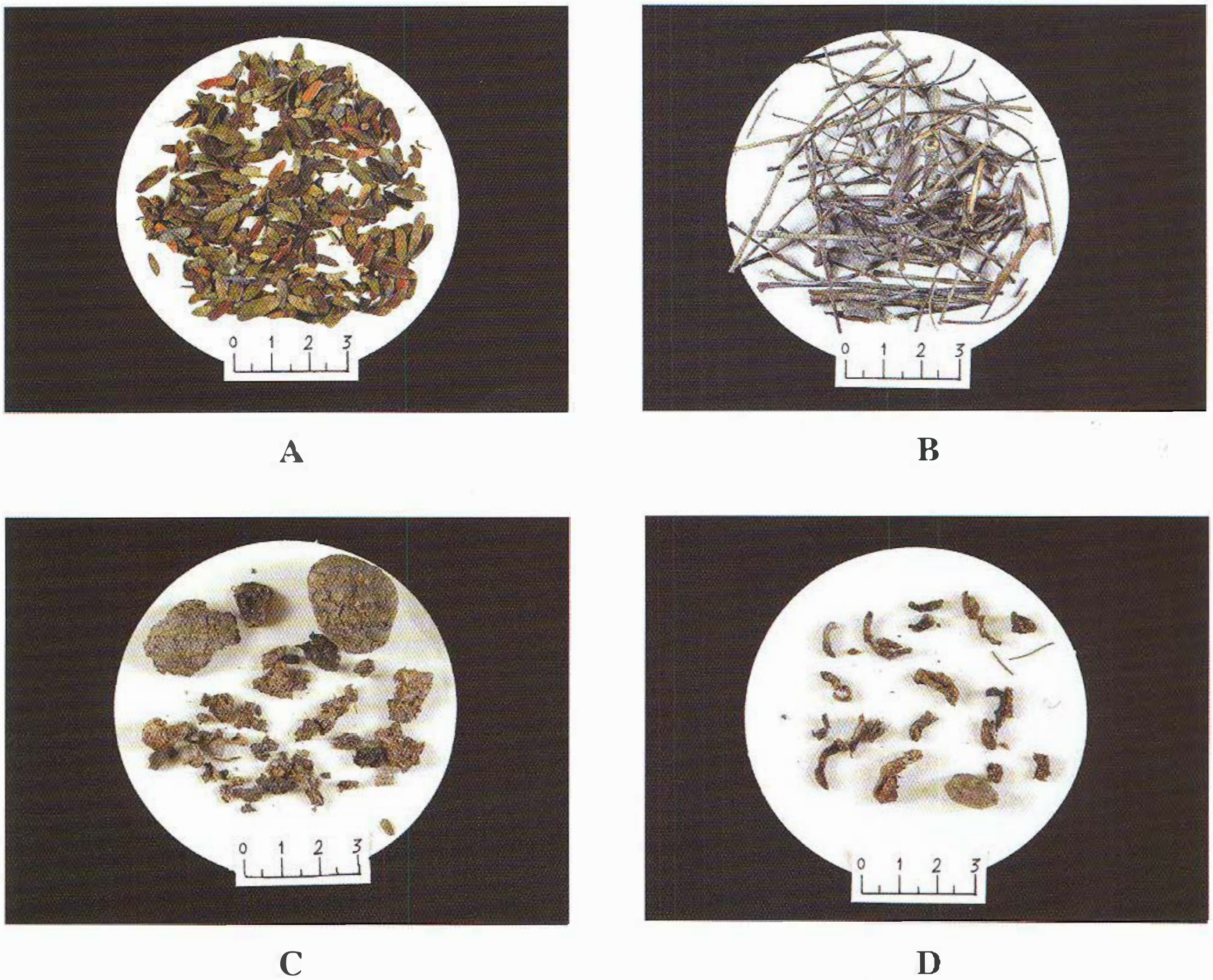


Plate 4. Litter fractions, camels' dung and droppings of other animals present on the soil collected from the intermediate position below the crown of *Prosopis cineraria* trees at Rawdat Rashid. April 23,2005. **A**=leaflets, **B**= axes of leaves and leafless branches, **C**=camels' dung, **D**=droppings of other animals

The total dry weight of both litter and animal droppings (including camels' dung) amounted to 540.7 g m^{-2} at the intermediate location and decreased to 200 g m^{-2} (=37% of the intermediate location) in the centre position and to 68.7 g m^{-2} (=12.5% of the intermediate location) at the outer position of the canopy.

At the intermediate position, camel's dung constituted the largest fraction of the organic matter deposited on the soil. This is mainly attributed to the presence of camels which excrete dung during their visits to the tree for browsing and/or for resting under shade in the subcanopy area. Other herbivorous animals that may feed on the broken tree branches which had fallen during the browsing of camels and/or their stay under shade, may visit the tree subcaopy area. *P. cineraria* trees may provide a substrate to small mammals for climbing or to birds for perching. The tree supports a diverse insect fauna in the different microhabitats of the subcanopy and outside the canopy. Studies have indicated that all *Prosopis* species support insect populations that are a source of food for higher trophic levels (Pasiecznik *et al.*, 2001).This explains the occurrence of different forms of droppings among the organic matter collected from the soil surface of the intermediate and the outer locations of the subcanopy. (Plate 4, and Figure 2).

The presence of a high content of animal droppings together with the already existing soil chemical nutrients and clay in the intermediate subcanopy positions possibly increases the enrichment of the fertility patches. One of the best-documented spatial patterns of nutrient distributions in arid and semiarid ecosystems are the "islands of fertility" associated with shrubs and trees (Garcia-Moya and Mckeel, 1970; Charley and West, 1975; Schlesinger *et al.*, 1996; Whitford, 2002). The previous researchers considered that the fecal deposition on the soil surface is one of the factors which increases the accumulation of nutrients beneath shrubs and trees.

3.3.7 Effects of *Prosopis cineraria* trees on the microclimate and the composition of vegetation

3.3.7.1 Microclimate

The broad crown and the permanent greening of *Prosopis cineraria* trees create different microhabitats in the subcanopy. Figures 3, 4 and 5 show some climatic factors in the different locations of the subcanopy and outside the subcanopy. There was a characteristic diurnal variations of the climatic factors measured. Air temperature (Figure. 3), soil temperature (Figure. 4) and light intensity

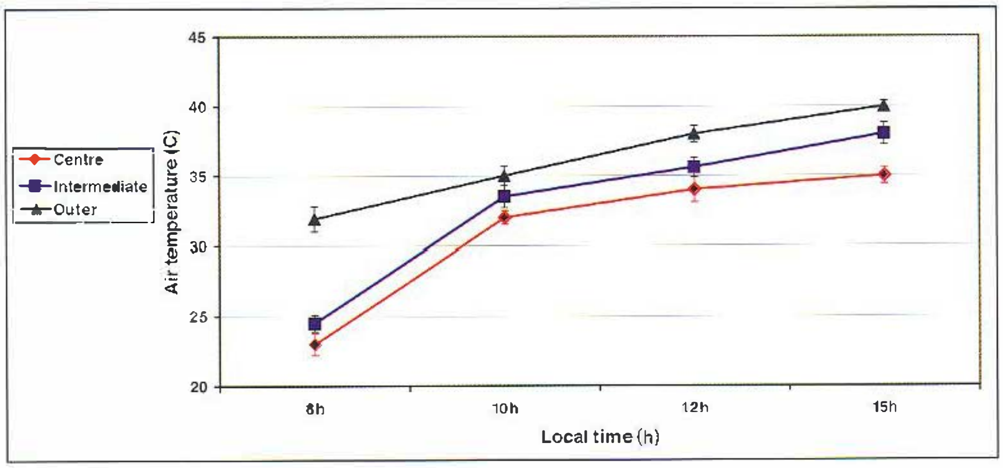


Figure 3. Variations of air temperature in three locations under *Prosopis cineraria* trees. March 19, 2005. Each value is the mean of three determinations. Vertical bars denote standard deviations.

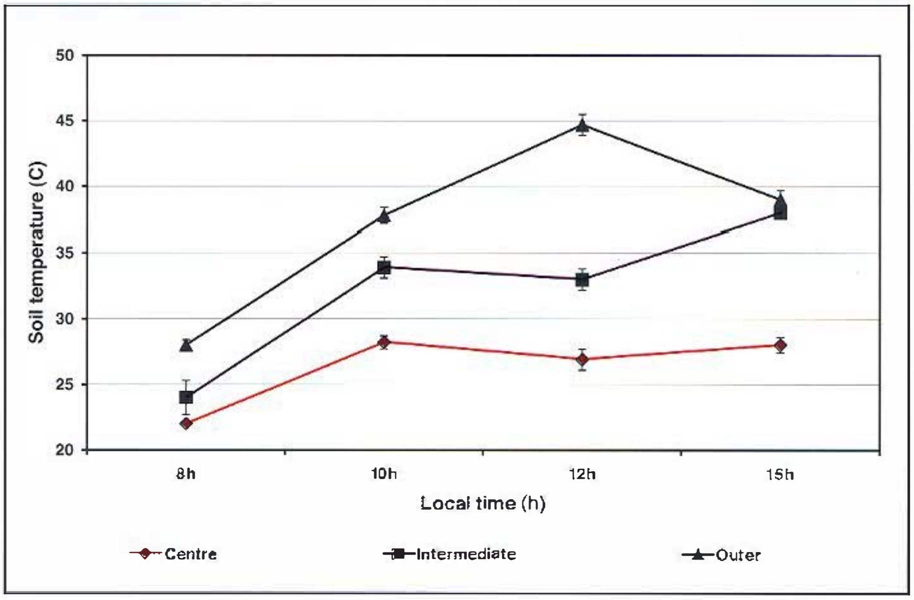


Figure 4. Variations of soil temperature in three locations under *Prosopis cineraria* trees. March 19, 2005. Each value is the averages of 3 determinations.Vertical bars denote standard deviations.

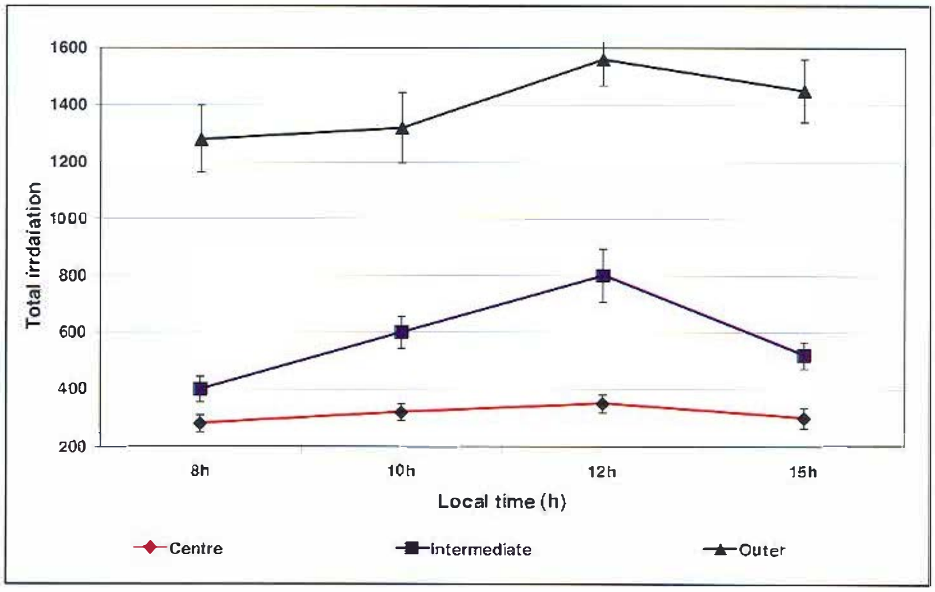


Figure 5. Variations of total irradiation (W m^{-2}) in three locations under *Prosopis cineraria* trees. March 19, 2005. Each value is the average of 3 determinations. Vertical bars denote standard deviations.

(Figure. 5) decreased towards the centre of the canopy. The lowest values of these climatic elements occurred during the morning time (at 8.00h).The climatic conditions in the intermediate positions of the subcanopy were milder than those in the outer location. For example, at 12.00h, the air temperature ranged from 34 to 38°C in the centre and in the outer locations of the subcanopy, respectively. Likewise, the soil temperature ranged from 26.9 to 44.7°C in the same positions, respectively. The midday values of the climatic measurements were higher than the values obtained in the morning.

The importance of the broad crowns of *P. cineraria* in producing shade and reducing soil and air temperature was further supported from the climatic data measured on April 23, 2005, i.e. after about one month from the diurnal measurements shown above. Figure. 6 shows that the soil temperature at 1 cm depth in the outer location of the canopy was 52.3°C which was about 1.4 times the temperature in the centre and in the intermediate positions of the subcanopy. The same trend occurred in the light intensity which was higher in the outer locations (=1720 W m^{-2}) and decreased towards the centre of the canopy (=160 W m^{-2}).

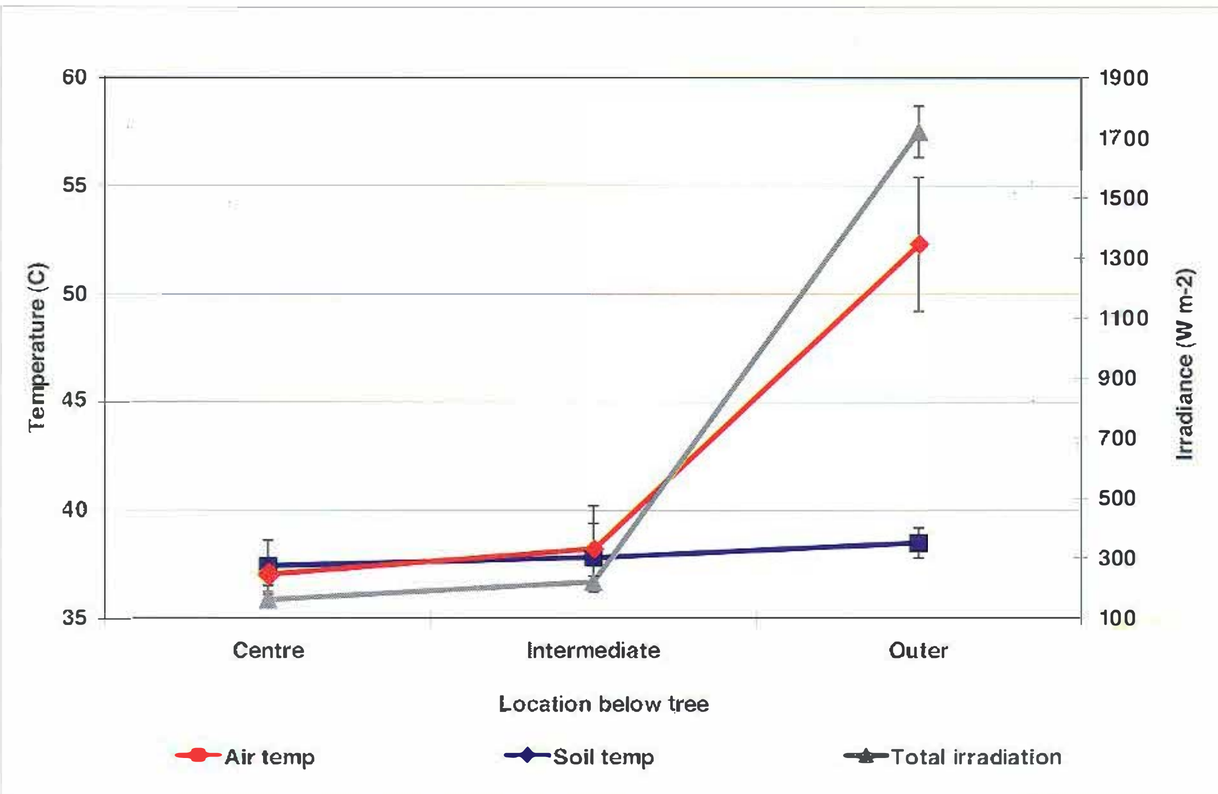


Figure 6. The temperatures of air and soil surface and the total irradiation (W m^{-2}) at midday time in three locations below *Prosopis cineraria* trees. April 23, 2005. Vertical bars are the standrad deviations.

It is therefore apparent that *P. cineraria* trees provide shelter and ameliorate the microclimate in the subcanopy. The shade possibly limits the plant growth in the subcanopy. This feature can be explained from the data of the line transect which was laid out in the different locations below and outside the crown of the trees.

3.3.7.2 Composition of vegetation

The data shown in Table 3 indicate that 9 species were present as annuals growing in the different positions (microhabitats) under the canopy. These species belong to 8 families. The lowest values of the total cover of all species were recorded in the centre (1.6%) and in the intermediate locations (6.6%) under the crown. As we reached the outer position outside the canopy, there was an increase

Plate 5. *Aizoon canariense* is the most common plant growing in all locations under the canopy of *Prosopis cineraria* trees at Rawdat Rashid. March 2005.

in the number of species and the cover values (total plant cover=39%). It is worthy to indicate that *Aizoon canariense* (Plate 5) had the highest cover (Table 3).

Table 3. Absolute % cover of annual species growing in three locations under the tree of *Prosopis cineraria*. March, 2005. Cover was measured by the line intercept method. Each value is an average obtained from three trees. The numbers between brackets are the standard deviations of the means.

Species	Arabic name	Family	Centre	Intermediate	Outer
Aizoon canariense L.	جفنه	Aizoaceae	1(0.02)	2.7(0.3)	26.2(1.8)
Chenopodium murale L.	صمغة ريح	Chenopodiaceae	0	0.2(0.01)	0.5(0.03)
Eragrostis cilianensis (All.) F. T. Hubb	تيراب	Gramineae	0	0	1(0.01)
Launaea nudicaulis (L.) Hook. F.	حوا	Compositae	0	2.5(0.3)	3(0.04)
Malva parviflora L.	خبيزه	Malvaceae	0.5(0.03)	0.5(0.03)	0.8(0.06)
Rumex vesicarius L.	حميض	Polygonaceae	0	0	0.5(0.03)
Spergula fallax (Lowe) E. L. Krause	دفيقة	Caryophyllaceae	0.1(0.0)	0.1(0.02)	6(0.8)
Stipagrostis plumosa (L.) Munro ex. T. Anderson	هلتا	Gramineae	0	0.6(0.07)	1(0.02)
Tribulus terristris L.	جاثا / قطب	Zygophyllaceae	0	0.3(0.02)	0
Total Cover			1.6 (0.05)	6.9 (1.02)	39 (2.79)

The scarcity of understorey species observed in the centre (total cover =1.6%) and in the intermediate (total cover =6.9%) positions of the subcanopy lead to the conclusion that the shade conditions created by the canopies restrict the growth of understorey plants. The occurrence of *Aizoon canariense* in the three locations under the trees indicate that this species has a wide range of tolerance to the microhabitat conditions of each location. Likewise, *Spergula fallax* showed similar pattern to *Aizoon* but with much lower cover values.

Prosopis trees have important effects on other neighboring vascular plants throughout the Americas via the shelter offered, amelioration of the microclimate and some possible negative allelopathic effects (Pasiecznik *et al.*, 2001). Naturally, we can not ignore the interactions between *Prosopis cineraria* trees and the associating microorganisms as well as the insect fauna. The investigation of the above mentioned effects have been undertaken in subsequent parts of this study .

3.3.8 Structure-function relationships of the leaflets of *Prosopis cineraria*

3.3.8.1 Morphology and surface area of leaves

Like the majority of the members of the Leguminosae, the leaves of *P. cineraria*, *A. tortilis* (family: Mimosaceae) and *L. esculenta* (family: Fabaceae) are compound with prominent petioles. In *Prosopis* and *Acacia*, the leaf is bipinnate, while in *Lens* the leaf is imparipinnate. Despite both *Prosopis* and *Acacia* are desert legumes with microphyllous leaves (Levitt, 1980; Gibson, 1996), the former has larger leaf areas than the later (Plate 6 and Table 4). Moreover, *Prosopis* and *Acacia* display narrower leaflets than those of *Lens* which is a mesophytic species. Apparently, the mesophytic category of *Lens* does not imply that it must have the highest leaf area. The largest leaf area of *Prosopis* is attributed to the presence of a large number of leaflets but *Lens* has the highest leaflet area in comparison to *Prosopis* and *Acacia* (Table 4). Both desert and Mediterranean plants mostly have small leaves (Pyykko, 1966). This feature is prominent in *Prosopis* and *Acacia* in the present study. The narrow leaflets have thinner air boundary layers, maximizing leaf temperature closely (or lower than) the ambient air temperature (Lewis, 1972; Nobel *et al.*, 1975). This ensures moderate to high rates of carbon assimilation for high biomass accumulation (Ludwig, 1987) without substantial transpiration cooling costs (Gibson, 1996).

3.3.8.2 The epidermal tissue system

The form and distribution of the epicuticular waxes differ markedly between the species investigated. Heavy crystalline wax deposits are present on the leaflets of *Prosopis* (Plates 7, 8 and 9). The wax deposits covering the leaflets of *Acacia* (Plates 10 and 11) are heavy and appear as platelets on the epidermal cells as well as the guard cells (Plate 11). *Lens* leaflets (Plate 12) have the least deposits of thin platelets (Plate 13) which are restricted to the epidermal cells and absent on the outer surface of the guard cells.

The adaxial (upper) surfaces of the leaflets investigated have deeper stomatal pores than the abaxial ones. The stomatal pore depth ranges from 10.1 µm in *Lens* to 24 µm in *Prosopis* (Figure. 7, Plates 14, 15, 16 and 17). The stomatal pore depths of *Acacia* show intermediate values (ranges from 12.5 µm to 15.2 µm on the lower and upper surfaces, respectively). The sunken nature of the stomata of *Prosopis* is apparent after the removal of the wax deposits by the action of chloroform (Plates 16 and 17). The thickness of the outer walls of the adaxial epidermal cells of all the species investigated is higher than those on the abaxial side (Table 4). The highest thickness was recorded in *Prosopis* (Table 4, Plate 15) followed by *Acacia*.

Table 4. Leaf areas and some anatomical characteristics of *Prosopis cineraria*, *Acacia tortilis* and *Lens esculenta*. Values are means followed by standard deviations of 5 measurements taken from five leaflets sampled from five individuals. March 2005.

Character		*Prosopis*	*Acacia*	*Lens*
Leaflet width (mm)		2.5 (0.1)	0.52 (0.03)	5.3 (0.41)
Area of one leaflet (mm^2 of one side)		20 (1.3)	0.73 (0.1)	50 (4.2)
Area of one leaf (mm^2 of one side)		1200(114)	116.8(10.3)	300(22.6)
Guard cell length (µm)	upper side	32.5 (1.4)	26.5 (2.1)	25.3 (1.7)
	lower side	30.3(2)	22.4 (1.8)	28.5 (1.2)
Thickness of outer wall of epidermis (µm)	upper side	11.3 (1.4)	8.5 (0.6)	2.5 (0.3)
	lower side	8.7 (0.7)	7.6 (0.5)	1.9 (0.2)
Thickness of epidermis (µm)	upper side	42.1 (5.1)	54.7(4.6)	25 (1.2)
	lower side	40.7 (4.2)	45.2 (2.8)	20 (1.0)
Thickness of lamina (µm)		410.3 (28)	353 (38)	150 (12)
Thickness of palisade tissue (µm)	upper side	154 (11)	108 (8.7)	45 (3.8)
	lower side	102 (9.5)	92 (7)	0.0
Total *Apal/A* (of upper and lower sides)		66.5 (6.2)	26.6 (2.2)	10.8 (2.0)

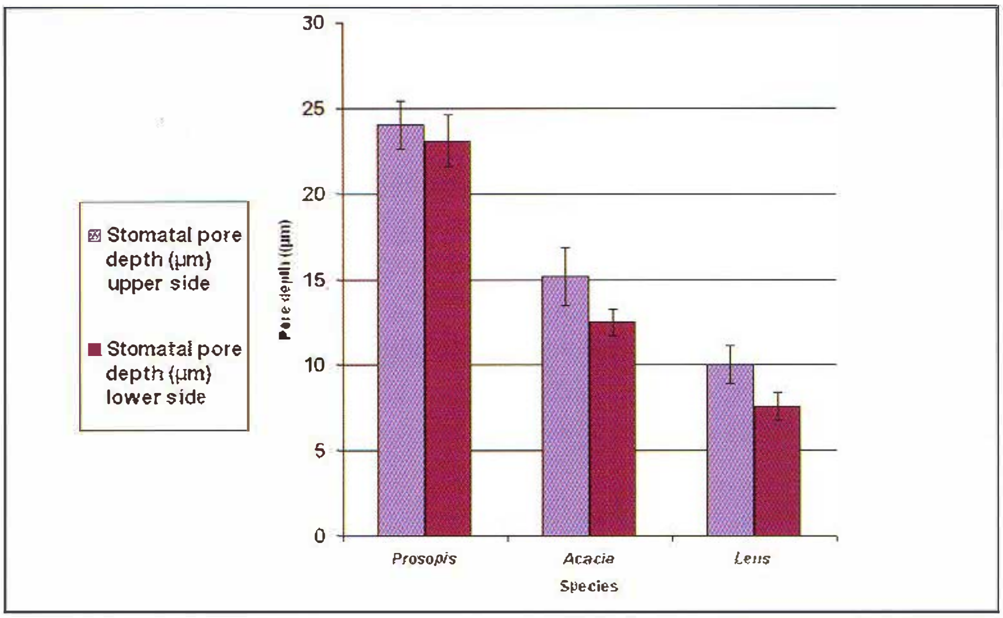


Figure 7. Stomatal pore depth (µm) on upper and lower surfaces of *P. cineraria, A. tortilis* and *L. esculenta* leaflets. Vertical bars are the standard deviations.

Many desert plants have thick cuticles and thick outer epidermal walls (Fahn and Cutler, 1992). The importance of the cuticle for the plant's life in arid regions is apparent when water stress increases. Under such condition most stomata are almost closed (Levitt, 1980) and the main pathway for the transpiration is then through the cuticle. Relatively little gas diffusion occurs through epidermal cells of leaves or stems when their tangential walls are impregnated with cutin - a water repellent wax. The presence of thick outer wall of the epidermis in both *Prosopis* and *Acacia* may possibly results in the reduction of cuticular transpiration in comparison to *Lens* which has a low density of wax deposits and a thinner outer wall of epidermal cells (Table 4).

Dense epicuticular wax on the epidermal cells of both *Prosopis* and *Acacia* possibly has a relationship to the observed greenish grey colour of their leaflets. Such colour may indicate special spectral properties. Ricosky and Hanover (1978) state that the reflective properties of epicuticular waxes of glaucous *Picea pungens* leaves reduce the energy that is absorbed by the leaf and result in reduction of leaf temperature. It is also concluded that *Prosopis* will be superior to *Acacia* with regard to the water retaining features since the sunken stomata of *Prosopis* are further blocked with wax deposits. In their studies on 28 South American species of the genus *Prosopis*, Vilela and Palacios (1997) pointed out that a thick cuticle and sunken stomata are among the specialized adaptations promoting efficient utilization and water retention.

Prosopis and *Acacia* which have thick laminas are characterized by a thick epidermis. It is well known that the possibility of heat storage increases in thick fleshy organs (Lewis and Nobel, 1977). Fahmy

(1997) concluded that the occurrence of thick epidermal cells in the non-succulent desert plants with thick leaves is to increase the absorption of the near infra red radiation prior to its transmission to the internal mesophyll of the leaf.

The three species investigated in the present study possess stomata on both surfaces of leaflets (amphistomatous leaves). The density of stomata is higher on the adaxial (upper) side than on the abaxial (lower) one (Figure. 8). In both *Prosopis* and *Acacia* the guard cell lengths on the upper sides are higher than those on the lower ones (Table 4). The reverse holds true in the case of *Lens*. Amphistomatous leaves are characteristic of plants growing in strongly lighted habitats and may increase the leaf conductance to CO_2 (Nobel, 1991).

The notion that desert species have higher stomatal density per unit leaf area as compared to those

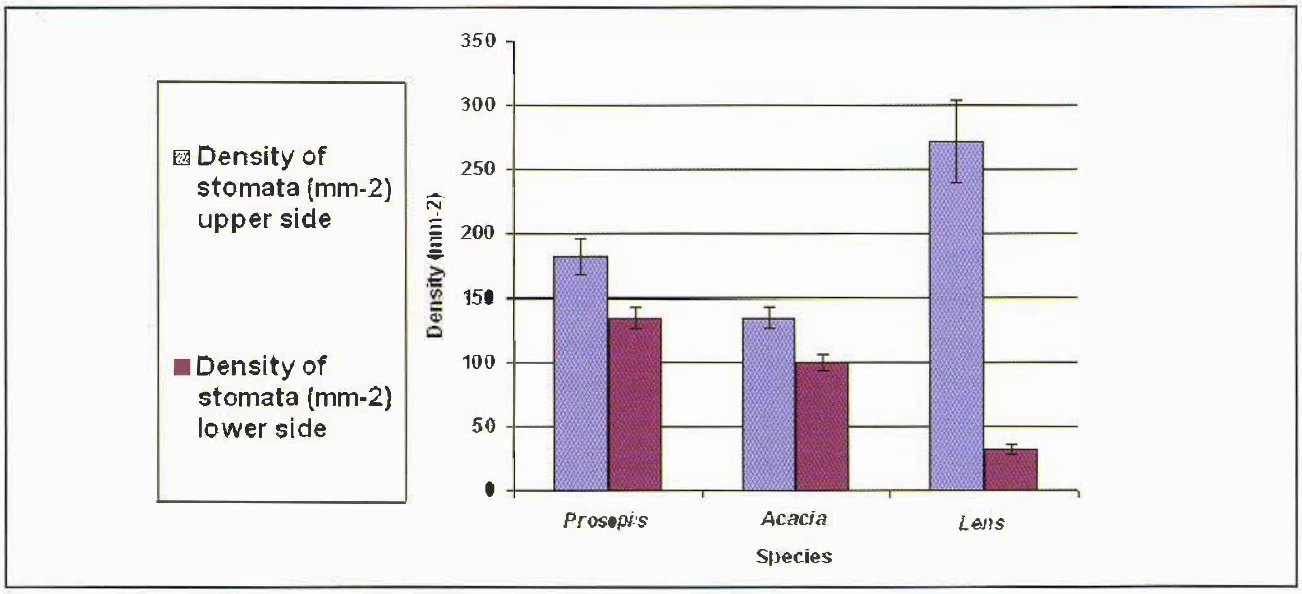


Figure 8. Density of stomata on upper and lower surfaces of *P. cineraraia, A. tortilis* and *L. esculenta* leaflets. Vertical bars are the standard deviations.

growing in less arid conditions (Fahn and Cutler, 1992) is not completely applicable to the taxa studied. Figure 8, shows that the stomatal density on the upper side of *Lens* (272 mm^{-2}) is much higher than in *Prosopis* (182 mm^{-2}) and *Acacia* (135 mm^{-2}). However, the notion of Fahn and Cutler (1992) may be valid if applied to the stomatal densities on the lower sides of the leaflets of the three species. It is suggested that, the characteristic folding of leaflets which commonly occurs under dry conditions in the three species investigated, is a mechanism to change the form and orientation of the leaflets (Plate 18). For example, under stress conditions (heat and/or water stress), folding of leaflets may protect the adaxial surfaces with their higher stomatal densities from water loss. Folding of the leaflets of both *Prosopis* and *Acacia* (Plate 18 b and d) can further reduce leaflet width, already narrow (=0.52 mm in *Acacia* and 2.5 mm in *Prosopis*), reducing leaflet area available to absorb radiation and thereby lowering both temperature and transpiration (Fahn and Cutler, 1992; Gibson, 1996).

The guard cell length of the species investigated is relatively short, as compared to Gibson's findings (1996) [the length of short guard cells ranges from 17-46° m. Large guard cells create wide stomatal pores (Sundberg, 1986) and decrease stomatal resistance to water vapour. It is apparent that the small guard cells of *Prosopis*, *Acacia* and *Lens* may lead to an increase in the stomatal resistance to water vapour. This pattern may be valid and applicable to both *Prosopis* and *Acacia* which live under desert conditions, but can not be applied to *Lens* (a mesophyte). In *Lens*, the small guard cell length is compensated by the high stomatal density on the upper epidermis (272 mm^{-2}, Figure. 8). The presence of many small guard cells will yield higher stomatal conductance which is acceptable under mesic conditions.

3.3.8.3 Thickness of leaflets and their mesophyll properties

The thickness of *Prosopis* and *Acacia* leaflets is largely due to the presence of palisade tissue which consists of cells arranged on each side forming a unfacial or isobilateral leaflet (Table 4, Plate 14). The palisade layers enclose a spongy tissue of rounded (in cross section) compact cells with small intercellular spaces. In *Lens* leaflet, palisade tissue is restricted to the upper side (Table 4). The ratio of palisade layer/spongy layer ranges from 0.8 for the leaflet of *Lens* to 3.6 and 3.7 for *Prosopis* and *Acacia* leaflets, respectively. A high ratio has been proposed as one of the characters increasing the photosynthetic efficiency of leaves (Shields, 1951; Nobel, 1991).

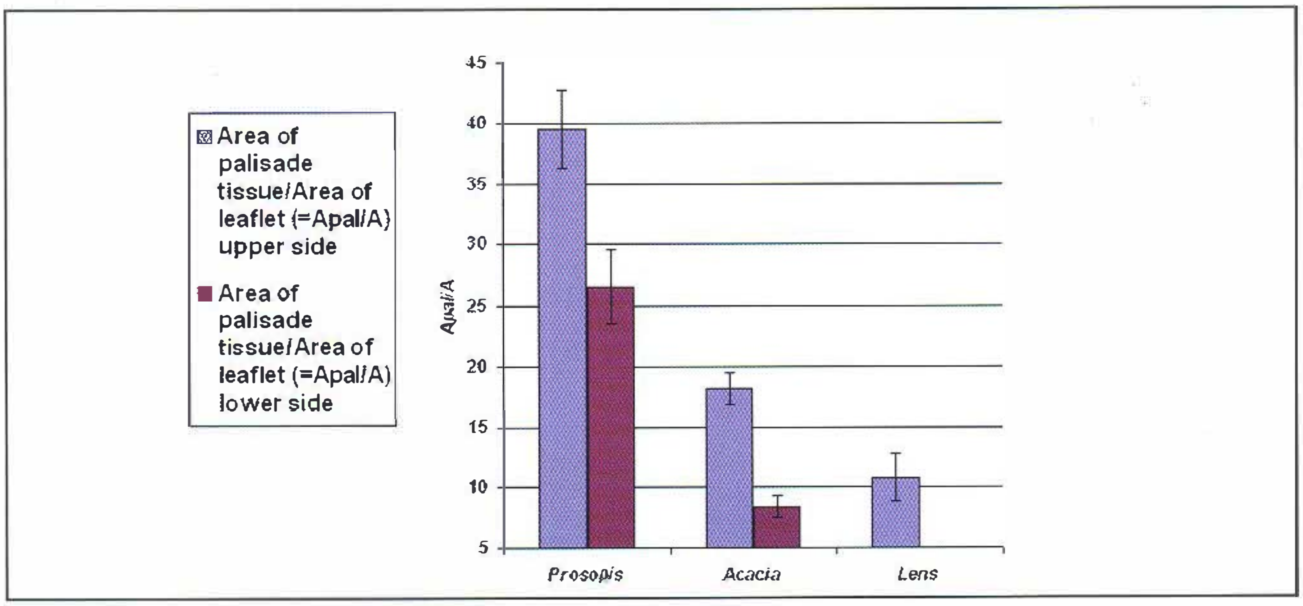
Both *Prosopis* and *Acacia* showed greater thickness of palisade on the upper side than on the lower side. The total palisade thickness follows a similar trend to that of the lamina thickness, being higher in the thick *Prosopis* leaflets (Table 4 and Plate 14). As compared to earlier studies, it is apparent that non succulent xerophytes have thicker leaves than mesophytes, because they have more highly developed palisade parenchyma (Ibrahim and Fahmy, 1985; Nobel, 1991; Fahmy, 1997). This is clear in the case of *Prosopis* and *Acacia*.

The similar arrangement of palisade cells on each side of the lamina is a common character found in plants growing in full sun, often in high temperature habitats such as deserts (Böcher, 1979; Nobel and Walker, 1985; Gibson, 1996; Fahmy, 1997). In crop plants such as the sunflower (Dengler, 1980) and *Lens* in the present study, the occurrence of adaxial (upper) palisade and abaxial (lower) spongy tissues is a characteristic feature of leaves from mesic habitats.

In *Prosopis* and *Acacia*, the ratio of A_{pal}/A adaxially is higher than abaxailly (Figure. 9). The total A_{pal}/A was low in the thin leaflets of *Lens* (A_{pal}/A=10.8) and high in both *Acacia* (A_{pal}/A=26.6) and *Prosopis* (A_{pal}/A=66.5) which have thick leaflets (Table 4). Previous studies (Turrell, 1936; Fahn,

1982) indicated that the area of mesophyll cells per leaf area (A_{mes}/A) is small in shade leaves (6.8 to 9.9) and large in mesomorphic leaves (11.6 to 19.2). Moreover, xerophytes tend to have a somewhat more developed palisade region than do mesophytes which result in values of 20 to 50 for A_{mes}/A (Nobel, 1991) or from 22.6 to 49.6 for A_{pal}/A in non succulent desert perennials (Fahmy, 1997). The significant positive relationship between the total A_{pal}/A and the thickness of leaflets of the species of the present study (r=0.846, number of observations=15) suggest the usefulness of measuring either of these criteria as a convenient method of clarifying the photosynthetic efficiency. Nobel *et al.* (1975) established a relationship between the mesophyll area/leaf area (A_{mes}/A) and leaf thickness. Fahmy (1997) pointed out that in 20 non succulent desert perennials, the A_{pal}/A is highly correlated with the palisade thickness (r=0.541, N=100) and with the thickness of lamina (r=0.525, N=100).

Figure 9. Area of palisade tissue/area of leaflet (A_{pal}/A) of *P. cineraria, A. tortilis* and *L. esculenta*



leaflets. Vertical bars are the standard deviations.

The significant positive relationship between the A_{pal}/A of *Prosopis*, *Acacia* and *Lens* and the guard cell length (r=0.967, N=15) indicates that the leaflets are built up for maximum photosynthetic efficiency; a suggestion that is supported by theoretical and physical considerations (Nobel and Walker, 1985; Nobel, 1991; Gibson, 1996).

In the present investigation, the xeromorphic features of *Prosopis cineraria* leaves were compared to those of *Acacia tortilis*; a common desert tree in the State of Qatar in order to examine shared features, if any. Moreover, leaves of both *Prosopis* and *Acacia* were compared to those of *Lens esculenta*; an annual leguminous crop plant living under mesic conditions. In conclusion the xeromorphic adaptations which were detected in *Prosopis* and *Acacia* may possibly contribute to the reduction in the rates of transpiration and photosynthesis as compared to *Lens*. The characteristics of the lamina include a group of "water retaining features", summarized as follows:

- Morphological features: these include small size of leaflets, which lowers the boundary layer conductance and most likely is advantageous to the plant under conditions of high temperatures and large humidity deficits.
- Anatomical features: these include (a) non-stomatal features (dense cover of epicuticular wax deposits); (b) stomatal related characteristics.

The former affects the leaflet temperature while the later responds to metabolic and environmental factors and hence affect the water retaining features by regulating water loss.

Compared to several earlier investigations, it is apparent that the ranges of leaflets thickness and the ratio of palisade cells surface area/leaflet area (A_{pal}/A) are consistent with other species inhabiting sunny habitats (Lewis, 1972; Nobel, 1991; Gibson; 1996; Fahmy, 1997; Fahmy *et al.*, 2005, under publication). Based on the examined xeromorphic features, it can be concluded that *Prosopis* is superior to *Acacia*. In *Prosopis*, the dense cover of epicuticular wax combined with the presence of sunken stomata as well as high A_{pal}/A, appear as specialized adaptations promoting efficient utilization and retention of water.

Plate 6. The morphology of the leaves of three leguminous plants *Prosopis cineraria* (middle), *Acacia tortilis* (left) and *Lens esculenta* (right).

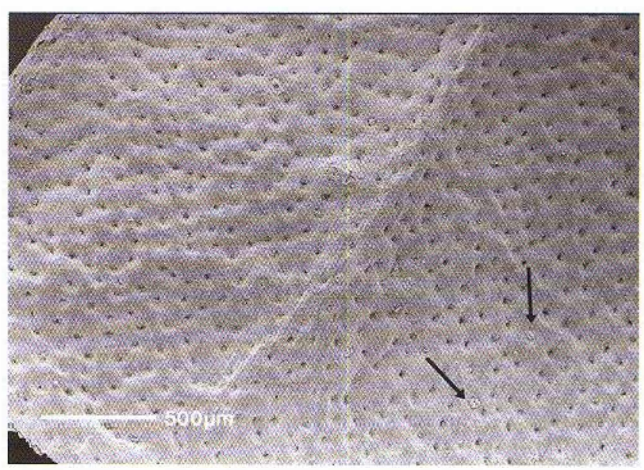


Plate 7. Scanning electron micrograph (SEM) of the adaxial pidermis of *Prosopis cineraria* leaflets showing the sunken stomata. Wax deposits cover the epidermis and may block the stomatal areas (single arrows). Magnification 40X.

Plate 8. SEM of the epidermis of *P. cineraria* leaflet with dense epicuticular wax covering which may entirely block the stomatal areas (single arrows) or leaving small aperture leading to a sunken stomatal pore (sp). Magnification 400X.

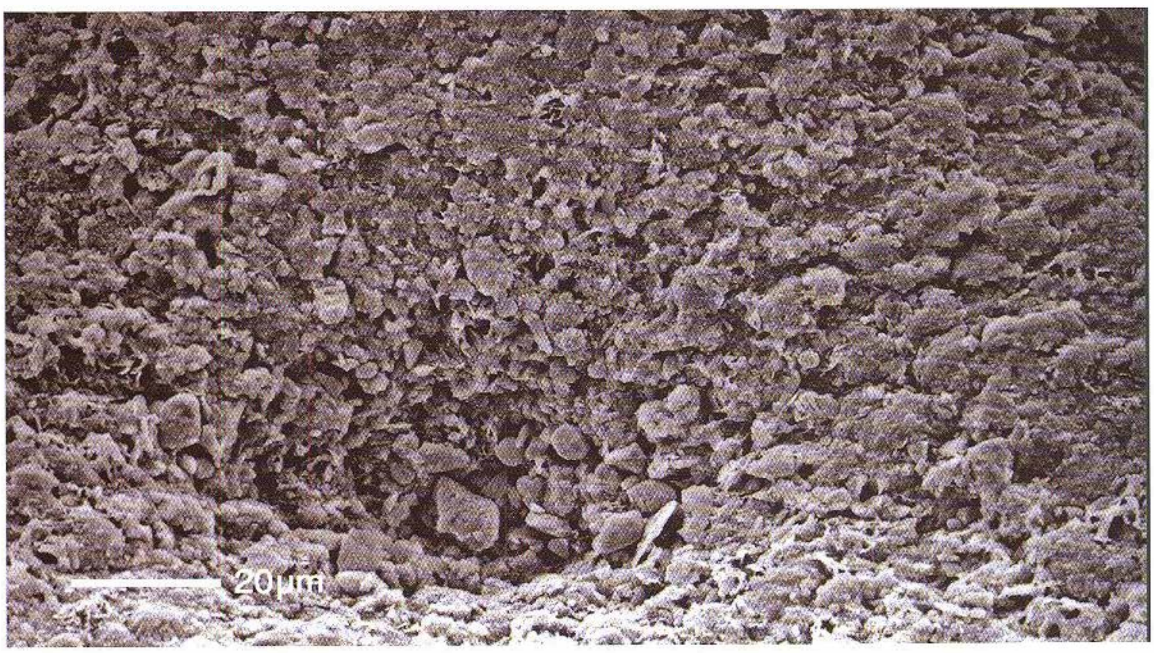


Plate 9. SEM of the leaflets surface of *P. cineraria* showing a sunken stoma blocked with wax. Magnification 800X.

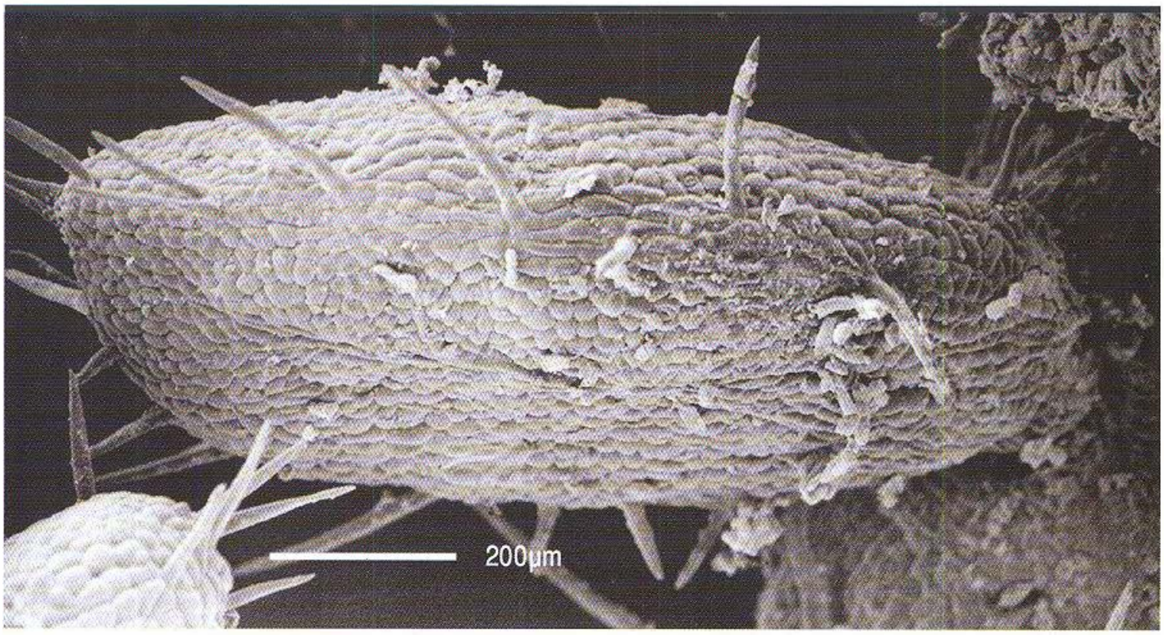


Plate 10. SEM of the leaflet surface of *Acacia tortilis*. Note that the leaflet is connected to the rachis of the leaf and the presence of some scattered trichomes covering the surface especially on the margin. Magnification 100X.

Plate 11. SEM of the dense epicuticular wax platelets covering the guard cells (single arrow) and the epidermal cells (arrowhead) of *Acacia tortilis* leaflet. Magnification 2000X

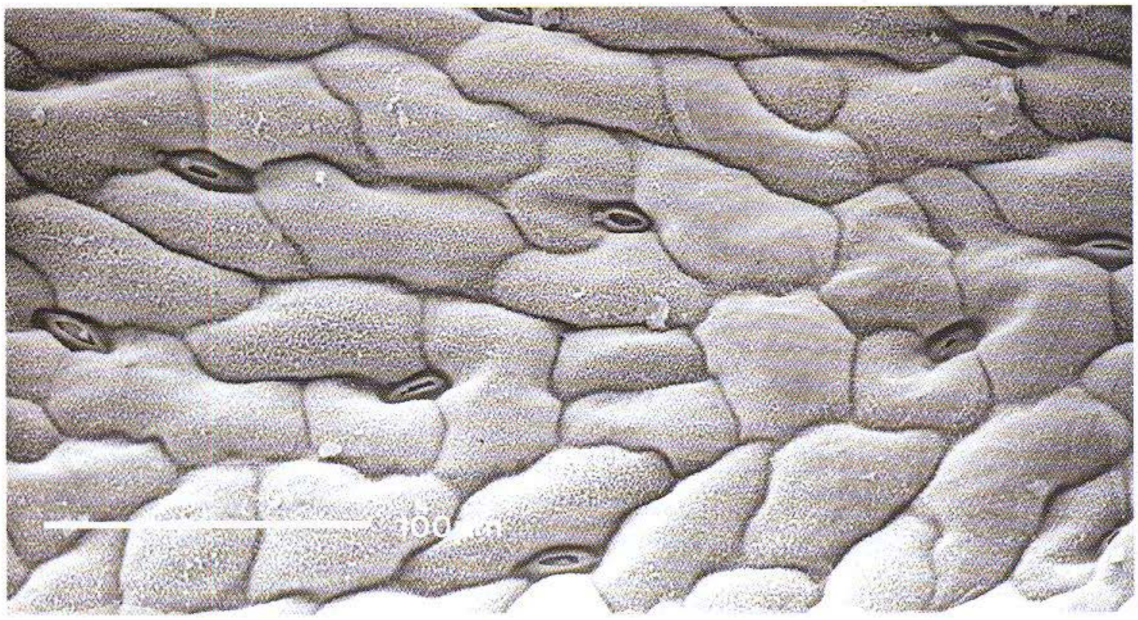


Plate 12. SEM of the epidermis of *Lens esculenta* leaflet showing numerous stomata and thin epicuticular wax platelets covering the epidermal cells. Magnification 350 X.

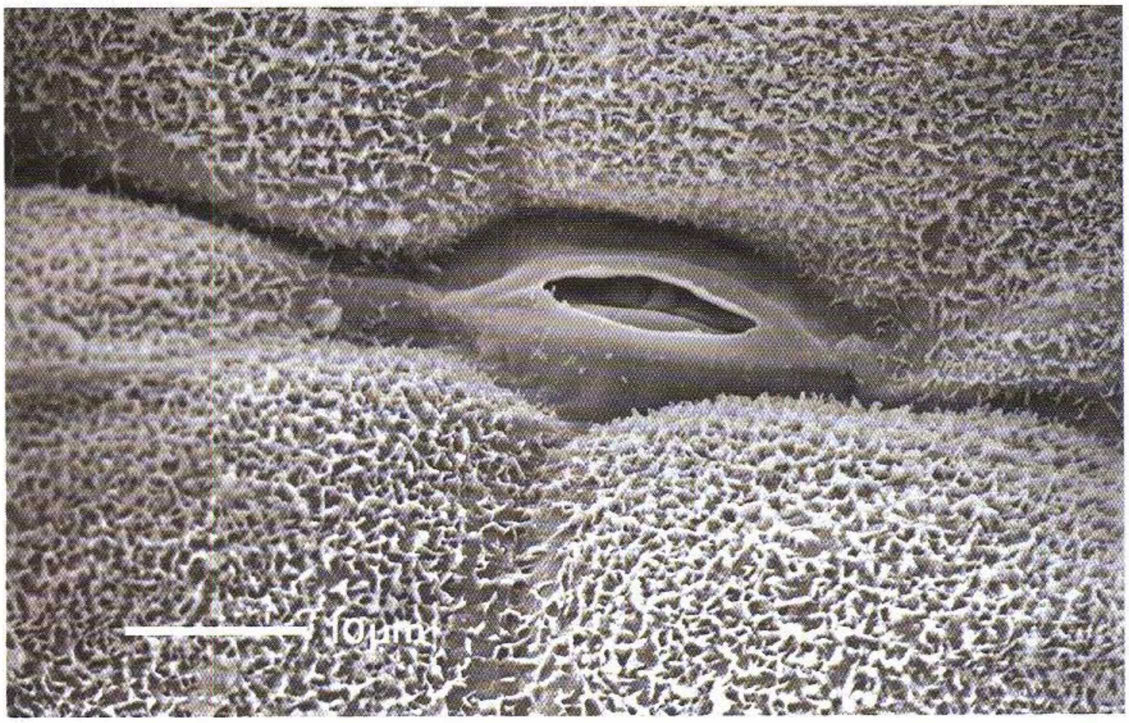


Plate 13. SEM of the thin wax platelets covering the epidermal cells of *Lens esculenta* leaflet. Note that the guard cells have smooth surfaces with very few wax deposits. Magnification 2000X.

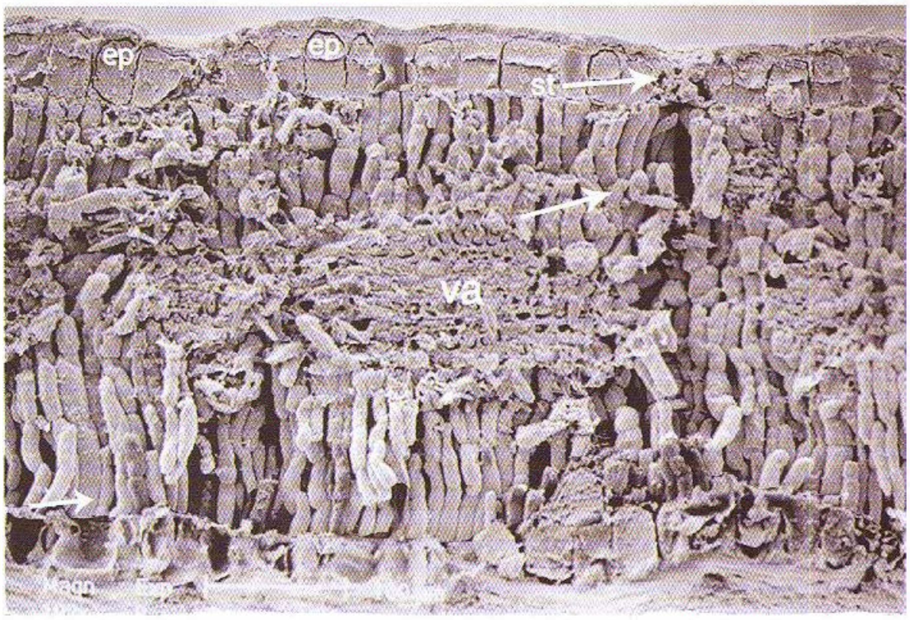


Plate 14. SEM of a cross section of *Prosopis cineraria* leaflet. The thickness of the cross section is due to the multilayered palisade cells (single unlabelled bold arrows) and the thick epidermal cells (ep) are arranged on each side. Note the vascular tissues (va) and the sunken stoma (st) in the cross section. Magnification 192X.

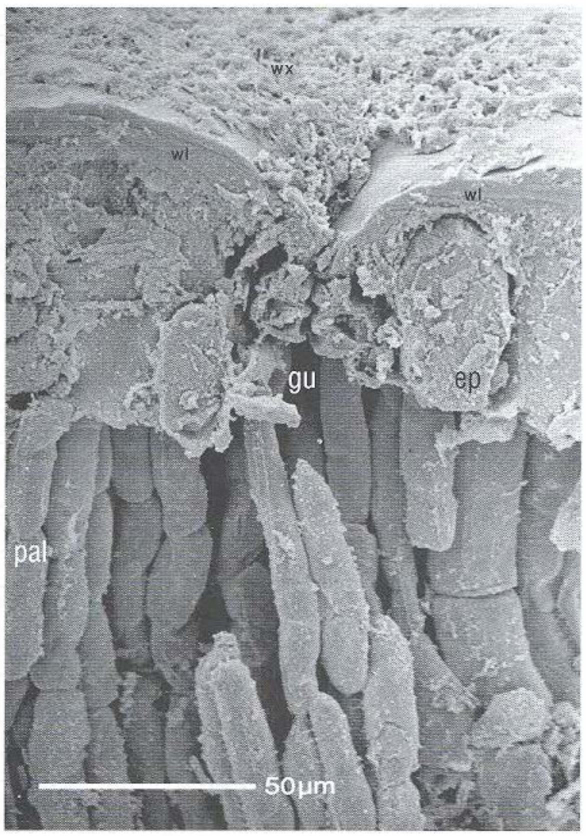


Plate 15. SEM of a magnified portion of a cross section of *Prosopis cineraria* leaf showing dense epicuticular wax platelets (wx) covering the epidermal cells (ep) which have thick outer wall (wl). The guard cells (gu) level lies below the epidermal cells, indicating that the stoma is sunken. Note the multilayered palisade cells (pal). Magnification 600X.

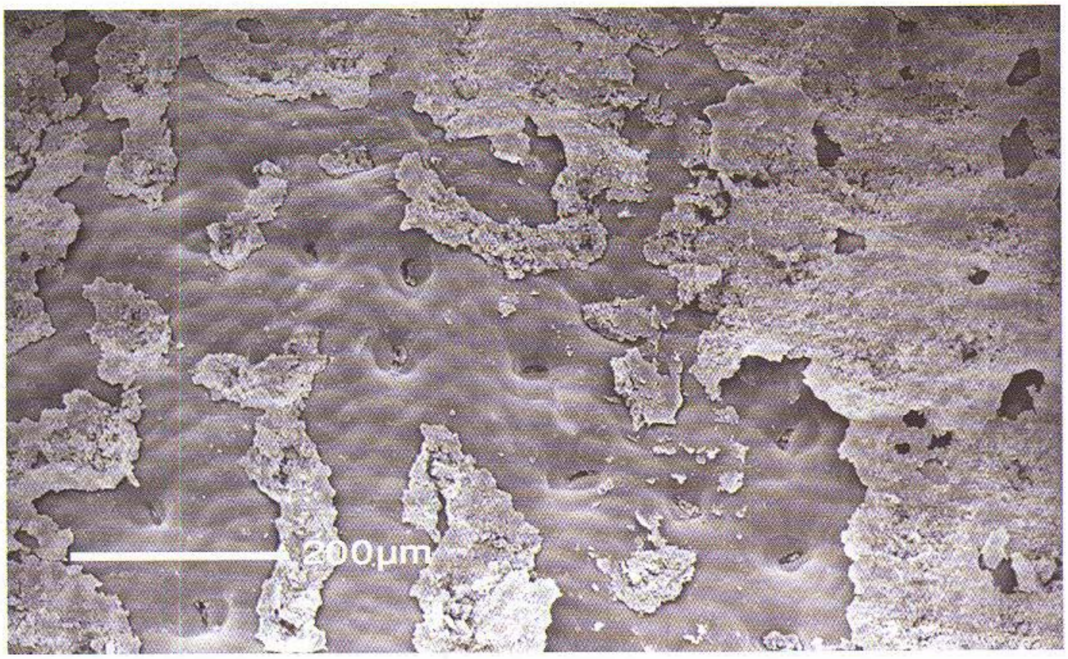


Plate 16. SEM of the leaf surface of *Prosopis cineraria* showing that some epicuticular wax deposits have been removed after rinsing the leaflet in chloroform for one minute. Note the apparent smooth nature of the outer wall of the epidermal cells and the sunken nature of the guard cells below the level of the epidermal cells. Magnification 125X.

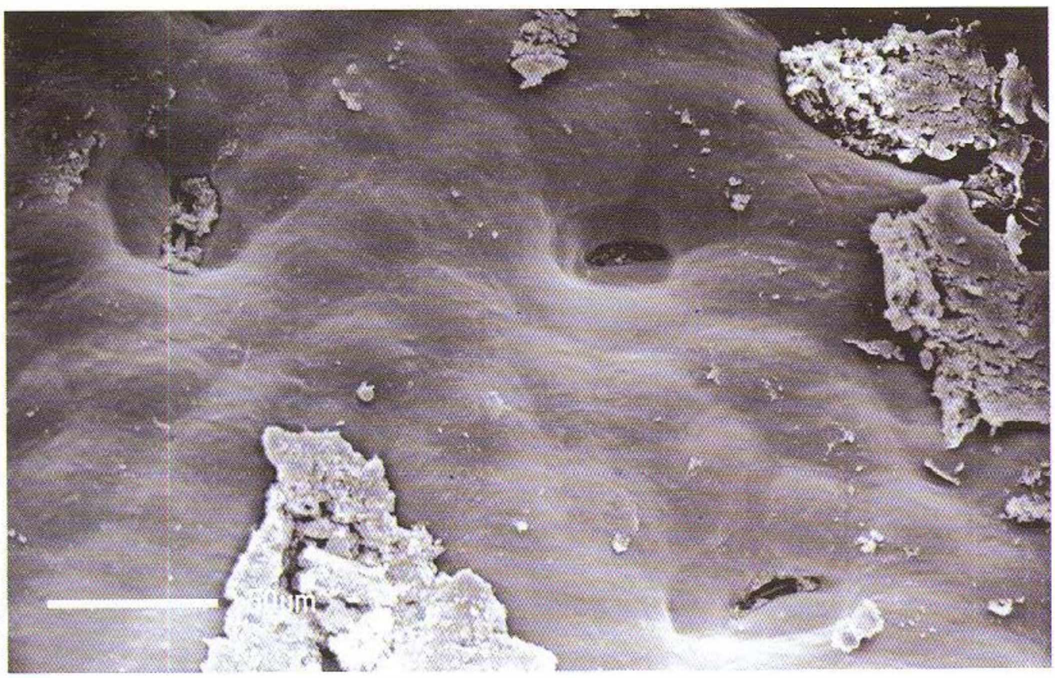


Plate 17. SEM of a magnified portion of Plate 16. Note the three apparent sunken stomata and that the stoma on the left is largely blocked with wax deposits. Magnification 400X.

a

b

c

d

Plate 18. Leaves of 2-months old young plants of *Prosopis cineraria* (**a** and **b**) and *Acacia tortilis* (**c** and **d**). The plants were water stressed by withholding irrigation for 48 hours (**b** and **d**) or irrigated normally every 24 hours (**a** and **c**). All the plants were exposed to natural conditions and photographed at midday local time (11.30 h) on Monday the 30th of May 2005. The air temperature in the shade was 39° C and the solar radiation intensity at the leaf level was 1800 W m^{-2}. Note the leaflets folding in water stressed plants (**b** and **d**) and the unfolding in plants receiving normal irrigation (**a** and **c**).

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CHAPTER - 4

PLANT-INSECT RELATIONSHIP IN *PROSOPIS CINERARIA*

By

Dr. Mahmoud Saleh Abdel-Dayem

4.1 Introduction

Prosopis cineraria (L.) or Ghaf (Ar.) is one of the most well known multi-purpose trees in the Arabian Gulf region. It is useful to humans for various uses and essential to the survival of wildlife in the desert ecosystem: Mammals, birds, spiders, ticks, and insects eat the pods, leaves, and wood; seek shelter under its canopy; and benefit from the leaf litter and nutrient rich soil under the tree.

The "Ghaf" ecosystem is inhabited by a number of small creatures, of which the ants and beetles are perhaps best known. Ghaf provides different kinds of niches for a variety of arthropod population. The crowns of trees including the trunk, branches, leaves, flowers and fruits provide niches essential to arthropod fauna like spiders, ticks and insects.

Attention to the importance of Ghaf tree in Qatar was highlighted by the program "A Flower Each Spring" initiated and supported by H.H. Shaikha Mozah Bint Nasser Al-Misned consort of H.H. the Amir of the State of Qatar. The Friends of the Environmental Centre organized a number of programs to increase public awareness of the Ghaf tree and its role in protecting and beautifying the environment with its choice as the flower for Spring 2005. In addition, the Environmental Studies Centre (ESC) encouraged scientific research in the study of the Ghaf tree.

This study is a contribution to the scientific study of the Ghaf tree and tackles the entomofauna that is associated with the tree. Information about the invertebrates associated with *P. pallida* and *P. julifora* are available (Pasiecznik *et al.*, 2001) whereas the information on the pests and diseases that affect *P. cineraria* are very rare. Studies of the complete macrofauna of the Ghaf tree sites in Qatar were not carried out before, and the opportunities for scientific discovery are abound! In this study it is only possible to provide general comments regarding the Ghaf entomofauna. It is hoped that this contribution would help decision makers to propose an action plan for the rehabilitation, conservation and sustainable use of the Ghaf, *Prosopis cineraria* in Arabian Gulf region and particularly in the State of Qatar.

4.2 Materials and Methods

The survey included a number of visits to the main study area at Rawdat Rashid (Plate 1) during the period from March to May, 2005. The research area for the insects included:

- Investigating the 8 trees at Rawdat Rashid including all vegetative parts and within crevices in the bark and root area.
- Searching the immediate undercanopy both the shaded and non-shaded zones (subcanopy and outside canopoy).
- Searching the area surrounding the central depression for a distance of at least 500 m.
- Investigating the associates in the vegetation within Al Ghafat.

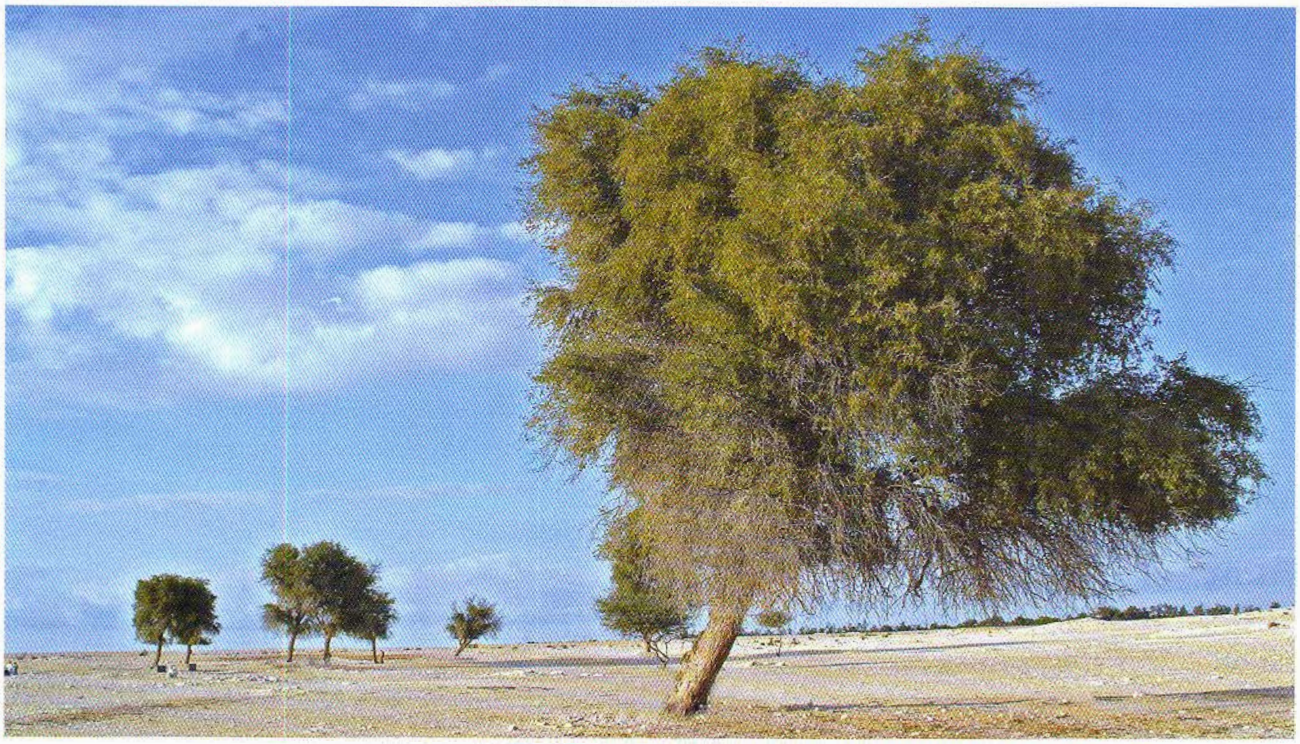


Plate 1. General view of Al Ghafat depression and the 8 individual Ghaf trees (March, 2005).

The search for insects included turning up stones and rocks, spreading debris and digging up insect holes. The insects encountered were collected using areal net, an aspirator, as well as by hand. Due to the deterrants incurred by both the distance to Rawdat and the time factor, only diurnal insects were collected.

Documentation was carried out by the following:

- Field photography to show the natural habitats.
- Studio photography to focus on the taxonomic characters.
- Mounted specimens prepared for checking.

All insects found were killed in polyethylene bottles provided with a piece of tissue paper with few drops of ethyl acetate; the soft bodied insects were killed in 70% alcohol with few drops of glycerin. These insects were later examined, identified (at least to their family levels) and mounted as museum specimens. Most of the specimens were photographed at the unit of scientific photography, the University of Qatar.

4.3 Results

Arthropods are invertebrates with segmented body and appendages, and are undoubtedly the most common group of animals in the immediats of the Ghaf habitat. Two classes are especially common, the Arachnida and Insecta.

4.3.1 Insecta (insects)

Insects are the most diverse group of organisms alive on the earth (making about 75% of all living animal species). Although widespread on land and in freshwater, they are less common in the sea. It is easy to distinguish between insects and other arthropods by the following features:

- Adults have a body divided into three parts: head, thorax and abdomen.
- All insects have a single pair of antennae.
- All insects have three pairs of legs.

An invertebrate with wings is definitely an insect, but not all insects have wings. Many Ghaf insects, ants, termite, and silver-fishes are wingless.

Though numerous in the Ghaf habitats, insects are less obvious to the casual visitor than birds or mammals.

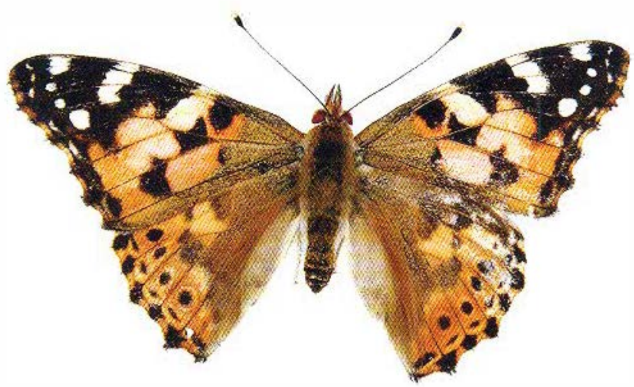
The most common groups of insects that were recorded in the Ghaf area include the:
- Beetles & weevils (Order Coleoptera)
- Ants, bees & wasps (Order Hymenoptera)
- Moths & butterflies (Order Lepidoptera)
- Flies (Order Diptera)
- Termites or white ants (Order Isoptera)
- Bugs (Order Hemiptera)
- Grasshoppers (Order Orthoptera)

The young of insects are called caterpillars, maggots, grubs, wrigglers, etc., but all are more easily called larvae! These are more frequently seen than the adults, on plants and under stones and plant debris.

However, it is difficult to know what a larva becomes after metamorphosis. The only sure way is to rear it to the adult stage.

Diptera (flies & mosquitoes)

Coleoptera (beetles & weevils)

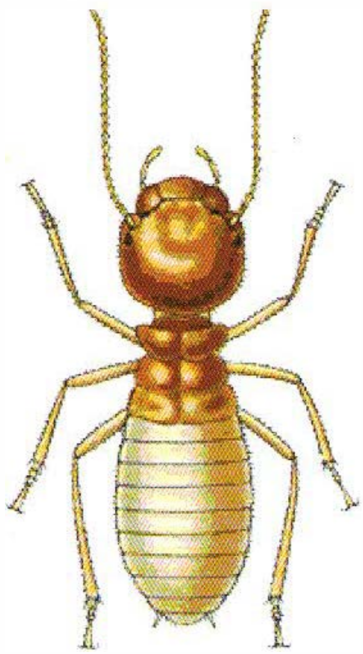


Lepidoptera (butterflies & moths)

4.3.2 Arachnida (spiders and ticks)

Unlike insects, arachnids (spiders, scorpions, ticks and mites) do not have wing or antennae, have 4 pairs of legs, and their bodies are divided into cephalothorax (head with thorax) and an abdomen. Many spider species have been recorded in Al-Ghafat area during the spring season of 2005 (11 spider species, one camel spider or solifuge species, and only one tick species).

Orthoptera (locusts and grasshoppers)



Isoptera (termites or white ants)

Hymenoptera (ants, bees, and wasps)

Hemiptera (bugs)

4.3.3 Associated insect fauna

Insects utilize *P. cineraria* along with other desert trees, shrubs, and wild plants for shade, protection and food. Physical safety is obtainable from the sun by a broad crown, and the thorns and the shrubby form can offer excellent protection of insects from large predators.

Insects are important in the overall ecology of *P. cineraria* trees and stands, feeding on living or dead tissue or using the trees for shelter and as hunting and mating grounds. In the following sections the author summarizes the information available on insect pests relevant to the Ghaf tree, and makes the few generalizations that are possible.

4.3.4 Species richness composition

A total of 480 specimens belonging to 65 insect species (some identified only to genus or family level) belonging to 33 families and representing 9 orders have been found to occur in the Ghaf tree area (Table 1).

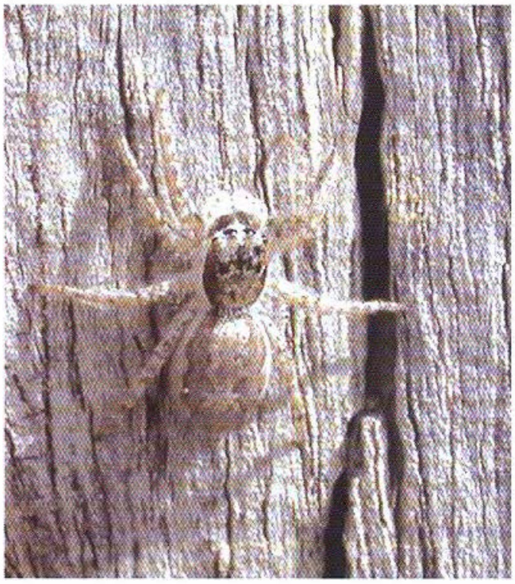
Of the total 65 species, 29 species represnting 44.6 % of the total catch belong to one order; the Coleoptera or beetles. The remaining 8 orders comprise the Hymenoptera (ants, wasps and bees) which represent 20% of the total insect fauna and the Diptera or flies represents 9.2% whereas the Lepidoptera or butterflies and moths and the Heteroptera or bugs are represented by 9.2% and 7.7% respectively. The remaining orders comprise: Isoptera, Neuroptera, Orthoptera and Thysanura making up the remaining 9.2% of all recorded orders (Figure 1).

4.3.5 Distribution of insect species in Al Ghafat area

Insect species appear to differ greatly in the extent of their distribution at the Ghafat area. The faunal data can be divided into three groups based on the overall association trends of the insect species with the Ghaf tree (Table 1). The first group includes the fauna encountered on the trees trunks, the second group presenting the fauna found under the canopy, and the third group represent the insect fauna collected beyond the canopy (outside the crown). The results demonstrate that (Figure 2) the groups are varied in their species composition. The figure also summarizes the variation not only in the species composition but also by the number of species shared between different pairs of groups and the number of species unique to each group.

An investigation was carried out to assess the effect of *P. cineraria* on the entomofauna at Rawdat Rashed. The samplings was carried out for a period of 2 months during the spring season of 2005, transects from the undercanopy of three trees to the open areas.

The species richness under the canopy of *P. cineraria* was higher as compared to the outside canopy. Species richness varied among different sampling units. The enormous variation in species richness is attributed to soil and climatic factors. The high organic matter under the canopy offer excellent niches for different groups of insects. The leaf litter under the canopy plays an important role as a substrate for surface dwellers and soil inhabiting insects.



Arachnida (spider)

Arachnida (ticks)

Arachnida (camel spider)

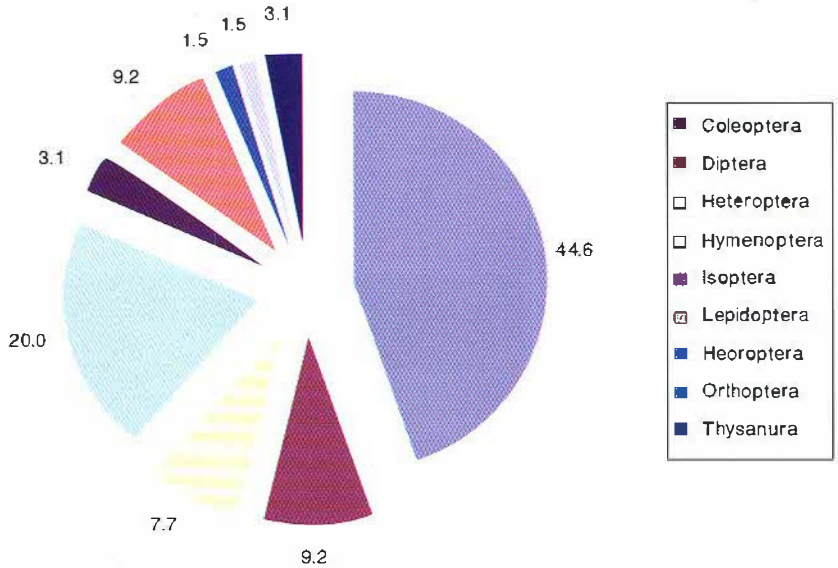


Figure 1: Species richness among orders of insects in Ghaf tree area in Rawdat Rashid (Spring 2005).

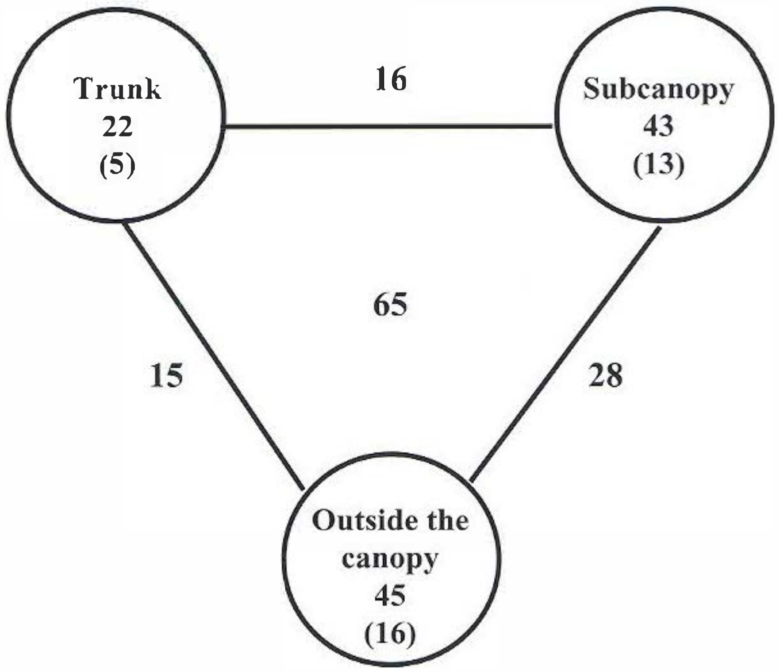


Figure 2: Insect species at Ghafat, Rawdat Rahsid, Qatar[March-May,2005]. The total number of species at the Ghafat habitat is given in bold at the middle of the triangle. The number of species in each group is given in bold, the number of species occurring in common in different groups is given along the lines joining the groups, and the number of species unique to each group is given within parentheses within the circles.

4.3.6 Feeding habit

The Ghaf trees harbour insects that defoliate, produce galls or leaf mines, eat seeds, suck sap or bore in stems, roots or branches. Some insects, mainly the sap suckers, also transmit pathogens. The debilitating impact of insects on forage quality and quantity or on seed production may be so great that remedial activity is desirable. Insect associations with *P. cineraria* and different associated plants can be differentiated by the type of feeding habits (Table 1).

The most obvious effective element of the insects' presence is the phytophagous species causing damage to the Ghaf tree and its associated flora. This group of pests includes 21 species and represent 32.3% of the total number.

Ants are among the most successful insects, and have evolved to fill a variety of different ecological niches as predators, herbivores, leaf-cutters, seed-harvesters, and fungus-growers. The ants were the most common group of insects (8 ant species in *P. cineraria* area), foraging on the branches, trunk, and under crown (Plates 8 , a-c).

4.3.6.1 Leaf feeding insects:

Defoliating insects are common species in the area of the Ghaf trees; they numbered 9 species mainly moths and butterflies. Many caterpillars of moths and butterflies were recorded during early spring and their adults emerged during late spring. The larvae feed on the leaves of the Ghaf and other associated plants, while the adults feed on the nectar and use the tree as shade and for hiding (Plates 1-4). Locusts and grasshoppers were uncommon and only one species *Sphingonotus savignyi* was recorded (Plate 9).

4.3.6.2 Pollinators:

These are of great importance in the area. Some insects feed on the flowers, while others use them as mating grounds, and others use them as hunting places. Pollinators recorded in the area included bees, wasps, ants, flies, adult moths and butterflies.

4.3.6.3 Wood boring insects:

Wood boring beetles are rarely specific to *P. cineraria* and attack several taxa of woody perennials. Only 2 species of metallic wood boring beetles were recorded: the jewel beetle or *Julodis euphratica* (Plate 12) and *Psiloptera*. White ants or termites were encountered also at the foot of *P. cineraria* trees and in the trunk. These crevices invade the old galleries that were made by the wood boring beetles in the stems and branches of shrubby trees (Plate 6).

4.3.6.4 Predators and parasitoids:

These play an important role in controlling the phytophagous insects. They constitute about 20 species mainly of beetles and wasps (Plates 13-24)

4.3.6.5 Detrivores:

These are considered as the natural cleaners of the area. They feed on different types of dead matter of either plant or animals origin. They comprise about 20 species including omnivorous and saprophagous species.

4.3.7 Microhabitat

Table (1) shows that the plant cover is very important for many groups of insects and offers food or shelters for more than 49 species (75.4%). The most specious microhabitat is the ground surface sand under stones, where more than 29 species (44.6%) live and hide. Furthermore litter, plant debris, and organic matters were inhabited by 12 species (18.5%).

Table 1. Insects collected at Rawdat Rashid, March - May 2005

Taxonomic position and scientific names	Habitat	Association with Ghaf canopy	Feeding Habit	Common Name
Coleoptera				
Anthicidae				
Anthicus crinitus (Laferte, 1848)	Under decaying matterial	Outside	Predators	Ant beetle
Cyclodinus debilis (Laferte, 1848)	Under decaying matterial	Outside	Predators	Ant beetle
Endomia bivittata (Truqui, 1855)	Under decaying matterial	Outside	Predators	Ant beetle
Buprestidae				
Julodis euphratica (Cast. & Gory, 1835)	On and in the branches	Underneath	Wood feeders	Jewel beetle
Psiloptera sp.	On and in the branches	Both	Wood feeders	Metallic wood boring beetle
Carabidae				
Calosoma chlorostictum (Dejean, 1831)	Under stones	Outside	Predators	Ground beetle
Glycia ornate (Klug, 1831)	Under stones	Underneath	Predators	Ground beetle
Tachys sp.	Under decaying matterial	Outside	Predators	Ground beetle
Trichis maculata (Klug, 1831)	Under stones	Underneath	Predators	Ground beetle
Cleridae				
Necrobia rufipes (De Geer)	Under decaying matterial	Outside	Predators	Red-legged ham beetle
Curculionidae				
Hypera sp.	At foot of trees, and beneath plants	Both	Root feeders	Weevil
	At foot of trees, and beneath plants	Underneath	Root feeders	Weevil

Table 1. Contd.

Taxonomic position and scientific names	Habitat	Association with Ghaf' Canopy	Feeding Habit	Common Name
Elateridae				
Unidentified	At foot of trees	Underneath	Root feeder	Click beetle
Histeridae				
Saprinus sp.	In dung	Outside	Predators	Hister dung beetle
Staphylinidae				
Atheta sp.	Under decaying matterial	Outside	Predators	Rove beetle
Unidentified	Under decaying material	Outside	Predators	Rove beetle
Tenebrionidae				
Adesmia cancellata (Klug, 1830)	Under stones and beneth plants	Both	Detrivores	Desert beetle
Akis elevate (Solier, 1836)	Under stones	Both	Detrivores	Darkling beetle
Erodius sp.	Under stones	Both	Detrivores	Darkling beetle
Gonocephalum setulosum (Faldermann, 1837)	Under stones	Both	Detrivores	Darkling beetle
Mesostena puncticollis (Solier, 1835)	Under stones	Both	Detrivores	Darkling beetle
Ocnera hispida (Forskal, 1775)	Under stones	Both	Detrivores	Darkling beetle
Opatroides punctulatus (Brulle, 1832)	Under stones	Both	Detrivores	Darkling beetle
Unidentified	Under stones	Both	Detrivores	Darkling beetle
Unidentified	Under stones	Both	Detrivores	Darkling beetle
Unidentified	Under stones	Both	Detrivores	Darkling beetle
Unidentified	Under stones	Both	Detrivores	Darkling beetle
Unidentified	Under stones	Both	Detrivores	Darkling beetle

Table 1. Contd.

Taxonomic position and scientific names	Habitat	Association with Ghaf Canopy	Feeding Habit	Common Name
Diptera				
Asilidae				
Apoclea algira (Fabricius, 1794)	On ground	Both	Predators	Robber fly
Calliphoridae				
Chrysomyia albiceps (Wiedemann, 1819)	Flying about and resting on plants	Both	Saprophagous	Blowfly
Muscidae				
Musca domestica (Linnaeus, 1758)	Flying about and resting on plants	Both	Omnivores	House fly
Musca Albina (Wiedemann, 1830)	Flying about and resting on plants	Both	Omnivores	
Sarcophagidae				
Wohlfahrtia indigena Villeneuve	Flying about and resting on plants	Both	Parasites	Grey flesh fly
Unidentified				
Unknown	Flying about and resting on plants	Both		
Heteroptera **Cydinidae**				
Cydnus	In litter	Underneath	Plant feeders	Burrowing bug
Pyrrhocoridae				
Pyrrhocoris	In litter	Both	Seed feeders	Fire bug
Reduviidae				
Reduvius	In litter	Underneath	Predators	Assassin bug

Table 1. Contd.

Taxonomic position and scientific names	Habitat	Association with Ghaf' Canopy	Feeding Habit	Common Name
Unidentified				
	In litter	Underneath		
Unidentified				
	In litter	Underneath		
Hymenoptera **Formicidae**				
Camponotus aegyptiacus (Emery, 1915)		Both	Omnivorous	Ant
Camponotus xerxes Forel, 1904	Under plants	Both	Omnivorous	Ant
Cataglyphis savignyi (Dufour, 1862)	On ground	Both		Ant
Messor sp.1	On ground	Under the canopy		Ant
Messor sp.2	On ground	Outside the canopy		Ant
Monomorium salomonis (Linnaeus, 1758)	On ground	Under the canopy		Ant
Tapinioma sp.	On branches	Under the canopy		Ant
Tetramorium sp.	Under stones	Both		Ant
		Both		Ant
		Both		Ant
		Both		Ant
Masaridae				
Cleonites sp.	On plants	Both	Pollen & nectar feeders	Solitary wasp

Table 1. Contd.

Taxonomic position and scientific names	Habitat	Association with Ghaf' Canopy	Feeding Habit	Common Name
Mutillidae				
Mutilla sp.	Under stones	Outside the canopy	Parasite	Velvet ant
Sphecidae				
Bembix sp.	On ground	Both	Predators	Sand wasp
Podalonia tydei (Le Guillou, 1856)	On ground	Both	Predators	Hunting wasp
	On ground	Both	Predators	Digger wasp
Tenthredinidae				
Cladius pectinicornis (Geoffroy, 1785)	On plants	Both	Leaf feeders	Sawfly
Isoptera				
Hodotermitidae				
ochraceus (Desneux, 1904)	Under decaying matterial	Outside	Wood feeders	Termite
Rhinotermitidae				
Psammoterme hybostoma (Desneux, 1904)	In sand & tunnels of wood boring by beetles in branches of trees	Both	Wood feeders	Termite
Lepidoptera				
Geometridae				
Unidentified	On plants and ground	Both	Plant feeders	
Unidentified	On plants and ground	Both	Plant feeders	
Noctuidae				
Heliothi peltigera (Denis & Schiffermuller, 1775)	On plants and ground	Both	Plant feeders	Bordered Straw
Spodoptera sp.	On plants and ground	Both	Plant feeders	
	On plants and ground	Both	Plant feeders	

Table 1. Contd.

Taxonomic position and scientific names	Habitat	Association with Ghaf' Canopy	Feeding Habit	Common Name
Nymphalidae				
Vanessa cardui (Linnaeus, 1758)	On plants and ground	Both	Plant feeders	Painted lady
Neuroptera **Myrmeleontidae**				
Mortar hyalinus (Olivier, 1811)	In ground	Both	Predators	Ant-lion
Orthoptera **Acrididae**				
Sphingonotus savignyi (Saussure, 1884)	On ground	Both	Leaf feeders	Grasshopper
Thysanura **Lepismatidae**				
Thermobia sp.	Under stones	Underneath	Detrivores	Silver-fish
Unidentified	Under stones	Underneath	Detrivores	Silver-fish

A. Phytophagous insects :

1. Leaf feeders: Moths & butterflies [Plate 1-5].
2. Wood feeders: Termites [Plate 6].
3. Seed feeders : Bugs and Ants [Plates 7-8a].
4. General foragers : Ants and grass shoppers [Plates 8b-9].
5. Root feeders : Weevils and beetles [Plates 10-12].

B. Predators : Beetles, bugs, wasps, ant-lion. [Plates 13a-21b].

C. Parasites : Ant, flies, bees. [Plates 22-24].

D. Detrivores : Beetles, blowfly. [Plates 25-32].

A- Phytophagous insects
1- Leaf Feeders

Plate 1: The Noctuid moth (*Grammodes*)

Order: Lepidoptera
Family: Noctuidae
Scientific name: *Grammodes* sp.; Plate 1.
Common name: Noctuid moth
Arabic Name: فراشة جرامودس ذات البقع البنية
Habitat: Adults rest on plants and ground, the larvae live on plants.
Feeding habit: Adults feed on nectar; immature stages feed on leaves of many wild plants, including Ghaf.
Association trend with Ghaf tree: Adults observed on the main trunk, branches and under the canopy, and beyound the canopy.

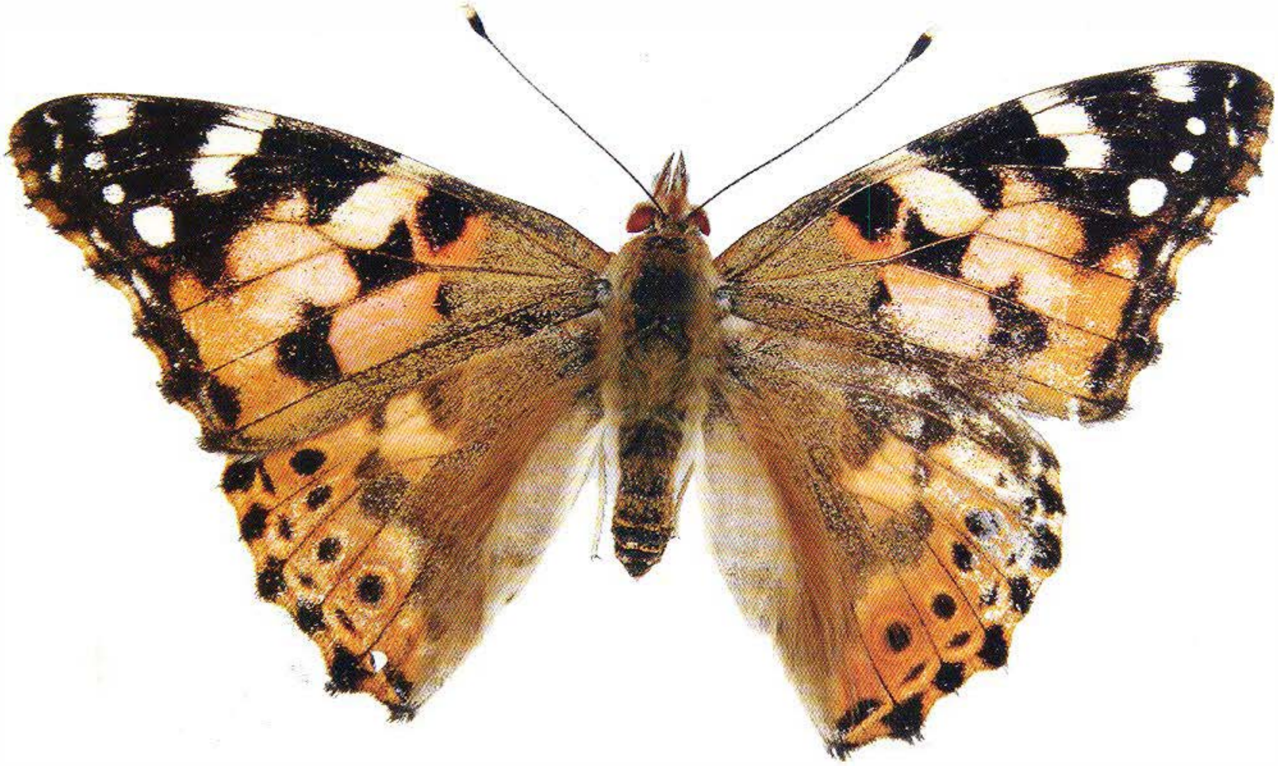


Plate 2: The Painted lady (*Vanessa cardui*)

Order: Lepidoptera

Family: Nymphalidae

Scientific name: *Vanessa cardui* (Linnaeus, 1758); Plate 2.

Common name: Painted lady

Arabic name: السيدة المزركشة

Habitat: Adults rest on plants and ground, immature stages on plants.

Feeding habit: Adults moth feed on nectar; immature stages feed on leaves of many wild plants.

Association trend with Ghaf tree: Adult observed resting under and beyound the canopy.

Plate 3: The Bordered straw (*Heliothis peltigera*)

Order: Lepidoptera

Family: Noctuidae

Scientific name: *Heliothis peltigera* (Denis & Schiffermuller, 1775); Plate 3.

Common name: Bordered straw

Arabic name: فراشة القشة المخففة

Habitat: Adults rest on plants and ground; immature stages on plants.

Feeding habit: Adults feed on nectar; immature stages feed on leaves of many wild plants.

Association trend with Ghaf tree: Adults observed resting and the larvae use it for feeding.

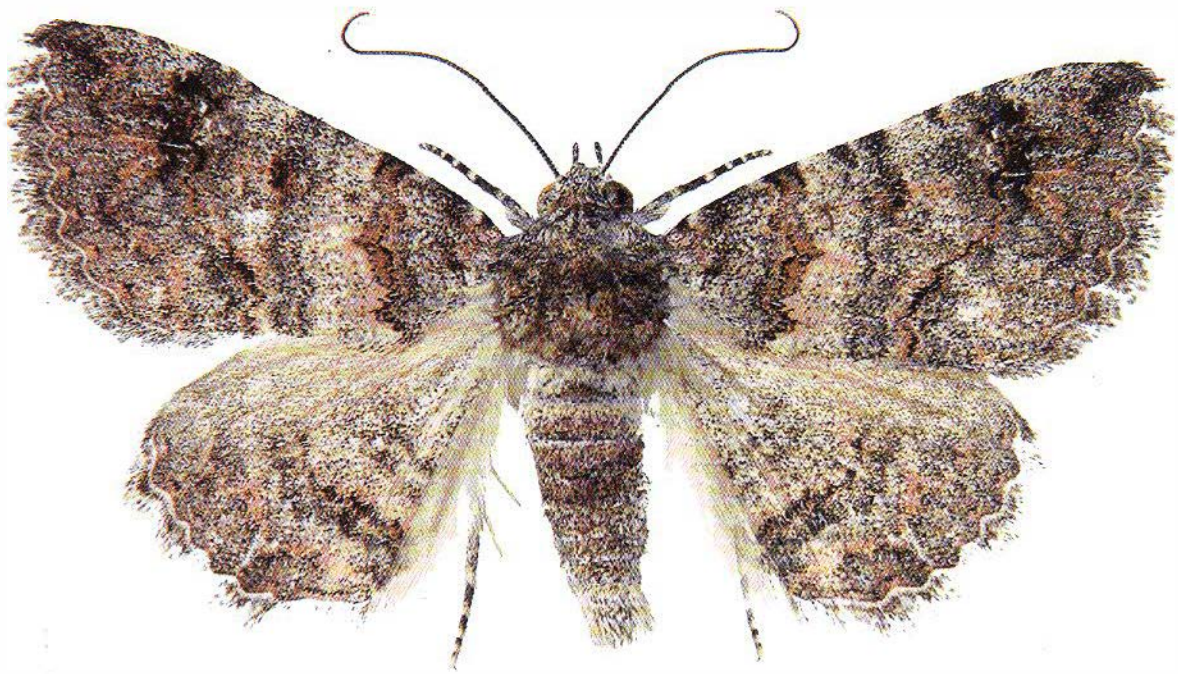


Plate 4: The Wave brown moth (*Scopula* sp.)

Order: Lepidoptera

Family: Geometridae

Scientific name: *Scopula* sp.; Plate 4.

Common name: Wave brown moth

Arabic name: الفراشة ذات الجناح بني التموج

Habitat: Adults rest on plants and ground; immature stages on plants.

Feeding habit: Adults feed on nectar; immature stages feed on leaves of many wild plants.

Association trend with Ghaf tree: Adults use the tree for resting and the larvae use it for feeding.

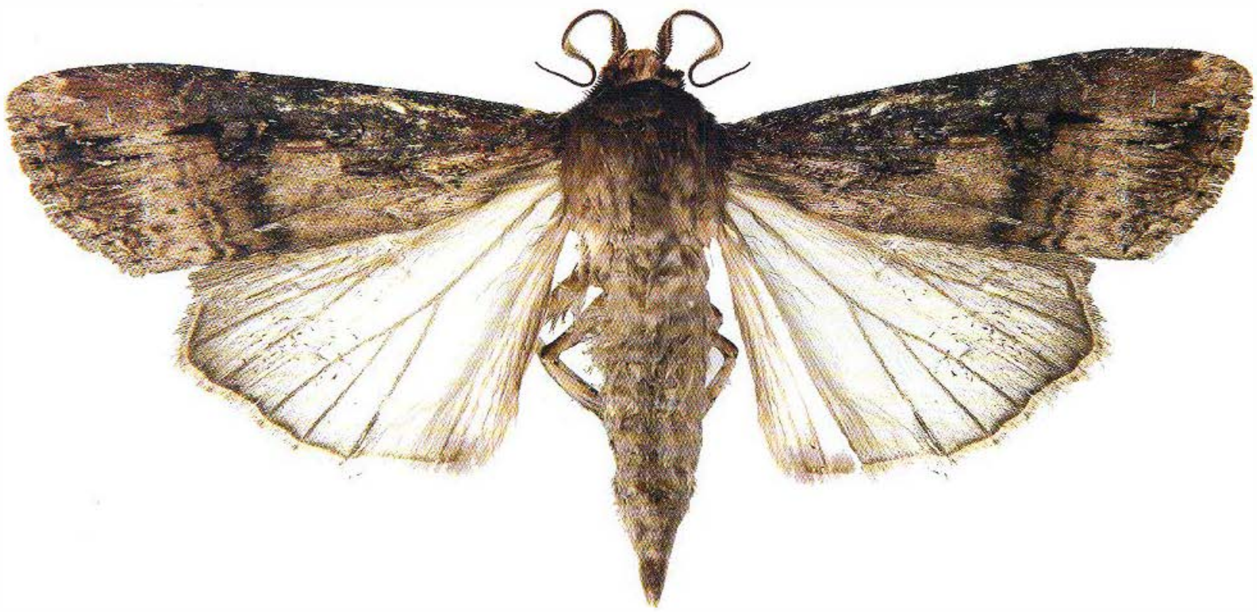


Plate 5a: The Black cut worm moth (*Agrotis ipsilon*) with spread wings.

Order: Lepidoptera
Family: Noctuidae
Scientific name: *Agrotis ipsilon* (Hufnagel, 1766); Plate 5.
Common name: Black cut worm moth
Arabic Name: فراشةالدودة القارضة
Habitat: Adults rest on plants and ground; and were observed resting on the trunk and under the canopy of Ghaf tree; immature stages on plants.
Feeding habit: Adults feed on nectar; immature stages feed on leaves of many wild plants.
Association trend with Ghaf tree: Adults resting on the trunk, and the larvae were found at the foot of the trees.

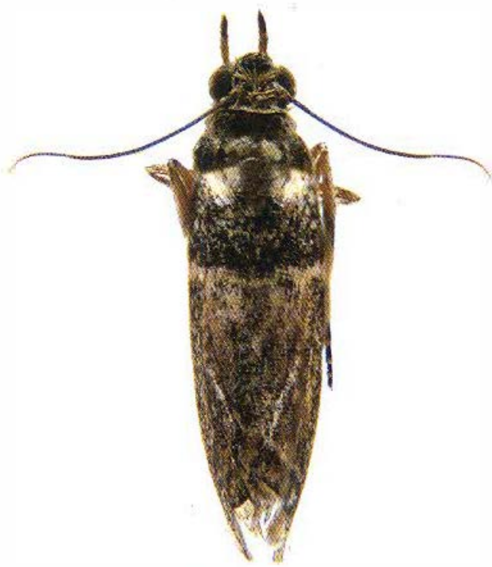


Plate 5b: Black cut worm moth (*Agrotis ipsilon*) with closed wings.

2- Wood Feeders

Order: Isoptera
Family: Rhinotermitidae
Scientific name: *Psammotermes hybostoma* (Desneux, 1904); Plate 6.
Common name: Sand termite
Arabic name: النمل الرمال الأبيض
Habitat: Observed nesting in soil and on trees inside the tunnels of wood boring beetles.
Feeding habit: Both adults and nymphs feed on wood of dead or life trees.
Association trend with Ghaf tree: The sand termites live inside the branches and use the tree for nesting, breeding and feeding.

Plate 6a: The sand termite (*Psammotermes hybostoma*) inside Ghaf tree wood.

Plate 6b: The sand termite (*Psammotermes hybostoma*).

3- Seed Feeders

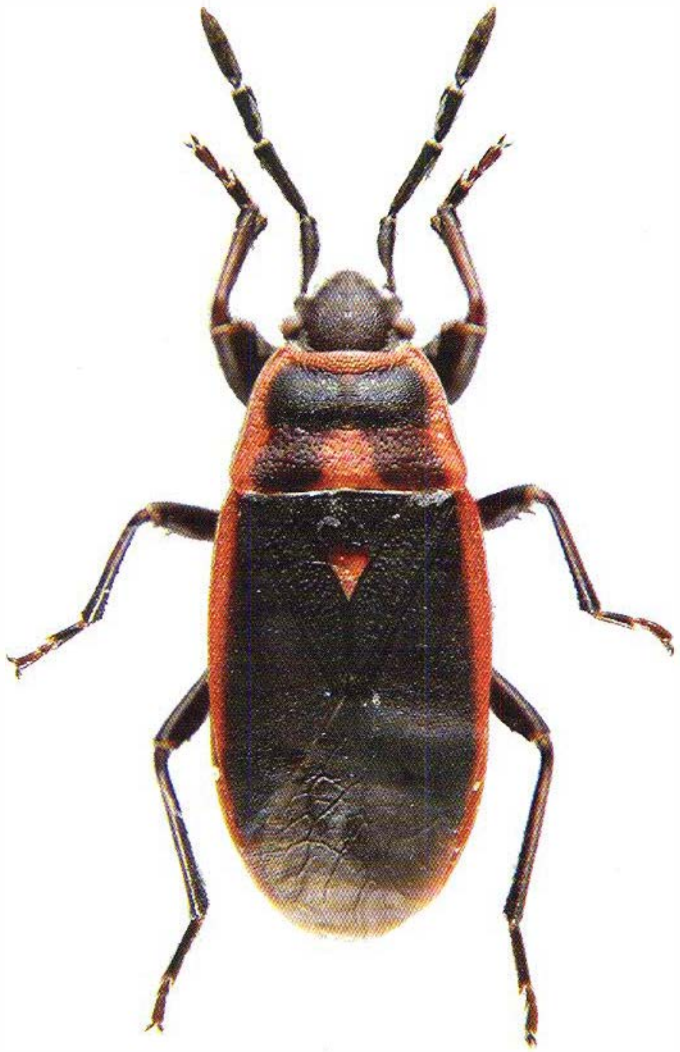


Plate 7 : The General features and habitat(see opposite) of the fire bug (*Pyrrhocoris* sp).

Order: Heteroptera
Family: Pyrrhocoridae
Scientific name: *Pyrrhocoris* sp.; Plate 7.
Common name: Fire bug
Arabic name: البق النارى
Habitat: Adults live in leaf litters and under stones.
Feeding habit: Both adults and nymphs feed on many kinds of seeds.
Association trend with Ghaf tree: Recorded under and beyond the canopy; they use the tree for hiding and resting.

Plate 8a: The Harvester ant (*Messor* sp.).

Order: Hymenoptera
Family: Formicidae
Scientific name: *Messor* sp.; Plate 8a.
Common name: Harvester ant
Arabic name: النمل الحصاد
Habitat: Adults build their nests directly into the earth in open ground. The nests have a crater-like entrance.
Feeding habit: Most species are mainly seed eaters.
Association trend with Ghaf tree: Found under and beyond the canopy; they use the tree for shading.

4- General Foragers

Plate 8b: The ant (*Tetramorium* sp.).

Order: Hymenoptera

Family: Formicidae

Scientific name: *Tetramorium* sp.; Plate 8b.

Common name: Ant

Arabic name: النمل

Habitat: Adults usually nest in decaying wood or in compressed leaf litter; while some are arboreal, few species nest directly into open ground.

Feeding habit: Most species of this genus are generalized foragers.

Association trend with Ghaf tree: Observed under the canopy and on branches; they use the tree for nesting and feeding.

Plate 8c: The ant (*Plagiolepis* sp.).

Order: Hymenoptera
Family: Formicidae
Scientific name: *Plagiolepis* sp.; Plate 8c.
Common name: Ant
Arabic name: النمل
Habitat: Nests are made under the bark of trees, in rotten wood or twigs or in hard-packed earth.
Feeding habit: Generalized foragers
Association trend with Ghaf tree: Observed under the canopy and on branches; they use the tree for nesting and feeding.

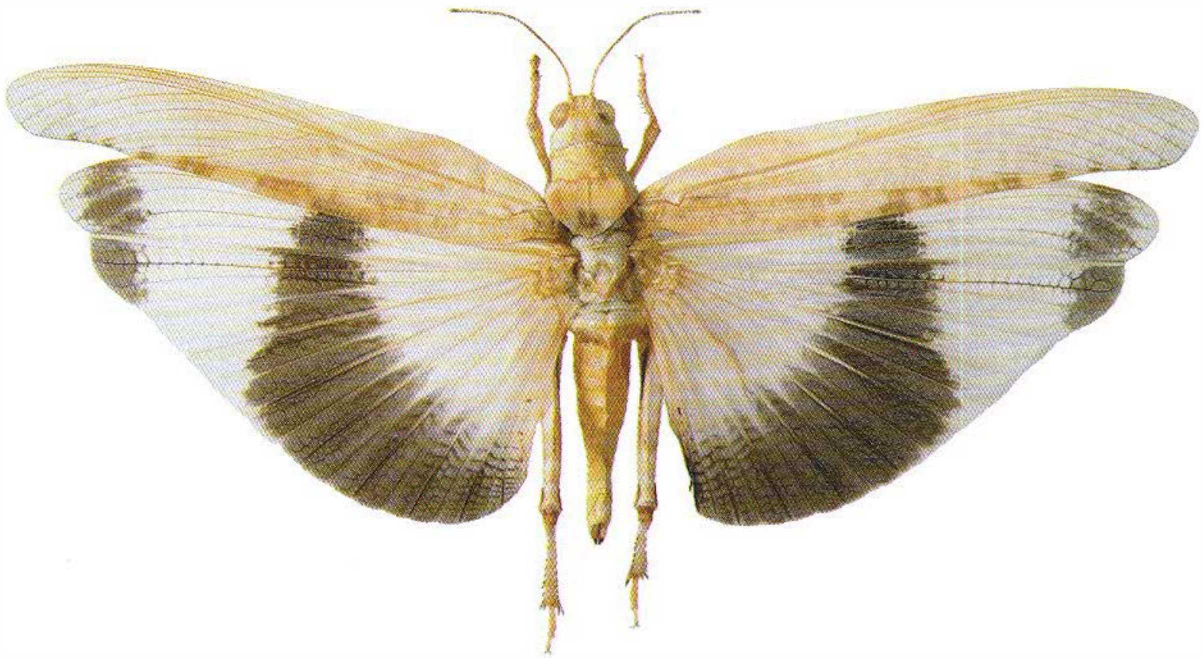


Plate 9a: The Desert grasshopper (*Sphingonotus savignyi*) with wings spread.

Order: Orthoptera
Family: Acrididae
Scientific name: *Sphingonotus savignyi* (Saussure, 1884); Plate 9.
Common name: Desert grasshopper
Arabic name: نطاط صحراوى
Habitat: Adults resting on the ground in the stony open area.
Feeding habit: Both adults and nymphs feed on a wide range of desert plants.
Association trend with Ghaf tree: Adults use the tree for shading and may be for feeding; more common beyond the canopy than under the crown.

Plate 9b : The desert grasshopper resting on stony ground.

5- Root Feeders

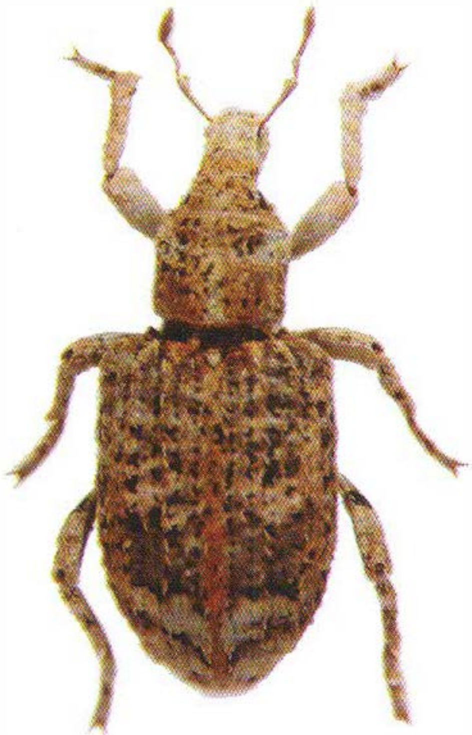


Plate 10a : The Weevil (*Callirus* sp.).

Order: Coleoptera
Family: Curculionidae
Scientific name: *Callirus* sp.; Plate 10a.
Common name: Weevil
Arabic name: سـوس
Habitat: Adults hide under stones, leaves and the litter under the crown of the Ghaf tree.
Feeding habit: Adults feed on roots of many wild plants.
Association trend with Ghaf tree: Adults use the under canopy for protection, food, and mating.

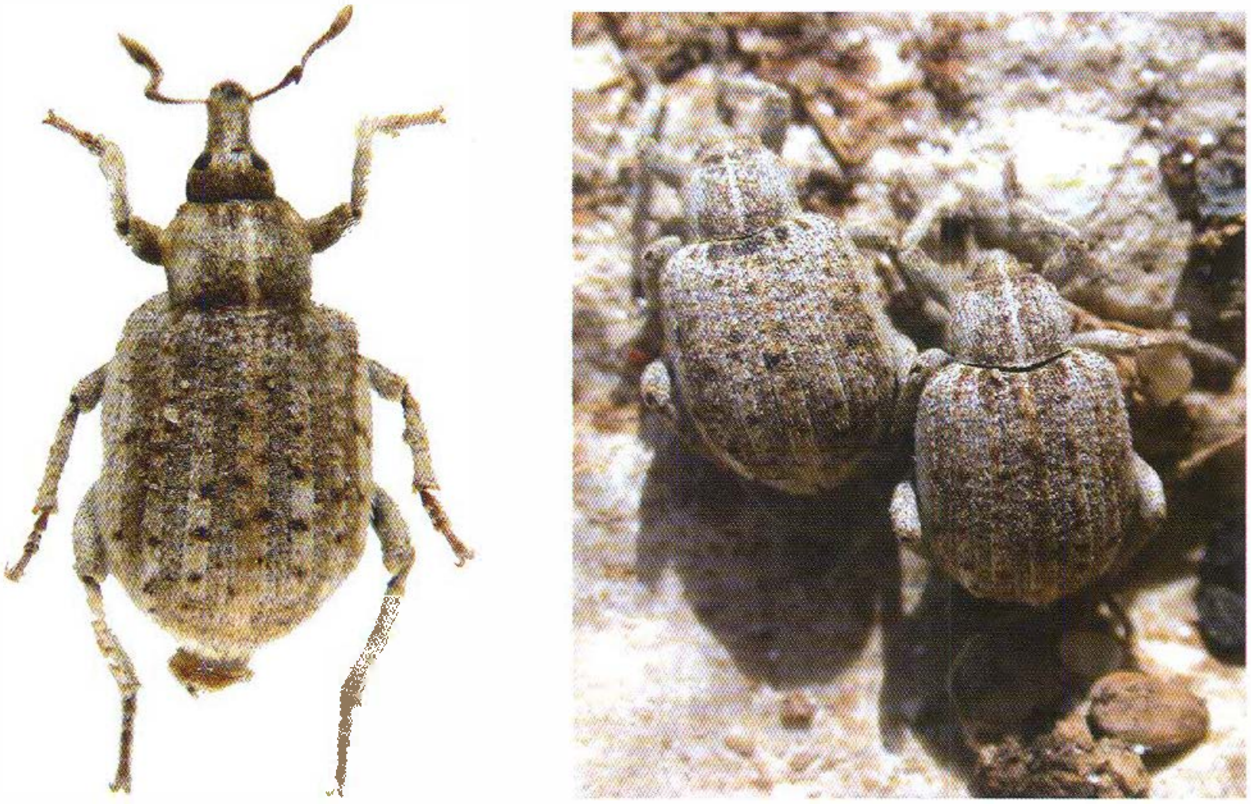


Plate 10b: The Weevil (*Hypera* sp.).

Order: Coleoptera
Family: Curculionidae
Scientific name: *Hypera* sp.; Plate 10b.
Common name: Weevil
Arabic name: ســوس
Habitat: Adults hide under stones and leaves' litter under the crown and at foot of the Ghaf tree.
Feeding habit: Feeding on roots of many wild plants.
Association trend with Ghaf tree: Adults use the under and beyond the canopy for hiding, feeding, and mating.

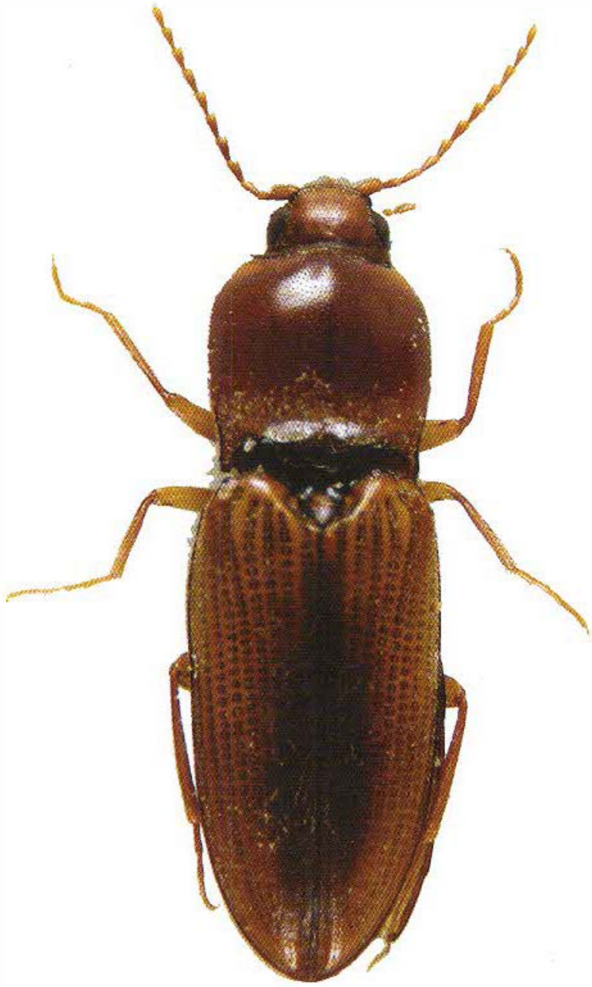


Plate 11: The Click beetle (*Isidus* sp.).

Order: Coleoptera

Family: Elateridae

Scientific name: *Isidus* sp.; Plate 11.

Common name: Click beetle

Arabic name: الخنفساء المفرقعة

Habitat: Adults live under debris.

Feeding habit: Adults feed on roots of plants.

Association trend with Ghaf tree: Recorded at the foot of trees which they use for breeding and feeding.

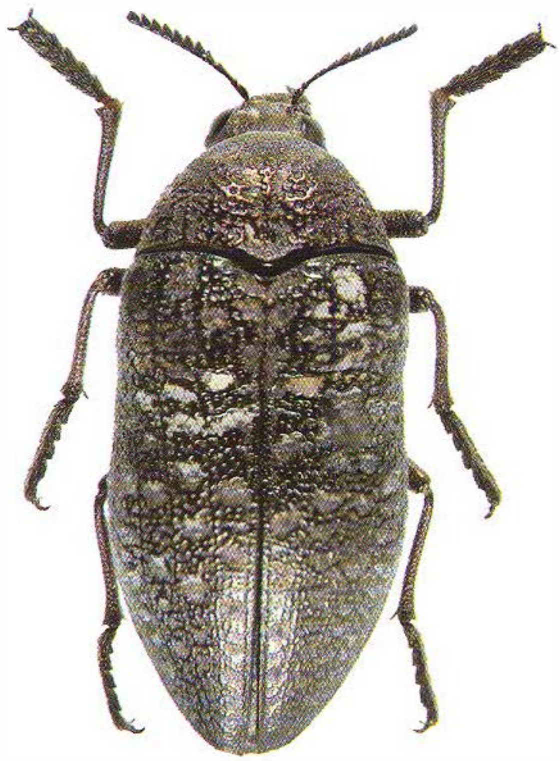


Plate 12: The Jewel beetle (*Julodis euphratica*).

Order: Coleoptera

Family: Buprestidae

Scientific name: *Julodis euphratica* (Cast. & Gory, 1835); Plate 12.

Common name: Jewel beetle

Arabic name: خنفساء الجوهرة

Habitat: Adults live on the branches, immature stages found on the ground close to the roots.

Feeding habit: Adults feed on leaves; larvae feed on roots.

Association trend with Ghaf tree:

Adults were observed on the branches and on the main trunk, using the trees for breeding, mating and feeding.

B- Predators

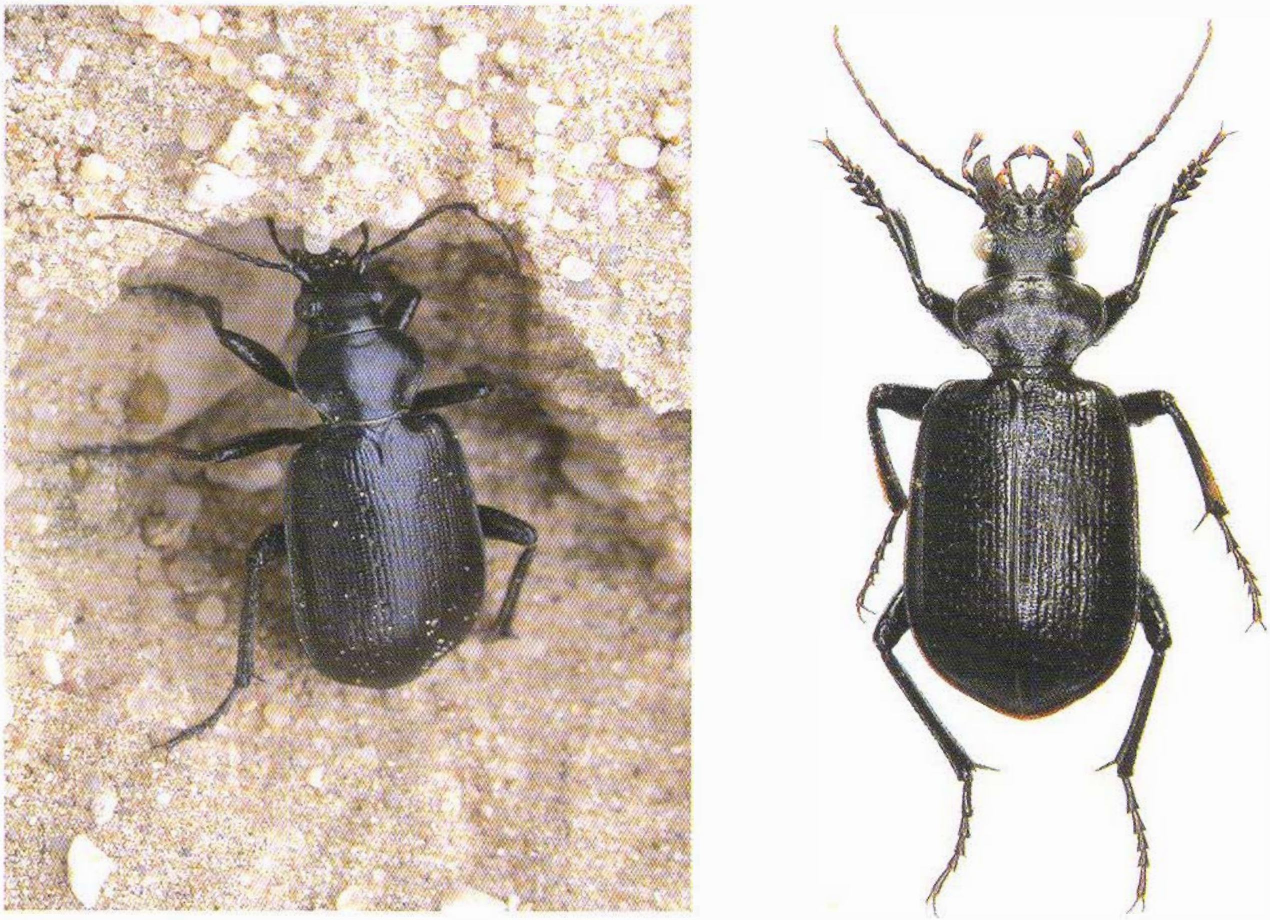


Plate 13a : The Ground beetle (*Calosoma chlorostictum*)

Order: Coleoptera
Family: Carabidae
Scientific name: *Calosoma chlorostictum* (Dejean, 1831); Plate 13a.
Common name: Ground beetle
Arabic name: خنفساء الكالوسوما
Habitat: Adults hide during the day under stones or plant debris, and become active during the night searching for their prey.
Feeding habit: Both adults and larvae prey on the larvae of many moths and butterflies and equally hunt bugs.
Association trend with Ghaf tree: Observed hiding beyond the canopy. They search the canopy's substrate for their prey.

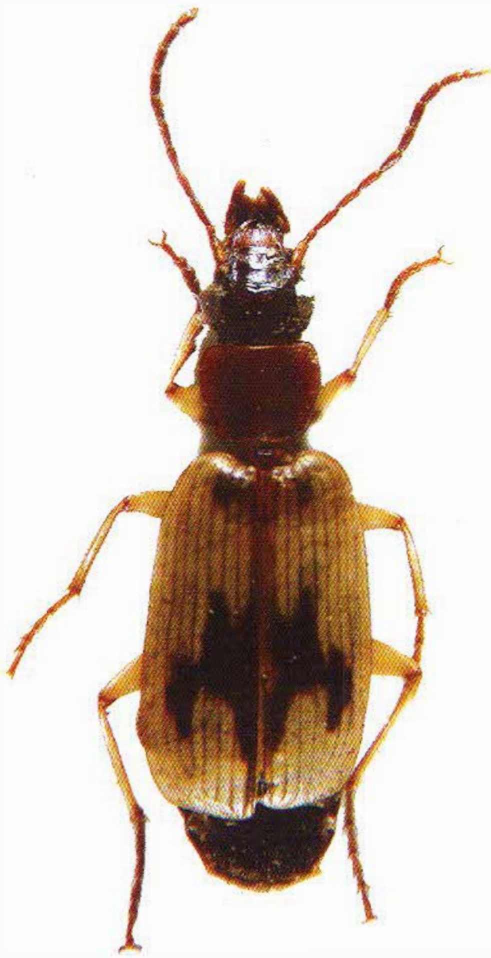


Plate 13b: The Ground beetle (*Glycia ornata*).

Order: Coleoptera

Family: Carabidae

Scientific name: *Glycia ornata* (Klug, 1831); Plate 13b.

Common name: Ground beetle

Arabic name: خنفساء جليشيا المزخرفة

Habitat: Adults live under stones and become active nocturnally.

Feeding habit: Predators of different insect species.

Association trend with Ghaf tree: Adults live under the canopy and use the tree as a store for their food.

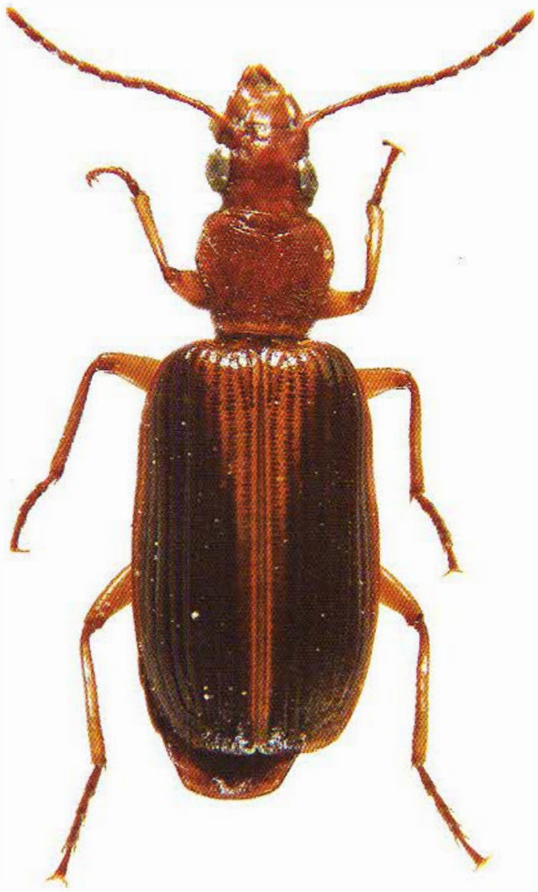


Plate 13c: The Ground beetle (*Trichis maculata*).

Order: Coleoptera
Family: Carabidae
Scientific name: *Trichis maculata* (Klug, 1831); Plate 13c.
Common name: Ground beetle
Arabic name: خنفساء تريكيس ذات اللطخة
Habitat: Adults live under stones and become active nocturnally.
Feeding habit: Predators of different insect species.
Association trend with Ghaf tree: Collected under the canopy. They use the tree as a store of their prey.

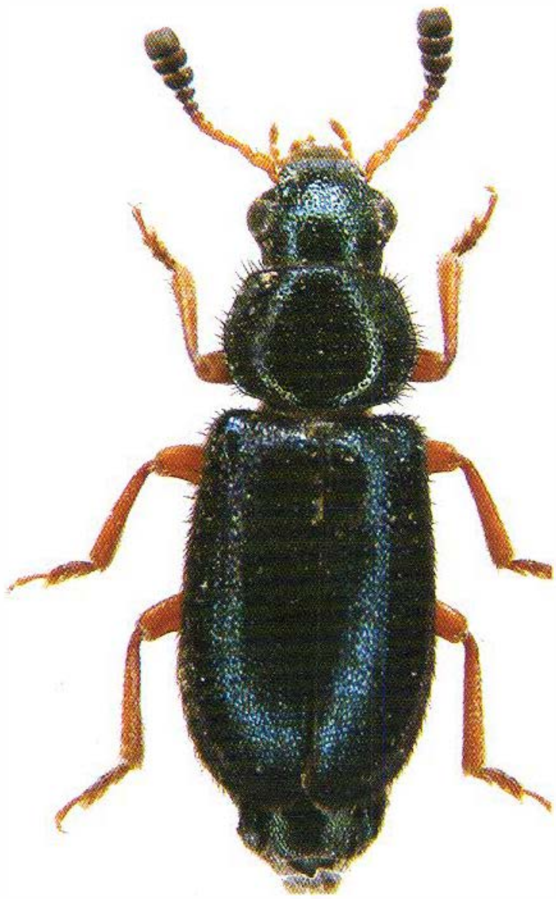


Plate 14: The Red-legged ham beetle (*Necrobia rufipes*).

Order: Coleoptera

Family: Cleridae

Scientific name: *Necrobia rufipes* (De Geer, 1775); Plate 14.

Common name: Red-legged ham beetle

Arabic name: الخنفساء الخنزيرية ذات الأرجل الحمراء

Habitat: Adults hide under decaying matter.

Feeding habit: Adults are saprophagous and predaceous.

Association trend with Ghaf tree: Recorded beyond the canopy and their relation with Ghaf needs further investigation.

Plate 15: The Hister beetle (*Saprinus* sp.).

Order: Coleoptera
Family: Histeridae
Scientific name: *Saprinus* sp.; Plate 15.
Common name: Hister beetle
Arabic name: خنفساء الهيستر
Habitat: Adults associated with carrion, manure, refuse, and decaying vegetable matter.
Feeding habit: Adults are predators feeding on other insects and larvae of flies.
Association trend with Ghaf tree: Recorded beyond the canopy and their relationship to Ghaf needs further investigation.

Plate 16: The Rove beetle (*Atheta* sp.).

Order: Coleoptera
Family: Staphylinidae
Scientific name: *Atheta* sp.; Plate 16.
Common name: Rove beetle
Arabic name: الخنفساء الرواغة
Habitat: Adults found under decaying material.
Feeding habit: Both adults and larvae are active aggressive predators which feed on small insects, spiders and mites.
Association trend with Ghaf tree: Recorded beyond the canopy and their relation with Ghaf needs further investigation.

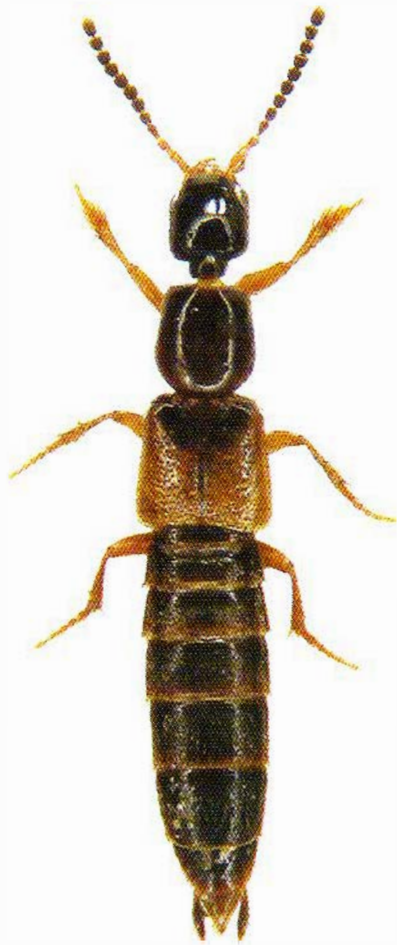


Plate 17: The Rove beetle (*Staphylinus* sp.).

Order: Coleoptera
Family: Staphylinidae
Scientific name: *Staphylinus* sp.; Plate 17.
Common name: Rove beetle
Arabic name: الخنفساء الرواغة
Habitat: Adults found under decaying material.
Feeding habit: Both adults and larvae are active aggressive predators, which feed on larvae of flies.
Association trend with Ghaf tree: Recorded beyond the canopy and their relation with Ghaf needs further investigation.

Plate 18: The Robber fly (*Apoclea* sp.).

Order: Diptera
Family: Asilidae
Scientific name: *Apoclea* sp.; Plate 18.
Common name: Robber fly
Arabic name: الذباب السارق
Habitat: Adults rest on the ground and between stones in the open area.
Feeding habit: Adults feed on flying flies and mosquitoes.
Association trend with Ghaf tree: Observed beyond the canopy, but use the tree as substrate for their prey and for resting.

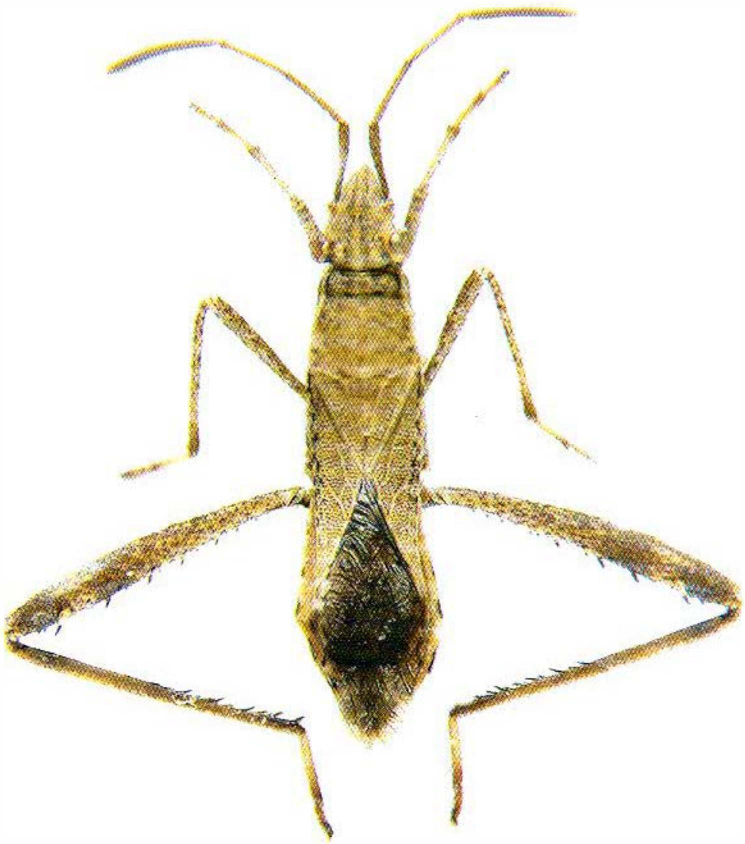


Plate 19 : The Assassin bug (*Reduvius* sp.).

Order: Heteroptera

Family: Reduviidae

Scientific name: *Reduvius* sp.; Plate 19.

Common name: Assassin bug

Arabic name: البق السفاح

Habitat: Adults live beneath leaves' litter and under the plant debris.

Feeding habit: Both adults and nymphs are predaceous, feeding on small insects.

Association trend with Ghaf tree: Recorded under the canopy; they use the tree for breeding, mating, and hunting.

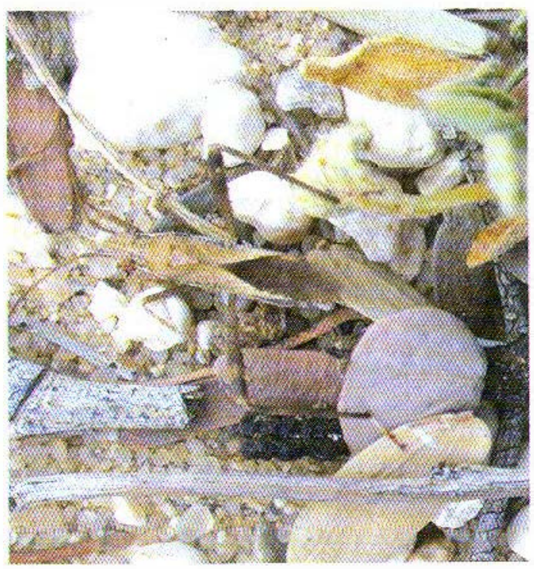


Plate 20a: The Sand wasp (*Bembix* sp.).

Order: Hymenoptera
Family: Sphecidae
Scientific name: *Bembix* sp.; Plate 20a.
Common name: Sand wasp
Arabic name: دبور الرمل
Habitat: Adults hover on the plants and rest on the ground. Females dig nests in the sand for their larvae.
Feeding habit: Adults hunt flies to supply the nest of their larvae with provision.
Association trend with Ghaf tree: Observed resting and hovering under and beyond the canopy, they use the tree as a shelter place and for capturing their prey.

Plate 20 b: The Hunting wasp (*Podalonia tydei*).

Order: Hymenoptera
Family: Sphecidae
Scientific name: *Podalonia tydei* (Le Guillou, 1856); Plate 20b
Common name: Hunting wasp
Arabic name: الدبور الصياد
Habitat: Adults nest in the soil and fly and hover around plants and rest on the ground.
Feeding habit: Adults feed on nectar, while the larvae feed on the larvae of moths mainly *Agrotis*. The females dig in search of *Agrotis* larvae, paralyze them and carry them to the nest.
Association trend with Ghaf tree: Observed hovering and resting beyond and under the canopy. Their use of the tree is indirect being the place where their prey hides.

Plate 21a : The Ant-lion (*Mortar* sp.).

Order: Neuroptera
Family: Myrmeleontidae
Scientific name: *Mortar* sp.; Plate 21.
Common name: Ant-lion
Arabic name: أسد النمل
Habitat: Adults hide under plants and stones during the day and become active during the night. Larvae live in conical pits in the earth.
Feeding habit: Larvae feed on ants.
Association trend with Ghaf tree: Adults use the tree for breeding, nesting and feeding. Larval conical pits were observed under and beyond the canopy.

Plate 21b : Conical pits of hidden larvae of Ant-lion

C- Parasites

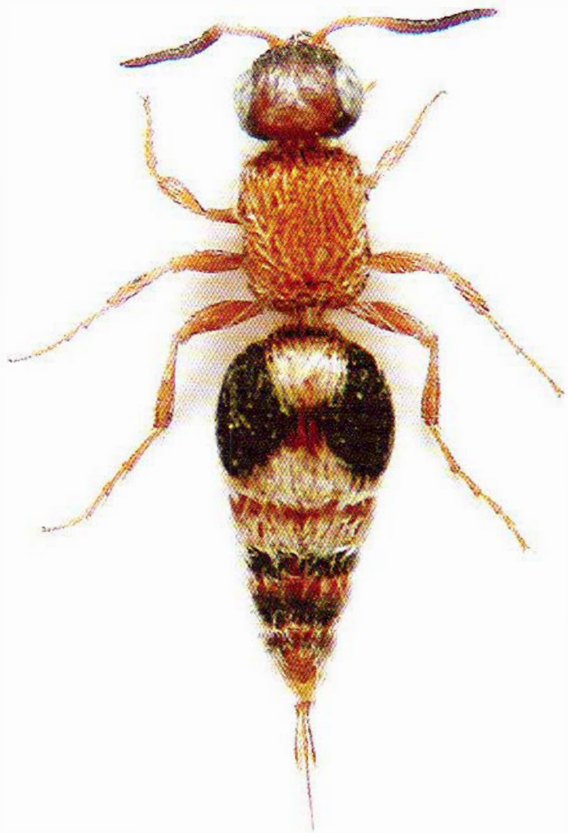


Plate 22: The Velvet ant (*Mutilla* sp.).

Order: Hymenoptera
Family: Mutillidae
Scientific name: *Mutilla* sp.; Plate 22.
Common name: Velvet ant
Arabic name: النمل القطيفي
Habitat: Adults live under stones.
Feeding habit: Adults parasitize on the larvae of solitary bees.
Association trend with Ghaf tree: Collected from beyond the canopy, and the tree may be considered as a place of its hosts.

Plate 23: The Grey flesh fly (*Wohlfahrtia* sp.).

Order: Diptera
Family: Sarcophagidae
Scientific name: *Wohlfahrtia* sp.; Plate 23.
Common name: Grey flesh fly
Arabic name: ذبابة اللحم الرمادية
Habitat: Adults hover and rest on plants, while the larvae live inside the bodies of their hosts.
Feeding habit: Larvae parasitize animals and cause myiasis.
Association trend with Ghaf tree: Adults observed on the trunk of the tree; they use the tree for resting and awaiting their hosts for oviposition.

Plate 24: The Bee fly (*Anthrax* sp.).

Order: Diptera
Family: Bombyliidae
Scientific name: *Anthrax* sp.; Plate 24.
Common name: Bee fly
Arabic name: ذبابة النحل
Habitat: Adults hover around plants, and lay their eggs on sand. After hatching the larvae migrate to the nests of solitary bees. They play an important role as pollinators.
Feeding habit: Adults are nectar feeders and the larvae are parasitic on solitary bees.
Association trend with Ghaf tree: Observed hovering beyond the canopy.

D- Detrivores

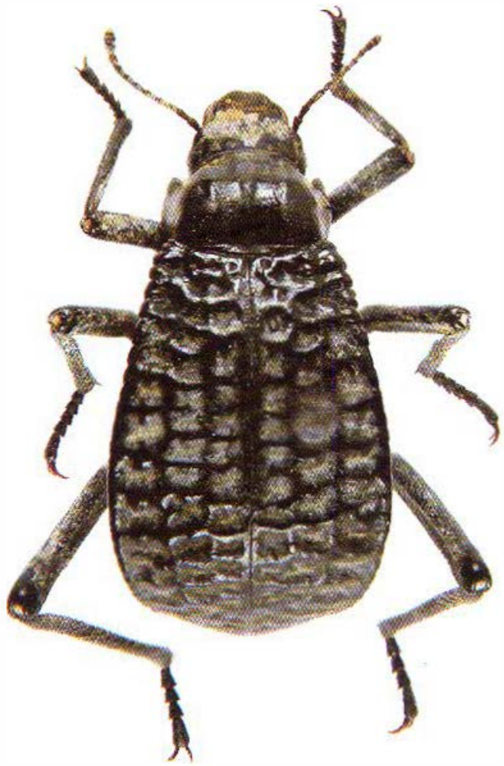


Plate 25 : The Desert beetle (*Adesmia cansellata*).

Order: Coleoptera

Family: Tenebrionidae

Scientific name: *Adesmia cancellata* (Klug, 1830); Plate 25.

Common name: Desert beetle

Arabic name: الخنفساء الصحراوية

Habitat: Adults active during the day time, seen moving on the ground around the plants, and hiding under the plants.

Feeding habit: Adults feed on any types of plant debris and litter.

Association trend with Ghaf tree: Observed foraging under and byeond the canopy.

Plate 26 : The Akis beetle (*Akis elevata*).

Order: Coleoptera
Family: Tenebrionidae
Scientific name: *Akis elevata* (Solier, 1836); Plate 26.
Common name: Akis beetle
Arabic name: خنفساء أكيس
Habitat: Adults live under stones in association with Ocnera hispida.
Feeding habit: Adults feed on dead plant material.
Association trend with Ghaf tree: Found under the canopy and use the tree for shelter and feeding on its litter.

Plate 27: The Darkling beetle (*Gonocephalum setulosum*).

Order: Coleoptera

Family: Tenebrionidae

Scientific name: *Gonocephalum setulosum* (Faldermann, 1837); Plate 27.

Common name: Darkling beetle

Arabic name: الخنفساء السوداء

Habitat: Recorded under stones and leaf litter. They associate with ants or with other darkling beetle species.

Feeding habit: Adults consume different dead plant parts.

Association trend with Ghaf tree: Collected under and beyond the canopy; they use the tree as a shelter and a source of food.

Plate 28: The Darkling beetle (*Mesostena puncticollis*).

Order: Coleoptera
Family: Tenebrionidae
Scientific name: *Mesostena puncticollis* (Solier, 1835); Plate 28.
Common name: Darkling beetle
Arabic name: خنفساء الأوبوسوم أو الخنفساء السوداء ذات الصدر المخرز
Habitat: Living under stones and plants.
Feeding habit: Adults feed on dead plant material, including Ghaf leaf litter.
Association trend with Ghaf tree: Observed under and beyond the canopy; they use the tree as a shelter and source of food.

Plate 29 : The Darkling beetle (*Ocnera hispida*).

Order: Coleoptera
Family: Tenebrionidae
Scientific name: *Ocnera hispida* (Forskal, 1775); Plate 29.
Common name: Darkling beetle
Arabic name: خنفساء أوكنيرا ذات الأشواك
Habitat: Adults hide under stones and plant debris.
Feeding habit: Adults feed on many plant parts.
Association trend with Ghaf tree: Recorded under and beyond the canopy; they use the tree as a source of shelter and food.

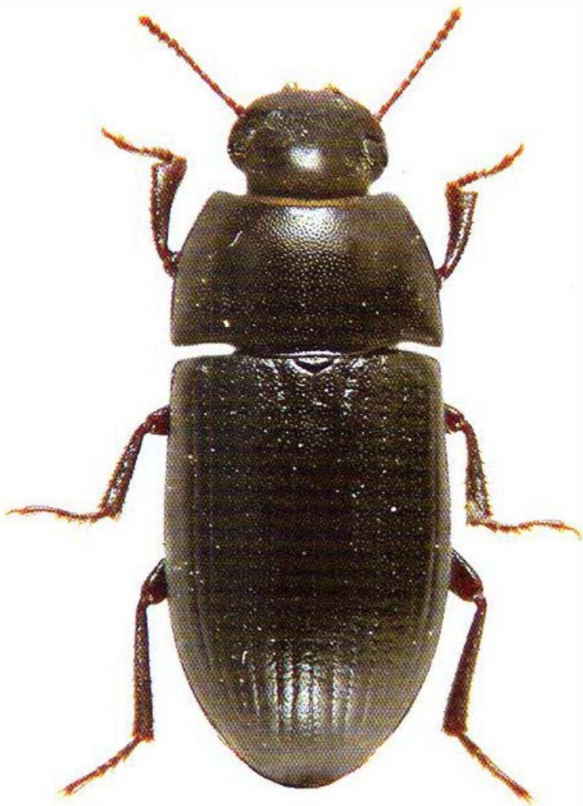


Plate 30 : The Darkling beetle (*Opatroides punctulatus*).

Order: Coleoptera
Family: Tenebrionidae
Scientific name: *Opatroides punctulatus* (Brullé, 1832); Plate 30.
Common name: Darkling beetle
Arabic name: خنفساء أوباترويدس المحززة
Habitat: Adults live under stones and plants.
Feeding habit: Adults feed on dead parts of different plants.
Association trend with Ghaf tree: Collected from under and beyond the canopy; they use the tree as a source of shelter and food.

Plate 31 : The Darkling beetle (*Pimelia* sp.).

Order: Coleoptera
Family: Tenebrionidae
Scientific name: *Pimelia* sp.; Plate 31.
Common name: Darkling beetle
Arabic name: خنفساء من جنس بيميليا
Habitat: Adults live under stones and plants.
Feeding habit: Adults feed on dead parts of different plants.
Association trend with Ghaf tree: Collected from under and beyond the canopy; they use the tree as a shelter and a source of food.

Plate 32 : The Blowfly (*Chrysomyia albiceps*).

Order: Diptera
Family: Calliphoridae
Scientific name: *Chrysomyia albiceps* (Wiedemann, 1819); Plate 32.
Common name: Blowfly
Arabic name: الذبابة الذهبية
Habitat: Adults and larvae live on carcasses. They prefer to breed in large carcasses (such as camel carcasses) as these contain more moisture and provide a large quantity of available food which is not subjected to immediate desiccation. This could be consumed by the larvae up to their full growth especially during the hot and dry months.
Feeding habit: Adult females feed on protein sources for the development of their ovaries and also obtain sugar from plant nectar, whereas the larvae feed on the carcasses.
Association trend with Ghaf tree: Observed hovering around, under and beyond the canopy; they may use the tree for resting.

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CHAPTER - 5

MICROBIOLOGICAL ANALYSIS OF *PROSOPIS CINERARIA* (L.) DRUCE IN THE STATE OF QATAR

By

Dr. Roda Fahad Al Thani

INTRODUCTION

This study covers 3 aspects regarding the association of microorganisms and the localized population of Prosopis cineraria at Al Ghafat. These are :

A- The Microbiology of the Rhizosphere.

B- The Microbiology of the Phyllosphere.

C- The Antimicrobial Activity.

5.A The Microbiology of Rhizosphere

5.A.1 Introduction: Scientific theories and studies on the microbiology of the rhizosphere

The term rhizosphere was coined by Hiltner in 1904 to describe the part of the soil that is influenced by plant roots. Originally the rhizosphere was thought to extend 2 mm outward from the root surface. Now it is accepted that the rhizosphere can extend 5 mm or more as a series of gradients of organic substrates, pH, O_2, CO_2 and H_2O. Essentially two regions of the rhizosphere are now recognized: (1) the rhizosphere soil and (2) the soil in direct contact with the plant root, which is termed the rhizoplane (Pepper, 1999). Microorganisms also inhabit the root itself and are known as endophytes.

The **rhizosphere** effect is caused by the release of organic and inorganic compounds from the plant roots. Substrates released from roots have many origins and were initially classified by Rovira *et al.* (1979) as:

* **Exudates**–compounds of low molecular weight that leak non-metabolically from intact plant cells.
* **Secretion s**–compounds metabolically released from active plant.
* **Lysates** –compounds released by the autolysis of older cells.
* **Plant mucilages**–polysaccharides from the root cap, root cap cells, primary cell wall , and others cells.
* **Mucigel** –gelatinous material of plant and / or microbial origin.

In natural vegetation systems, plant roots are in intimate contact with soil particles. Soil exists as a discontinuous environment with a matrix of organic and inorganic constituents combined in diverse conditions and is therefore a unique environment for many microorganisms. These organisms include viruses, bacteria, actinomycetes, fungi, algae, protozoa, and nematodes. Aerobic and anaerobic micro-sites exist in close proximity, allowing organic and inorganic substrates to be metabolized by organisms with different modes of nutrition. These conditions permit billions of organisms to coexist in soil (Whipps, 2001).

The components of this system (microorganisms, plant, and soil) interact with each other, which distinguishes the rhizosphere from the bulk soil. The activity of root microorganisms is affected by soil environmental factors or by environmental factors operating indirectly through the plant. Root microorganisms can affect the plant and plant nutrient uptake, directly by colonizing the root and modifying its structure or, indirectly by modifying the soil environment around the root.

Stimulation of bacterial growth is due to the release from plant roots of a vast range of organic materials, particularly carbohydrates, vitamins, amino acids and enzymes. Organic acids and lipids reduce the pH of the rhizosphere and also have a role in the chelation of metals (Curl and Truelove, 1985). Direct benefit to the plant is less easy to demonstrate but activities essential to plant growth, including mineralization and nitrogen fixation by free-living bacteria, are concentrated in the rhizosphere, (Whipps, 2001). Miscellaneous compounds including volatile substances can physiologically stimulate or inhibit organisms.

As the root cap extends through the soil, viable root border cells and some non-viable material (sloughed cells) are released into the soil. From the root tip to the root hair zone, the root is frequently covered with a layer composed of sloughed root border cells and polysaccharides of plant and microbial origin, which is termed mucigel (Miki *et al.,* 1980). These plant products are excellent substrates for microbial growth, in particular soil bacteria, which are extremely competitive at metabolizing simple sugars. Thus mucigel is in intimate contact with bacteria that consume the material, as well as bacteria that contribute bacterial polysaccharides to the mucigel. The amount of mucigel on a particular root depends on the net production and consumption of the material, so that in some instances parts of the root may have no mucigel. Mucigel may protect the root tip from injury and desiccation, as well as, playing a role in nutrient uptake through its pH dependent cation-exchange capacity.

Major factors affecting release of organic compounds include plant species and cultivars, age and stage of plant development, light intensity and temperatures, soil factors, plant nutrients, plant injury, and soil microorganisms (Pepper and Bezdicek, 1990; Wieland *et al.,* 2001). Because so many factors affect the release of compounds, generalizations are difficult, including the actual rate of exudation (Kennedy, 1997). However, it is known that plant genes control the release of root border cells (Hawes *et al.,* 1996).

Soils directly affect the growth and vigor of plants and therefore influence shoot growth, photosynthesis, and the amount of exudation into the rhizosphere. The concentration of oxygen in the rhizosphere is usually lower than in non- rhizosphere soil as a result of its utilization by large rhizosphere populations. Hence, in heavy textured soils oxygen may become limiting, resulting in reduced rhizosphere populations compared to coarser-textured soils. The physical environment around the plant and its roots also affects rhizosphere populations by affecting the amount of organic material released into the soil. Factors such as light, moisture, and temperature can all cause changes in plant metabolisms and the rhizosphere effect. In summary, rhizosphere populations are dependent on many diverse interacting factors, and care must be taken when interpreting different studies.

The rhizosphere effect is often evaluated in terms of R/S ratios, where R = the number of microbes in the rhizosphere and S = the number of similar microbes in bulk soil. Thus the greater the R/S ratio, the more pronounced the rhizosphere effect. R/S ratios are useful in delineating the rhizosphere effect, but they are only estimates and vary with different crop plants and different soil environments (Table 1).

Table.1 Numbers of microorganisms in the rhizosphere (R) of wheat (*Triticum aestivum*) and non rhizosphere soil (S) and their resultant ratio **R/S.**

Microorganisms	**CFU* g soil**		**R/S ratio**
	Rhizosphere	Nonrhizosphere	
Bacteria	120 x 10^7	5 x 10^7	24.0
Fungi	12 x 10^5	1 x 10^5	12.0
Protozoa	2.4 x 10^3	1 x 10^3	2.4
Ammonifiers	500 x 10^6	4 x 10^6	125.0
Dentrifiers	1260 x 10^5	1 x 10^5	1260.0

Source: Rouatt *et al.* (1960) *CFU, colony-forming units.

The genus *Prosopis* of the family Mimosaceae is recognized worldwide as a genus of economic importance and an excellent example of a multi-purpose tree found in many parts of arid and semi-arid environments (Al-Rawahy, *et al.*,2003). Out of several *Prosopis* species, P. cinearia (L.) Druce is the only indigenous species of this genus in the State of Qatar. This species in morphologically distinct from the alien species, *P. juliflora* (Schwartz) D.C. which has been introduced from the arid south west of the United States and from northwest Mexico. In the State of Qatar, *P. juliflora,* a fast growing tree, has been used in landscape plantation and as a hedge plant/wind breaker in many local farms. It is since spread all over the country.

5.A.2 Materials and Methods

5.A.2.1 Soil sampling and analysis

On the 12th of March 2005, two trees were selected (Table 2) at Al Ghafat area at Rawdat Rashid. After the removal of the surface deposits on the soil, soil samples were collected from under each tree as follows: surface soil to 5- cm depth; 15-20 cm depth below the basal insertion of the trunk of each tree.

The selection of the sampling locations and soil characterization is as in (part 3.2.3). The samples were replicated 4 times.

The soil sampled from 0-5 cm and from the rhizosphere were as follows:

- Centre (centre canopy soil)
- Intermediate (intermediate canopy soil)
- Outer (outer canopy soil).
- Rhizosphere (at 15 – 20 cm depth below the trunk)

Table 2. The soil samples and area of collection.

Sample no.	Soil Sample	Tree no.
1	5-cm depth, around the centre of the sub canopy near the basal insertion of the trunk (centre canopy soil).	1
2	15-20 cm under surface layer (rhizosphere).	1
3	5-cm depth, and 2 m distance from the tree. (intermediate)	1
4	5-cm depth, at 10-m distance from tree centre. (outer)	1
5	5 cm under surface layer, around the centre of the sub canopy near the basal insertion of the trunk (centre canopy soil).	2
6	15-20 cm under the surface layer (rhizosphere).	2
7	5 cm under the surface layer and 2 m from the tree. (intermediate)	2
8	5-cm depth, at 10-m distance from tree centre. (outer)	2

5.A.2.2 Bacterial plating assays

Soil dilutions were plated within 24 h of soil collection. A 1 g sub-sample of each soil sample was suspended in sterile water and made up to a final volume of 10 ml. One millilitre serial dilutions to 10,000-fold dilution were prepared. Aliquots (0.1 ml) of these dilutions were plated onto nutrient agar plates (NG). Two replicate plates were used for each one of the two soil dilutions for each soil sample. The final sample dilution on the plates was 10^4. Inoculated plates were incubated at 35° C for 3 days prior to counting the colony. Only plates with 30 to 300 colonies per plate were counted.

5.A.3 Results and Discussion:

The results of the soil characteristics in the different locations of the subcanopy and outside the canopy of *P. cineraria* trees were shown and explained previously (Fahmy, table 2, 3.3.6, this volume).

The percentages of soil moisture and total organic carbon were higher in soils from the centre and intermediate locations than those from the outer ones. The clay content of the soil from the centre location was much higher (6 % oven dry soil) than in the other two locations (2.5% oven dry soil). The observed high content of organic matter, soil nutrients, clay and moisture in the subcanopy locations (centre and intermediate positions) of *P. cineraria* trees of this investigation clearly affect the richness of the below canopy sites.

The soil populations of bacteria in the rhizosphere were quite different from the non-rhizosphere sites (Table 3). In the rhizosphere, both trees was 343 x 10^4 . The bacterial count in non-rhizosphere soil of the centre and intermediate canopy soil were lower than in the rhizosphere. The loweset bacterial count (863 x 10^3) occurred in the outer canopy soil.

Table 3. Number of bacterial colonies recorded from soil samples obtained from different locations in the rhizosphere, in the subcanopy (centre and intermediate positions) and outside the canopy (outer canopy soil).

Sample	Colony forming unit / g soil
Rhizosphere	343 x 104
Centre	316 x 104
Intermediate	312 x 104
Outer	863 x 103

It is apparent that the observed high content of organic matter, soil nutrients, clay and moisture in the subcanopy locations (rhizosphere, centre and intermediate positions) of P. cineraria trees of this study possibly favours the colonization of bacteria. This explains the occurrence of high number of colony forming units in the rhizosphere, in the centre and intermediate locations in comparison to the low counts in the outer location. It is well known that the root rhizosphere favours greater populations of bacteria in comparison to the non-rhizosphere sites (Bachman and Kinzel, 1992). Moreover, the presence of plant litter, animal droppings together with the already existed soil chemical nutrients in the subcanopy positions of *P. cineraria* trees possibly increase the enrichment of these patches. One of the best-documented spatial patterns of nutrient distributions in arid and semi arid ecosystems are the "islands of fertility" associated with shrubs and trees (Whitford, 2002).

Plate 1 and 2 show a number of discrete colonies with diverse morphology appearing after dilution and plating from soil samples.

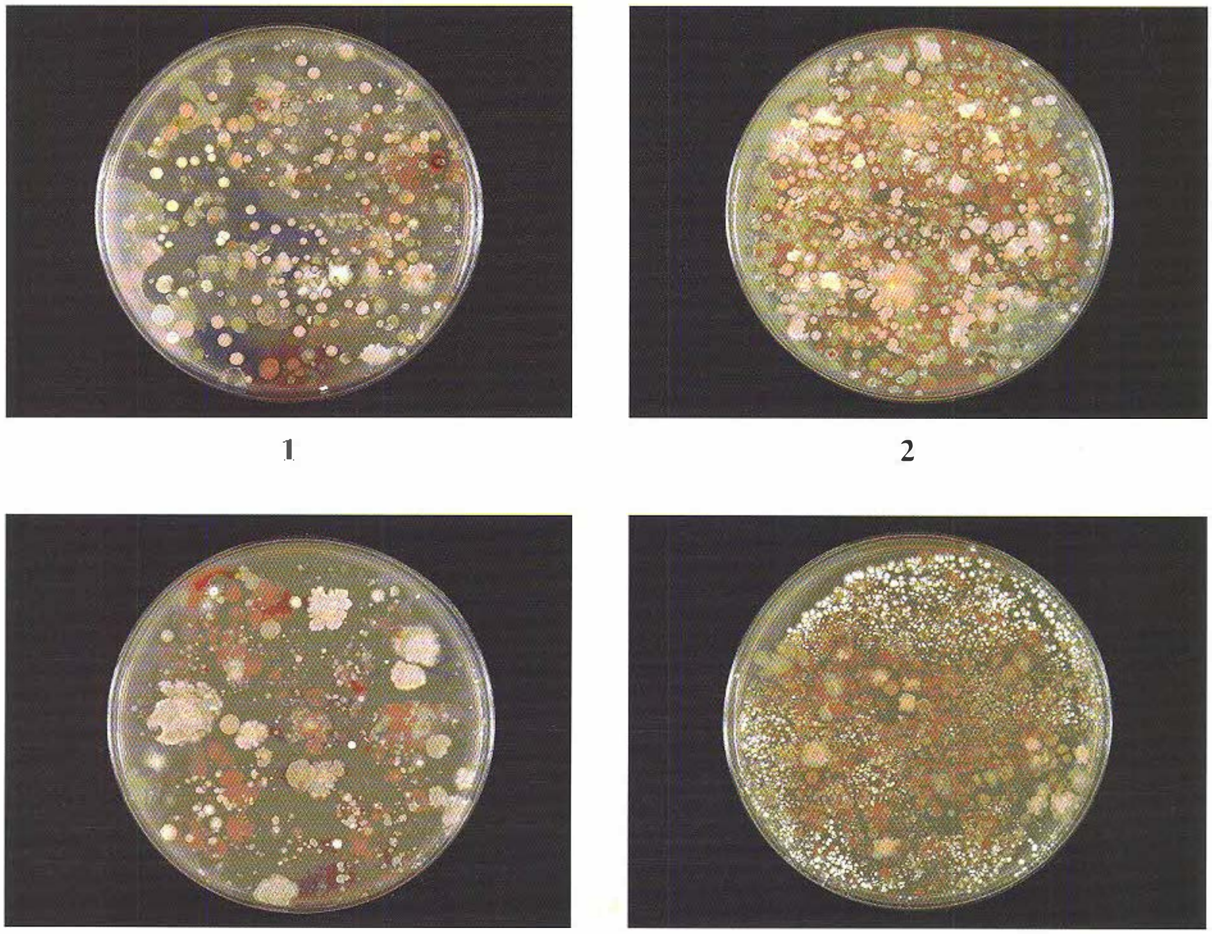
1

2

3

4

Plate 1. Bacterial colonies on nutrient agar plate isolated from Tree no.1, samples 1- 4. (1= rhizosphere, 2 = centre, 3 = Intermediate and 4 = outer canopy soil).



1 2

3 4

Plate 2. Bacterial colonies on nutrient agar plates isolated from Tree no.2; samples 1 - 4. Explanation of the numbers are shown in Plate 1 and in materials and methods section.

5. B - The Microbiology of Phyllosphere

5.B.1 Introduction: Scientific theories and studies on the microbiology of the phyllosphere

The above-ground parts of plants are normally colonized by a variety of bacteria, yeasts, and fungi. While a few microbial species can be isolated from within plant tissues, many more can be recovered from the surfaces of healthy plants. The aerial habitat colonized by these microbes is termed the **phyllosphere** and the inhabitants are called **epiphytes**. There has been some investigation of the colonists of buds and flowers (Andrews and Harris, 2000), but most work on **phyllosphere** microbiology had focused on leaves, a more dominant aerial plant structure.

The microbial communities of leaves are diverse and include many different genera of bacteria, filamentous fungi, yeasts, algae, and less frequently, protozoa and nematodes. Filamentous fungi are considered transient inhabitants of leaf surfaces, being present predominantly as spores, whereas rapidly sporulating species and yeasts colonize this habitat more actively. Bacteria are by far the most abundant inhabitants of the phyllosphere and the most numerous colonists of leaves, often being found in numbers averaging 106 to 107 cells/cm2 (up to 108 cells/g) of leaf (Hirano and Upper, 2000).

Epiphytic bacterial populations differ sharply in size among and within plants of the same species, as well as in close proximity, and over a short time as well as over a growing season (Thompson *et al.*, 1993). These considerable variations in population sizes are caused in great part by the large fluctuations in the physical and nutritional conditions characteristic of the phyllosphere. Equally, plant species appear to influence the microbial carrying capacity of the leaf, since the total number of culturable bacteria recovered from broad-leaf plants such as cucumber and beans was significantly greater than those recovered from grasses or waxy broad-leaved plants (Kinkel *et al.*, 2000). Reflective of the marked differences in the physio-chemical environments of above ground versus subterranean plant surfaces, the leaf bacterial flora differs substantially from that of roots. For example, pigmented bacteria, which are rarely found in the rhizosphere, dominate leaf surfaces (Fokkema and Schippers, 1986), presumably because solar radiation influences the ecology of the phyllosphere (Jacobs and Sundin, 2001). The differential composition of leaf and root bacterial communities is further evidenced by the failure of common root colonizers such as *Rhizobium* and *Azospirillum* to become established on leaves (Jurkevitch and Shapira, 2000).

The leaf surface has long been considered a hostile environment for bacterial colonists. The leaf surface is exposed to rapidly fluctuating temperature and relative humidity, as well as, repeated alternation between presence and absence of free moisture due to rain and dew. The leaf also provides limited nutrient resources to bacterial colonists. Several factors may influence the microhabitat experienced by bacteria on leaves. First, the leaf itself is surrounded by a very thin laminar layer in which moisture emitted through stomata may be sequestered, thereby alleviating the water stress to which epiphytes are exposed. Second, some cells in a leaf bacterial population, particularly in plant-pathogenic populations, may not reside in exposed sites on the leaf surface but instead may at least locally invade the interior of the leaf, avoiding the stresses on the exterior of the leaf by residing in substomatal chambers or other interior locations (Mercier and Lindow, 2000; Lindow and Brandl, 2003).

Studies on the composition of bacterial communities on leaves are numerous but rather limited in scope. It is generally believed that populations of culturable aerobic bacteria on leaves are dominated by a few genera. A few exhaustive studies of the variations in the microbial community of leaves over multiple time and space scales have provided important detailed knowledge about the identity and the ecology of bacterial leaf inhabitants (Jacques *et al.*, 1995).

Ercolani (1991), made an extensive inventory of culturable aerobic bacteria isolated from the surface of olive trees over six growing seasons and reported distinct bacterial community structures on leaves of the same age at a given time of the growing season. Thompson *et al.*,(1993), analyzed 1,236 bacterial strains from immature, mature, and senescent leaves of field-grown sugar beet over a complete growing season. They identified 78 species and 37 named and 12 unnamed genera of bacteria. They found distinct patterns of microbial colonization at different times of the year, with bacterial community diversity being lowest during the warmest and driest months of the season and highest during the cooler and rainy months. This was in agreement with the results obtained by Ercolani (1991).

Coincidentally, in both of the above described studies, communities on young leaves were composed of a greater number of taxa than those of old leaves. Thus, specific natural environments of the phyllosphere apparently select for the presence of specific genotypes within the leaf bacterial community. This is further supported by the finding that the acquisition by *Pseudomonas fluorescens* of plasmids that are indigenous to the leaf microflora coincided with a specific maturation stage of the plant over two consecutive years (Lilley and Bailey, 1997). This indicated that traits carried on these plasmids conferred variable selective fitness to specific plasmid-bacterial host combinations during the growing season, possibly in response to changing conditions in the phyllosphere habitat (Bailey *et al.*, 2002).

Thus, while some phyto pathogens may have the option of avoiding stresses, most other epiphytes apparently tolerate them in some way. Epiphytic bacteria, is a term which usually conveys the image of surface colonists of leaves. While a large majority of all bacterial colonists of plants are easily washed from leaves or killed by non penetrating agents such as peroxide or UV light, it is perhaps more fitting that epiphytic colonization be perceived as one which is somewhat more three dimensional than the planar process sometimes imagined. Therefore, the actual conditions to which epiphytes are exposed on leaves are probably quite different from those estimated from large-scale measurements of irradiation, humidity, etc (Yang *et al.*, 2001).

The surfaces of most plants are very tortuous at the small scales at which interactions with bacteria will occur. Epidermal cell produce bulges and troughs that will determine the shape and size of low areas on the surface, which in turn will influence the shape and spread of water droplets on the plant. The first contact between immigrating bacteria and a leaf normally occurs at the plant cuticle. This waxy layer, which has different three-dimensional crystalline structures on different plant species and can change as leaves ages, presumably in part due to microbial modifications (Knoll and Schreiber, 2000), limits passive diffusion of nutrients and water vapour from the plant interior onto the surface and defines the hydrophobicity of the leaf. These waxy cuticles have thus been thought to interfere with bacterial colonization of plants by limiting diffusion of nutrients and inhibiting the wetting of the leaf surface. Using maize mutants having epicuticular waxes altered in density or composition as well as in crystal structure. Beattie and Marcell, (2002) found that while attachment of bacterial cells to the cuticle was not substantially affected, bacterial establishment and maintenance on leaves was influenced in a complex manner; those glossy mutants with the fewest crystalline waxes were not the best hosts for epiphytic bacteria. Such results hint at small scale interactions between the plant and the bacterium that as yet are not understood.

The availability of carbon-containing nutrients on leaves is a major determinant of epiphytic colonization. Bacterial communities on well-fertilized plants are limited by carbon availability and only secondarily by nitrogen availability. Several studies have revealed that small amounts of nutrients can be washed from leaves. Simple sugars such as glucose, fructose, and sucrose are the dominant carbon sources on the plants that have been examined and are thought to simply leach from the interior of the plant (Mercier and Lindow, 2000). Several lines of recent evidence suggest that nutrient availability on leaves is highly spatially heterogenous. For example, chemical analysis revealed that about 0.2 to 10 μg of sugar (enough to support the growth of 10^7 to 10^8 cells/leaf) could be washed from uncolonized bean leaves. Substantial residual sugars could also be washed from leaves heavily colonized by bacteria, suggesting that nutrient resources may be spatially sequestered from epiphytes.

5.B.2 Materials and Methods

Prosopis leaves and bark were collected in sterile sample bags, stored in an ice box and transported to the laboratory for analysis. For phyllosphere analysis 10g of leaflets and bark were aseptically transferred into a flask with 9 ml of sterile water, shaken well and the appropriate serial dilutions were prepared. These were plated into nutrient agar plates to enumerate the bacteria. All samples were plated in duplicates, incubated at 35°C for at least 2-4 days. The number of colonies were recorded and the results of enumeration were reported as cfu./ g of leaves and bark on weight bases.

5.B.3 Restults and Discussion

Although many studies have examined the influence of environmental conditions and bacterial traits on bacterial colonization of leaves (Beattie and Lindow, 1999; Brandl and Lindow, 1998; Hirano and Upper 2000, Sundin and Jacobs, 1999; Yu *et al.*, 1999), few have examined the influence of specific plant traits. Some general traits, including the plant species, age, disease resistance, and nutrition can each influence the bacterial population size on the leaves. However, how these influences are mediated remains up to date unknown. The number of bacterial colonies on the phyllosphere for both trees [tree no.1 and tree no.2] are shown in Table 4. The results show that the bark of *Prosopis cineraria* trees was colonized by large number of bacteria in comparison to the leaves. Moreover, Gram-positive micro cocci and spore forming bacilli were the most dominant epiphytic forms on both the leaves and bark (data not shown). The pigmented bacteria (red, yellow and orange) were detected in the isolations from the leaves and the bark (Plate 3). Some bacterial colonies have diverse and characteristic morphology (Plate 3).

Table 4. Number of bacterial colonies recorded from leaves and bark of *P. cineraria.*

Sample	Tree no.	cfu/g
leaves	1	13×10^4
leaves	2	11×10^4
bark	1	288×10^4
bark	2	162×10^4

Fungal colonies with a number of discrete colonies and diverse morphology were also obtained. The genus Aspergillus seems to be the most abundant of the total fungal isolates, while the genera *Penicillium, Mucor, Alternaria, Absidia, Botrytis, Helminthosporium* and *Gliocladium* were detected as well but with very low representation (Plate 4).

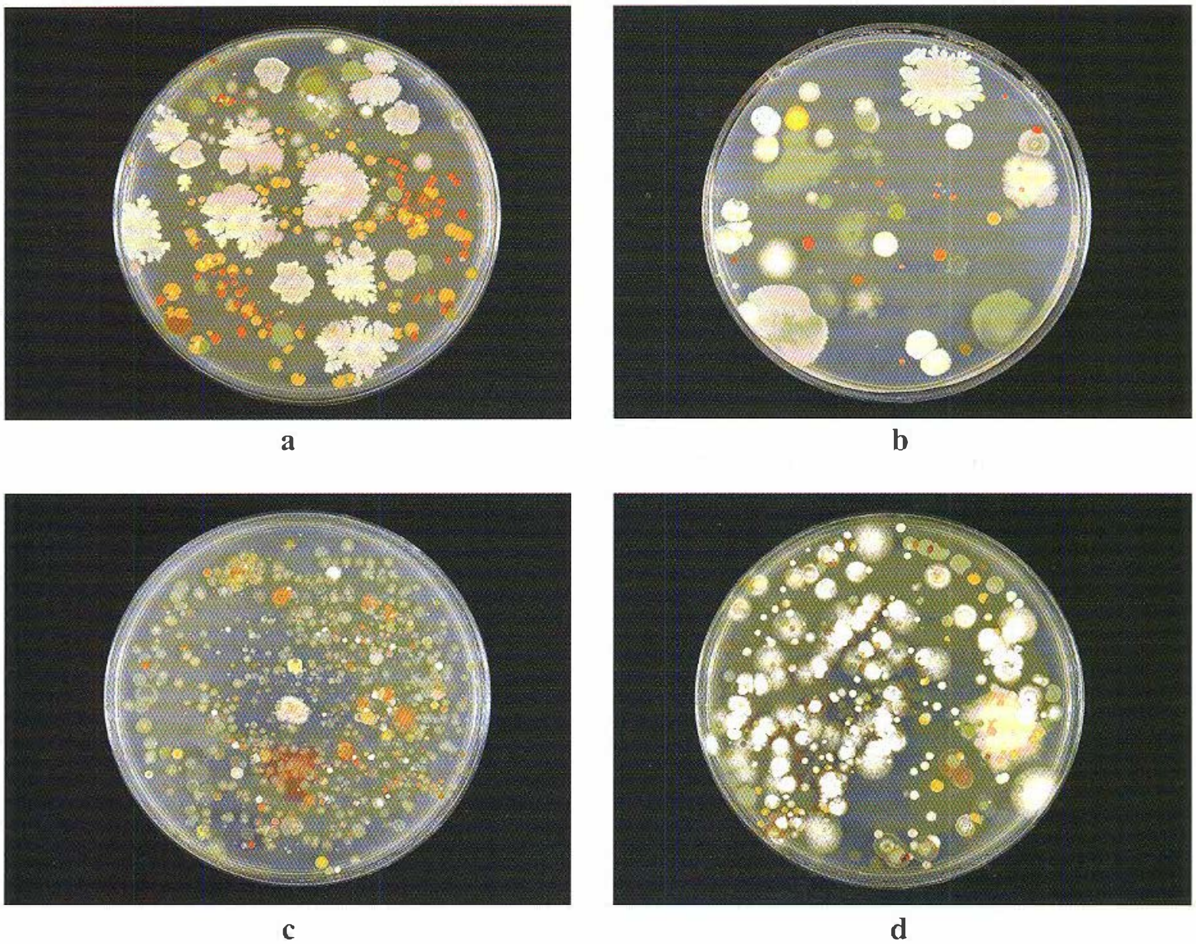
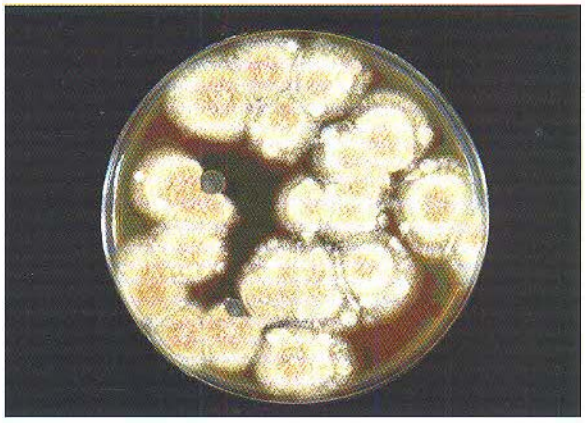


Plate 3. Bacterial colonies on nutrient agar plates isolated from Tree no. 1 (a. leaves, c. bark) and Tree no. 2 (b. leaves, d. bark).

a



b

Plate 4. Fungal colonies on a sabouraud agar plates isolated from Tree no.1(a) and Tree no. 2 (b).

5.C Antimicrobial Activity

5.C.1 Introduction: Scientific theories and studies on the antimicrobial activity of plants

Plants have an almost limitless ability to synthesize aromatic substances, most of which are phenols or their oxygen-substituted derivative (Cowan, 1999). Most are secondary metabolites, of which at least 12,000 have been isolated, a number estimated to be less than 10% of the anticipated total. In many cases, these substances serve as plant defense mechanisms against predation by microorganisms, insects, and herbivores. Some, such as terpenoids, give plants their odors; others (quinones and tannins) are responsible for the plant pigment. Many compounds are responsible for the plant flavor (e.g., the terpenoid capsaicin from chili peppers). Some herbs and spices used by humans to season food, also yield useful medicinal compounds.

According to Tshibangu *et al.*, (2002), plants have given western pharmacopoeia about 7000 different pharmaceutically important compounds and a number of top selling drugs of modern time, e.g. quinine, artemisinin, taxol, camptothecin, etc. Many reports show the effectiveness of traditional herbs against micro-organisms, as a result of which plants are one of the bedrocks for modern medicine to attain new principles (Evans, *et al.*, 2002). Conclusively, plants are valuable sources for new compounds and should receive special attention in research strategies to develop new antimicrobial compounds urgently required in the near future bearing in mind the present status of resistance of well known antibiotics.

Clinical microbiologists have two reasons to be interested in the topic of antimicrobial plant extracts, it is very likely that these phytochemicals will find their way into the arsenal of antimicrobial drugs prescribed by physicians; several are already being tested in humans. It is reported that, on average, two or three antibiotics derived from microorganisms are launched each year (Clark, 1996). After a downturn in that pace in recent decades, the pace is again quickening as scientists realize that the effective life span of any antibiotic is limited. Worldwide spending on finding new anti-infective agents (including vaccines) is on the increase. New sources, especially plant sources, are also being investigated.

Second, the public is becoming increasingly aware of problems with the over prescription and misuse of traditional antibiotics. In addition, many people are interested in having more autonomy over their medical care. A multitude of plant compounds (often of unreliable purity) is readily available over-the-counter from herbal suppliers and natural-food stores, and self-medication with these substances is common place. The use of plant extracts, as well as other alternative forms of medical treatments, is enjoying great popularity in the late.

The medicinal value of the genus *Prosopis* has been studied and its use as an astringent, demulcent and pectoral, anthelminitic, bronchitis, dysentery, refrigerant and a tonic has been reported. Leaves, bark, gum, roots, pods and seeds of Prosopis are used against a wide variety of diseases, wounds and burns. The bark contains a high content of tannins that are recommended for tanning (Khanuja *et al.*, (1999).

Dermititis has been reported from *P. juliflora* (Aqeel *et al.,* 1989). In the present study we seek evidence of antimicrobial activity since reports of use of *P. cineraria* as folk medicine are plentiful.

5.C.2 Materials and Methods:

5.C.2.a Preparation of plant material

The aerial plant parts (leaves, stem, and bark) were collected from trees growing at Al Ghafat. All samples were allowed to air dry in a sheltered area at a temperature of 35-40°C. When dry the samples were ground in a Wiley mill equipped with 2 mm sieve. The thoroughly mixed samples were then stored at ambient temperature in glass containers.

5.C.2.b Preparation of plant extracts

Plant extracts were prepared as described by Ahmed and Beg (2001) with little modification. For each sample, 100 g powdered plant material were soaked in 250 ml of 70% ethanol for 96 hours. Each mixture was stirred every 18 hours using a sterile glass road. At the end of the extraction, each extract was passed through Whatman filter paper No.1. The filtrate was concentrated on a rotary evaporator under vacuum at 35° C and stored at 4°C.

The percentage yield of the crude extract of each plant sample was determined in terms of mg of dry weight/100 g sample.

5.C.2.c Micro-organisms used and growth conditions

The test organisms used were the following strains :
Escherichia coli ATCC 35218 and ATCC 25922, *Pseudomonos oeruginosa* ATCC 27853, *Bacillus cereus*, ATCC 11778, *Staphylococcus aureus* ATCC 25923 and ATCC 25913, *Staphylococcus epidermides* ATCC 12228, methecillin resistant *S. aureus* (MRSA) ATCC43300, *Klebsilla pneumonia* ATCC 13883, and *Candida albicans* (Fungus) ATCC 98028. The bacteria were grown in nutrient broth at 37°C and maintained on nutrient agar slants at 4 °C.

5.C.2.d Anti-microbial assay

The agar well diffusion method (Perez *et al.*, 1990), as adopted by Ahmad and Beg (2001), was used. A 0.1 ml of diluted inoculums (105 c.f.u/ml) of the test organisms was spread on the nutrient agar (NA) and the sabouraud agar (SD) plates. Wells of 8mm diameter were punched into the agar medium and filled with 100 μl of the ethanolic plant extract (100 mg/ml). All plates were incubated for 18 hours at 37°C except for the test bacteria and *Candida albicans* plates which were incubated for 5-6 days at 28°C. The antimicrobial activity was evaluated by measuring the zone of inhibition against the test organism. The antibiotics, chloramphenicol and nystatin at 100 μl / ml conc. each were used in the test system as positive controls.

5.C.3 Results and Discussion

The antimicrobial activities of the ethanolic extracts of leaves, stems and bark of *P. cineraria* trees are presented in Table 5 and in Plates 5 and 6. The plant extracts tested inhibited the growth of various micro-organisms at 100 μl/well. Only alcoholic extracts were tested, as ethanol has been proven to be the most superior solvent for extraction of antimicrobial substances as compared to water and hexane (Ahmad *et al.*,1998). Broad spectrum antimicrobial activity (both antibacterial and antifungal) was detected among the crude extracts of *P. cineraria* (leaves and stems).

Aqeel, *et al.* (1989) noted that the inhibitory effect of julifloricine (an alkaloid isolated from *P. juliflora*) is significant against Gram-positive bacteria and insignificant on Gram-negative bacteria. Pena (1994) found that the fractions from the leaves of *P. vidaliana* were potential agents against some micro-organisms causing superficial bacterial and fungal skin infections and can be formulated into a non-irritating (safe), effective and stable ointment for skin infections.

The extracts of *P. cineraria* of this study were active against Gram-positive bacteria and yeast more than Gram negative bacteria. Extracts of the leaves, stems and bark demonstrated more antibacterial activity against *Staphylococcus epidermides* than *Staphylococcus aureus*. On the other hand, the extraction of the leaves was more efficient than the extraction of stems and bark against fungus. The bark extracts showed limited or no antibacterial/antifungal activity. The antimicrobial activity of *P. cineraria* has been reported earlier against selected organisms. However, these plant extracts have not been previously studied against such a wide variety of test pathogens.

In the present study, *S. epidermides, S. aureus* and MRSA were found to be the most sensitive bacterial strains, respectively. The basis of the varying degrees of sensitivity of the test organisms both of bacteria, and fungi may be due to the intrinsic tolerance of micro-organisms and the nature and combinations of phyto compounds present in the crude extracts. Two or more of the common phyto constituents, e.g. alkaloids, tannins, phenols, glycosides and flavonoids were detected in these active extracts. These major phyto compounds are known to have antimicrobial activity (Cowan, 1999).

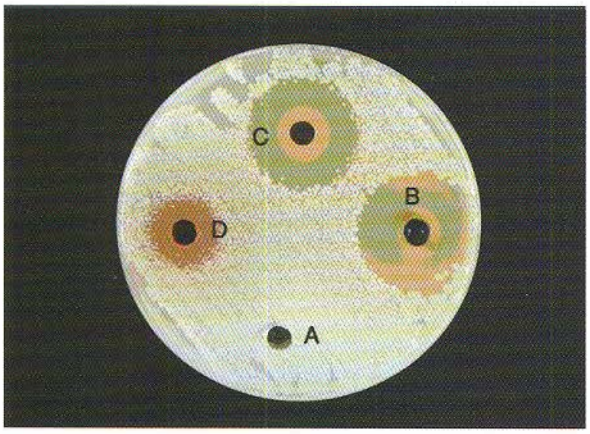
On the basis of the present investigations it has been shown that the plant extracts showed promising antibacterial and antifungal properties and could be developed and exploited against fungal and bacterial infections, at least for external use. Alternatively, the active principles of these extracts may be characterized and tested for their safety and efficiency to uncover their therapeutic potential in modern and traditional medicine against infectious diseases.

Table 5:Antimicrobial activities (cm inhibition zone diameter) of ethanol 70% and extracts of leaves stems and bark of *Prosopis cineraria* trees.

No.	micro organisms	code no.	Alcohol 70%	Leaves(B)	Stem (C)	Bark (D)
1	MRSA*	ATCC 43300	-	2.9	2.6	1.5
2	*C. albicans*	ATCC 98028	-	3	1.6	1.2
3	*K. pneumonia*	ATCC13883	-	-	-	-
4	*S .epidermidis*	ATCC12228	-	4.7	3.6	2.1
5	*P. aeroginosa*	ATCC 27853	-	1.1	0.8	0.6
6	*S. aureus*	ATCC 25913	-	2.6	2.5	1.5
7	S *aureus*	ATCC 25923	-	2.8	2.7	1.9
8	*E. coli*	ATCC 25922	-	1.2	1.6	0.6
9	*E .coli*	ATCC 35218	-	-	-	-
10	*B. cereus*	ATCC 11778	-	-	-	-

* methicillin resistant *S. aureus*

(-) no inhibition zone detected.



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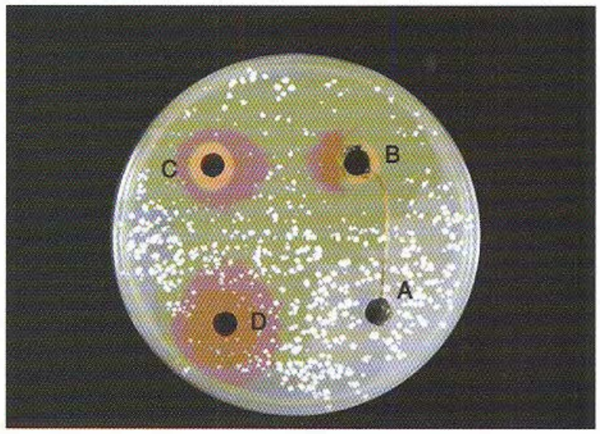

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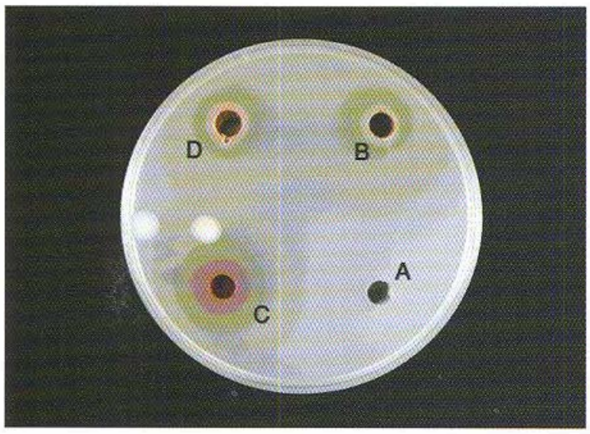

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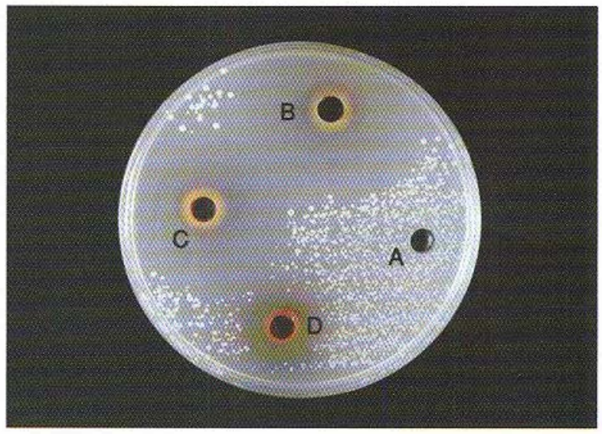

4

Plate 5. The anitimicrobial activities test of *Prosopis cineraria* extracts against the micro-organisms: 1. MRSA ATCC43300, 2. *Candida albicans* ATCC98028, 3. *Klebsilla pneumonia* ATCC13883 and 4. *S. epidermidis* ATCC 12228 on *P. cineraria* on the control (A), leaves (B), stems (C), and bark (D).

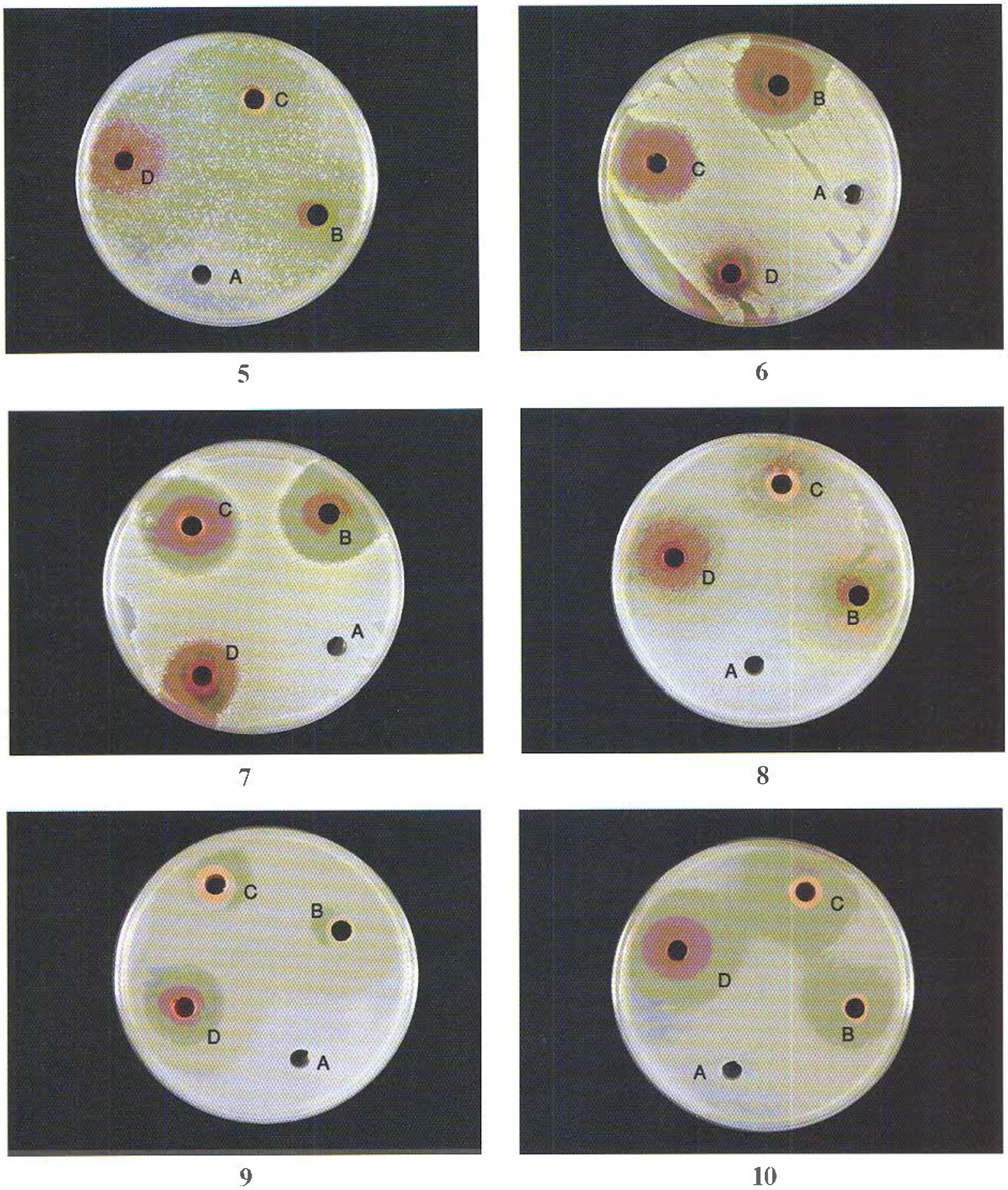

Plate 6. Antimicrobial activities of *Prosopis cineraria* extracts against the microorganisms : 5- P. aeroginosa ATCC 27853, 6- *S. aureus* ATCC 25913, 7- *S. aureus* ATCC 25923, 8- *E.coli* ATCC 25922, 9- *E. coli* ATCC 35218, and 10- *B. cereus* ATCC 11778.

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CHAPTER - 6

NATURALLY OCCURRING MINERAL EELEMENTS IN AL GHAF PLANT

By

Dr. Noora Jabor Al Thani

6.1 Introduction

Mounting pressure on the natural resources of the State of Qatar due to rocketing population rise has ushered in large-scale degradation of the environment and ecosystem, calling for immediate attention for seeking newer approaches in local practices and propagation of multipurpose trees in the existing systems to achieve multi-fold objectives. Moreover, crop productivity has been proven to enhance under tree canopy due to improved soil fertility (Young, 1989) and ameliorative influence of shade in a hot dry environment by reducing understorey temperature and mitigating evapotranspiration [Bunderson *et al.*, (1990)].

Prosopis cineraria (L.) Druce is a tree of arid areas. The tree is known locally as Al Ghaf (Arabic) and as Jandi or Khejri (India), Jand (Pakistan) (Plate 1). *Prosopis cineraria* is known as a multipurpose tree which provides fodder, fuel and shade and improves the soil and stabilizes sand dunes. It is extremely drought tolerant, growing in areas with an annual precipitation as little as 75mm. It grows in areas with long dry season and tolerates temperatures of up to 50° C, altitudes from sea level to 600m and a soil pH of up to 9.8 (Anonymous, 1999).

The tree is a deep-rooted species suitable for areas with low water tables. Its tap roots are reported to penetrate to depth of 25-36 m (Sardar, 1990). Because of its deep roots, it does not compete for moisture or nutrients with any growth particularly crops grown close to the trunk. This tree species was reported to be distributed at densities of 1.5trees/ha-1 and 28 trees per farm house in Rajasthan (Gupta, 1982). The canopy of this tree encourages the growth and above ground production of herbaceous flora in afforested and grazing lands (Sardar, 1990).

P. cineraria provides excellent firewood (calorific value, ca. 5,000 kcal/kg) and charcoal. Its wood is favored for cooking and domestic heating (Mahoney, 1990). The wood is hard and reasonably durable and has a variety of uses: house building, posts, tool handles, and boat frames.

Leaves of *Prosopis cineraria* are the most important animal feeding resource especially during the dry season since the leaf production rate occurs during the extremely dry summer months when other tree species are leafless.

The leaves are highly palatable and nutritious. Also the leaves are an available, excellent, and nutritious fodder, readily eaten by many other animals including camels and cattles. The *P. cineraria* leaves are an extremely important resource in desert areas such as Thar Desert of Rajasthan, India (Purohit and Khan, 1980) and the Sultanate of Oman (Brown, 1992) as the foliage is retained well into the dry season, after most of the surface vegetation has died back. Leaves contain 13.8% crude protein, 20% crude fiber, and 18% calcium (FFN 1991). The pods also provide a good fodder, containing a dry,

An individual tree of *Prosopis cineraria* population growing in Al-Ghafat area in Rawdat Rashid.

sweet pulp. Pods are eaten as a vegetable in the human diet in some areas. In Rajasthan, green pods called sangri are boiled and dried (FFN 1991).

Prosopis leaves and pods are eaten by many animal species and the tree produces leaves during the extremely dry summer months, when most other trees are leafless. A moderate sized tree may yield 45 kg of dry leaf fodder per year (Anonymous, 1999). The pods readily drop from the trees when ripened and they also provide good fodder. The unripe pods of *P.cineraria* are used as a feed supplement (Purohit and Khan, 1980; Brown, 1992). In an earlier study, adverse effects of *Prosopis* tannins on nutrient intake and angria ion in sheep were reported (Prasad *et al.*, 1997). Pods and leaves have been reported to contain 15.7% and 12.1% CP (crude protein), 15.1% and 20.1% CF (crude fiber), 8% and 3.2% EE (ether extract) and 13.8% and 12.2% ash, respectively (El Hag *et al.*, 2000).

The heartwood of *Prosopis* contains sugars, flavonones, fatty acids, and tannins (Burkart, 1976). Fresh leaves (ZMB)(zero moisture basis) contain 15.3%CP, 17.5%CF, 10.0% ash, 3.2%EE, 54.0%NFE, 2.65%Ca, and 0.24%P (Gohl, 1981).

The flowers are valuable for honey production. The bark yields an edible gum. The bark and flowers are used medicinally. In times of famine, the powdered bark has been mixed with flour and made into cakes (Bhandari 1978), (NAS 1980).

P. cineraria can withstand periodic burial (Gates and Brown, 1988). Because of its deep taproot, Al Ghaf trees are not believed to compete for moisture or nutrients with crops grown close to the trunk. During the growing season it casts only light shade and is therefore suitable as an agroforestry species. Farmers in semi-arid regions of India and Pakistan have long believed it increases soil fertility. Yields of sorghum or millet increased when grown under *P.cineraria,* as a result of high organic matter content, total nitrogen, available phosphorus, soluble calcium, pH in the soil (Mann and Shankarnarayan, 1980).

The aim of the present investigation is to analyse different plant parts of Prosopis cineraria trees for naturally occurring mineral elements and their concentration in leaves, stem and bark (macroelements, as well as, trace elements). Most of these elements are important as food supplements of many domestic animals. A number of the inorganic elements are regarded as absolutely essential to all of Life's *processes* (Table 1). Ensuring that the diets of the domestic animals contain the appropriate amounts and ratios of these essential macro and trace (micro) elements is a life long worry for animal herders and breeders. The essential elements are vital to the structure and/or operation of the metabolic machine and must be present in fairly constant concentrations in healthy tissues of all living animals. A deficiency of these elements in an otherwise nutritionally adequate diet can lead to very diverse and indefinite metabolic abnormalities.

Table 1. Macro- and micro- essential mineral elements.

No.	MACRO ELEMENTS
1	Calcium
2	Magnesium
3	Potassium

No.	MICRO ELEMENTS
1	Iron
2	Copper
3	Manganese
4	Zinc
5	Cobalt
6	Sulphur

Table 1. Contd..

4	Sodium
5	Chlorine
6	Molybdenum
7	Phosphorus

7	Fluorine
8	Iodine
9	Selenium
10	Chromium
11	Tin
12	Vanadium
13	Nickel
14	Silicon

Two categories are recognized: Macro- and microelements. Macroelements together account for 3.45% of the body weight and each is present in the body at a ratio of at least 50mg to one kilogram of body weight. Microelements, on the other hand, or as their other name "trace elements" shows, appear in minute quantities in the body, that is, considerably less than 50mg per kilogram of body weight.

It must be noted that the same element can either be essential or toxic to the organism, depending on the amount ingested.

6.2 Materials and Methods

6.2.1 Plant material

Fresh aerial parts of Prosopis *cineraria* were collected from Al Ghaf trees growing in the vicinity of Rawdat Rashid. The plant material was sorted into three groups: leaves, stems and bark. The plant material was air-dried, powdered, homogenized and stored in glass containers.

6.2.2 Plant material analysis

The dried leaves, stem and bark samples were digested by Microwave technique (speed wave MWS-2). The elements in the samples were measured by inductively-coupled plasma mass spectrometry (ICP/MS) model (Agilent 7500c with Octopole Reaction System). ChemStation software was used for data manipulation and a multi-element standard was used for calibration. The analyes were focused on the content of elements. (Table 2).

6.3 Results and Discussion

The results of the analysis of ICP/MS are given in Table (2) for the leaves, stems and bark.

Table 2: The contents of 24 elements (μgg-1 dry weight) in the different parts of *Prosopis cineraria* trees.

No.	Element	leaves	stems	bark
1	K	5.61	5.13	4.06
2	Ca	9.32	3.74	9.89
3	Mg	4.99	3.29	4.32
4	Zn	144.55	36.61	13.49
5	Mn	47.01	14.79	41.26
6	Cu	22.5	18.31	11.51
7	Ni	4.01	2.097	3.46
8	Co	0.46	0.13	0.38
9	Fe	1.35	0.44	1.16
10	Na	7.89	6.61	4.61
11	Al	2.41	0.74	1.92
12	Ti	0.45	0.33	0.49
13	V	3.41	1.55	2.82
14	Pb	3.66	2.24	1.66
15	Hg	0.52	0.28	0.36
16	Ba	25.21	22.85	27.82
17	Se	9.88	6.37	24.14
18	Li	29.96	4.59	8.68
19	Cr	5.16	2.14	3.73
20	Rb	2.16	1.05	1.73
21	Cd	1.19	1.15	1.03
22	Cs	0.15	0.14	0.15

The analysed elements can be classified into the following four catogories:

* Main elements [Sodium (Na), Magnesium (Mg), Potassium (K) and Calcium (Ca).].
* Essential trace elements [Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Vanadium (V), Chromium (Cr) and Selenium (Se).].
* Non-essential elements [Lithium (Li), Aluminum (Al), Thallium (Ti), Rubidium (Rb), Cesium (Cs) and Barium (Ba).].
* Toxic elements [Cadmium (Cd), Mercury (Hg) and Lead (Pb).].

The contents of elements in the different parts of the plant and their importance to plants life is explained as follows:

Potassium (K): Potassium was detected in Prosopis cineraria, in the bark, stem and leaves in the range of [4.06 μgg^{-1} , 5.13 μgg^{-1} 5.61 μgg^{-1}], respectively.

Potassium is regarded as a macronutrient which is necessary in the formation of sugars, starches, carbohydrates, protein synthesis and cell division in roots and other parts of the plant.

It helps in adjusting the water balance, improves stem rigidity and cold hardiness, enhances flavor and color of fruit and vegetable crops and increases the oil content of fruits. It is important in leafy crops and deficiencies result in a low yield, mottled, spotted or curled leaves and a scorched or burned appearance.

In animals potassium regulates the osmotic pressure and the acid-base balance but from within the cells, whereas sodium carries out these functions in the extracellular.

Sodium (Na): Is involved in osmotic (water movement) and ionic balance in plants. Hence its concentration level in leaves (7.89 μgg^{-1}) and stem (6.61 μgg^{-1}) is expected to be higher than in the bark (4.61μgg^{-1}). The results obtained confirmed this fact.

Sodium is found in the extracellular fluids, and therefore (together with chloride) is responsible for the regulation of the osmotic pressure outside the cell.

A sodium deficiency will adversely affect appetite and normal increase in weight and cause low blood pressure, rough coat and cardiac troubles.

Calcium (Ca): The calcium levels in leaves and bark were much higher (9.32 μgg^{-1} and 9.89 μgg^{-1} respectively) than those found in the stem (3.74 μgg^{-1}) .

Calcium plays an important role in the structure and function of living cell. It activates enzymes and is an important structural component of the cell walls. It influences water movement in cells and is necessary for cell growth and division. Some plants must have calcium to take up nitrogen and other minerals. Calcium is easily leached and once deposited in plant tissue, it is immobile (non-translocatable); so there must be a constant supply for normal growth. Deficiency of calcium causes stunting of new growth in stems, flowers and roots. Deficiency symptoms range from distorted new growth to black spots on leaves and fruit. Yellow leaf margins may also appear.

In animals the nutritional role of calcium is closely related to that of phosphorus, and therefore they are usually considered together. Together they form the chief elements of the skeleton; 99% of the calcium and about 80% of the phosphorus found in the body are located in the bones and teeth.

Calcium's main function consists of forming bones and teeth and it is also present in soft tissues where it carries out a number of regulatory functions in the body such as stimulating muscle contractions, making it important to the work of the heart. Besides bones and teeth, the greatest concentration of calcium is found in the blood. All of the larger animals have 10mg of calcium per 100ml of serum. The vital minimum level of calcium in the serum is not regulated by the amount of calcium ingested, but by that which is mobilized from the bones, which act as a calcium reserve.

Magnesium (Mg): Magnesium was found in concentration levels of 4.99 $\mu g g^{-1}$ and 4.32 $\mu g g^{-1}$ in leaves and bark respectively which were much higher than these detected in stem (3.29$\mu g g^{-1}$).

Magnesium is a critical structural component of the chlorophyll molecule and is therefore necessary for the functioning of plant enzymes to produce carbohydrates, sugars and fats. It is equally vital in fruit and nut formation and is essential for seed germination. Magnesium deficient plants appear chlorotic, show yellowing between veins of older leaves or the leaves may drop. Magnesium is leached by watering and must be supplied in plant feeding. It can however be applied as a foliar spray to correct its deficiency.

In animals about 60% of the body's magnesium is found in the skeleton. The remaining 40% is scattered throughout the body fluids. Magnesium activates many enzyme systems, particularly those concerned with carbohydrate metabolism. A normal blood count depends on magnesium to a great extent; for example 100ml blood serum contains 1-3mg of magnesium.

Diets extremely low in magnesium will cause hyperirritability, tetany, muscle twitching and reduced blood pressure.

Zinc (Zn): The concentration of zinc in ***Prosopis cineraria*** comprised the highest level among all elements investigated, and the highest value was detected in the leaves (144.55 $\mu g g^{-1}$) as compared to the stem (36.61 $\mu g g^{-1}$) or the bark (13.49 $\mu g g^{-1}$).

Zinc is an important component of enzymes and is a functional cofactor of a large number of enzymes and auxins (plant growth hormones). It is essential to carbohydrate metabolism, protein synthesis and internodal elongation during stem growth. Deficiency in plants result in mottled leaves with irregular chlorotic areas. Zinc deficiency leads to iron deficiency causing similar symptoms. Deficiency occurs on eroded soils and is least available at a pH range of 5.5 – 7.0. However lowering the pH can render zinc more available to the point of toxicity.

The animal body contains about 20 – 30mg zinc per kilogram body weight, and most of it is found in the liver, kidneys, bones, hair and pancreas. An excess of calcium inhibits zinc absorption, meaning an increased intake of zinc is necessary if the dietary share of calcium is high. Zinc is important primarily for skeletal development and the formation and regeneration of the skin and hair cells. Symptoms of a deficiency, particularly in young animals, are bone deformation and retarded growth.

Manganese (Mn): The level of manganese was found to be higher in the leaves (47.01 μgg^{-1}) than in the stem [14.79 μgg^{-1}] or the bark [41.26 μgg^{-1}].

Manganese is involved in enzyme activity for photosynthesis, respiration, and nitrogen metabolism, Deficiency in young leaves may show a network of green veins on a light green background similar to those in iron deficiency. In advanced stages of deficiency, the light green parts may become white, and the leaves are shed. Brownish, black, or greyish spots may appear next to the veins. In neutral or alkaline soils, plants often show deficiency symptoms where as in highly acid soils, manganese may be available to the extent that it results in toxicity.

The small amounts of manganese in the animal body, i.e. approx. 0.2 – 0.3mg per kilogram body weight, are concentrated mainly in the bone. It also supports the amino acid metabolism. Due to poor absorption of manganese in the gastro-intestinal tract and the low concentration of this trace element in the body tissues, great care must be taken to ensure a regular supply of manganese in the diet. A low manganese diet can often lead to sterility in male mammals and late sexual maturity in females.

Iron (Fe): Iron was detected in leaves (1.35 μgg^{-1}), stem (0.44 μgg^{-1})and bark (1.16 μgg^{-1}) in Prosopis cineraria and the level in the stem was lower than those found in leaves and bark.

Iron is critical for chlorophyll formation and photosynthesis. It is important in enzyme systems and respiration in plants.

In spite of the fact that there are as much as 60 – 90mg iron per kilogram body weight in the animal body, it still counts as a trace element. Seventy percent of the iron is found in haemoglobin – the colouring matter of red blood corpuscles; the remaining 30% is found chiefly in the liver, to some extent in the spleen and bone marrow, and in the plasma.

Absorbed iron is converted into haemoglobin and is therefore part of the process where oxygen is taken up from the air into the lungs and carried to the tissues. It contributes to the energy metabolism and aids resistance to infection. Anaemia is the well-known result of an iron deficiency, but a lack of this trace element can also lead to an increased susceptibility to infection and symptoms of toxicosis.

Copper (Cu): The level of copper was found to be higher in the leaves (22.5 μgg^{-1}) and the stem (18.31 μgg^{-1}) as compared to the bark (11.51μgg^{-1}). Copper is concentrated in the roots of plants and plays a part in nitrogen metabolism. It is a component of several enzymes and may be part of the enzyme systems that use carbohydrates and proteins. Deficiencies cause die back of the shoot tips, and the terminal leaves develop brown spots. Copper is bound tightly in organic matter and may be deficient in highly organic soils. It is not readily lost from the soil but may often be unavailable. Too much copper can cause toxicity.

As in the case of iron, copper is also stored in the liver and is found to a lesser extent in bone marrow. The animal body contains 1.5 – 2.5mg per kilogram body weight. Copper has an important function in hair growth, the formation of the melanin (dark) pigment of skin and hair, and the bone and connective tissue formation.

Nickel (Ni): Nickel was detected in leaves (4.01 μgg^{-1}), stems (2.097 μgg^{-1}), and bark (3.46μgg^{-1}) in Prosopis cineraria and the level in the stem was lower than those found in leaves and bark.

Nickel has just recently won the status as an essential trace element for plants according to the Agricultural Research Service Plant, Soil and Nutrition Laboratory in Ithaca, NY. It is required for the enzyme urease to break down urea to liberate the nitrogen into a usable form for plants. Nickel is required for iron absorption. Seeds need nickel in order to germinate. Plants grown without additional nickel will gradually reach a deficient level at about the time they mature and begin reproductive growth. If nickel is deficient plants may fail to produce viable seeds.

Nickel deficiency have been shown results in an inferior liver function.

Cobalt (Co): Cobalt was detected in leaves (0.46 μgg^{-1}), stem (0.13 μgg^{-1})and bark (0.38 μgg^{-1}) in Prosopis cineraria and the level in the stem was lower than those found in leaves and bark.

Cobalt is required for nitrogen fixation in legumes. The demand for cobalt is much higher for nitrogen fixation than for ammonium nutrition. Deficiency in its level could result in nitrogen deficiency symptoms.

In animals cobalt is of significance primarily in ruminant nutrition, and generally its deficiency produces symptoms of disease or illness. Cobalt is an integral part of vitamin B12 and is used in the synthesis of this vitamin by the rumen microflora.

Aluminum (Al): Aluminum is not essential for plant growth, although a beneficial role has been claimed for some plant species (Radojevic and Bashkin, 1999).

The aluminum level concentration detected in the leaves was higher than these detected in stem and the bark. Typically aluminum concentration are around 6-3500 μgg^{-1} (dry weight) in plants and 3-140μgg^{-1} (dry weight) in plant foodstuffs (lettuce, cabbage, beans, corn, and cereals) (Ward, 2000). In plants, this element, when present at toxic levels, causes stunting, dark green leaves, purpling of stems, death of the leaf tips and damage to the root system (Jones Jr., 1998).

Thallium (Tl): Not much is known about thallium chemistry and its effects on plant tissues and in the soil, except that it may be toxic if present at enough high levels (Radojevic and Bashkin, 1999). Jones Jr., (1998) reported that a typical thallium level in plants is 0.05 μgg^{-1} . In this investigation the concentration of thallium found where 0.45 μgg^{-1} in leaves, 0.33 μgg^{-1} in stem and 0.49 μgg^{-1} in the bark. These values are much higher than those condidered as the typical range suggested by Jones Jr. (1998).

Vanadium (V): Vanadium is an essential micronutrient for animals, but not for plants (Jones Jr., 1998). In plants, a typical concentration range is 0.001-1.5 μgg^{-1} (Radojevic and Bashkin, 1999) and in plant food stuffs, the figures reported by Ward (2000) is 0.001-0.7 μgg^{-1} . The results obtained show that the highest concentration was found in the leaves (3.41 μgg^{-1}) followed by bark (2.82μgg^{-1}) and the least value was detected in the stem (1.55μgg^{-1}).

All these concentrations are much higher than those reported as a typical concentration range.

Vanadium was shown to improve the growth rate of rats.

Lead (Pb): Lead is known for its toxicity to animals if taken accidentally in plant feed, it can cause anemia, anorexia, blindness, abortion, diarrhea and abdominal pain.

The level of concentration of lead was highest in the leaves 3.66 μgg^{-1} as compared to the levels of concentrations in the stem and the bark. High values of lead in the environment are usually attributed to unleaded gasoline and their emission by motorcars.

Mercury (Hg): The level of Hg was the highest in leaves (0.519 μgg^{-1}) decreased in the bark (0.36 μgg^{-1}) and the least level was detected in the stems (0.28 μgg^{-1}).

Mercury is known for its toxicity to animal if taken in plants feed as other source. Mercury is known to cause ataxia, kidney failure, convulsions and hemorrhage.

Barium (Ba): Not much is reported in the literature on the accumulation of Ba by plants. It was reported that there was relatively little accumulation of Ba by macrofungi growing on uranium mill tailings (Kalin and Stokes, 1981). Barium usually occurs in the soil as $BaSo_2$ (barytes) and $BaCo_3$

(witherite, alstonite) (Sharp, 1990). In this investigation, it was detected in the leaves, the stem and the bark. The average highest concentration level was detected in the bark (27.82 μgg^{-1}) as compared to its concentration in the leaves and the stem (25.21 μgg^{-1} and 22.85 μgg^{-1}, respectively).

Selenium (Se): Selenium is an essential element for animals in low levels and deficiencies occur if they feed on plants with Se concentrations of ≤ 0.05 μgg^{-1} (Radojevic and Bashkin, 1999). However, at high concentrations (> 4 μgg^{-1}), selenium can be toxic as it prevents proper bone formation in animals (Radojevic and Bashkin, 1999). Usually, the selenium levels in soils range from <0.1 to 100 μgg^{-1}. Although selenium may be present at trace amounts in the soil, it may accumulate in plants and crops in quantities that could pose a hazard to animals and humans feeding on them. Selenium pollution may result from its industrial uses, such as the production of rubber, glass, pigments, metal alloys, and electronics (Radojevic and Bashkin, 1999). The detected concentration levels of selenium in this investigation fall in the range of 24.14 μgg^{-1} in the bark to the lowest value of 6.37 μgg^{-1} in the stem. These values are extremely high and as yet cannot be explained. Because Prosopis cineraria is important to grazing animals, the problem should be further investigated.

Although classified as an essential trace element, it is also toxic in comparatively small quantities. Selenium occurs naturally either in foods, in the water supply or in the air, which means a normal and varied diet, makes a selenium deficiency practically impossible.

Conclusion

This study was intended as a preliminary investigation into a relic population of 8 trees of *Prosopis cineraria* occurring at Al Ghafat near Rawdat Rashid.

As has been shown in the results presented, the contents of the 24 elements have now been established as a baseline data. This data has not been presented in any earlier work on the local Al Ghaf plants.

Further investigation will be carried out on the remaining isolated trees reported to occur in the country. Equally, further research into the mineral content of *Prosopis cineraria* so as to study the variation of these elements in the different individuals should be undertaken. It is also recommended that the levels of the elements detected in Al Ghaf during Spring 2005 should be compared with further investigations at different season and at different stages of plant growth on plants raised from a known seed source.

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CHAPTER 7

PROSPECTUS OF AL GHAF IN THE STATE OF QATAR

By

Professor Ekhlas M. M. Abdel Bari

Prospectus of Al Ghaf in the State of Qatar

There are a number of questions concerning the present status of these isolated and relic populations at Al Ghafat in the vicinity of Rawdat Rahsid and the other isolated trees.

The species is reputed to be long-living with an estimated age of 200 years or more. How did they escape a well known fate of most permanent vegetation in arid conditions? Are these trees still producing flowers and viable seeds but none were detected in spite of the intensive search?

The species has been reported to propagate easily by seeds. Seeds are known to survive for many decades. The tree also reproduces by root suckers. Why were no seedling or saplings found ?

On the other hand, there are a number of questions raised pertaining to the future of these trees. How could we ensure that these trees continue to survive? How best can we protect them, given their present importance as shade and browsing trees in the area?

Since early times, Man and his animals maintained and manipulated life in the desert both its plants and wild animals. Trees are an important factor in the survival of man in the desert. Early nomadic desert tribes knew the importance of preserving a natural balance of their environment.

Land use practices of nomadic tribes preserved the desert vegetation. The continuous movement of the tribes and their relatively small herds, which were meant for their survival, maintained the components of the ecosystem and did not stress its fragile balance. Throughout history this respect, care and appreciation of what the desert offers has been portrayed in nomadic songs and poetry.

However, in recent times this respect for nature diminished when conditions of life in the desert changed. With no more tribes on the move and settlements building up, pressure on the limited resources increased: more animals were grazing the unrenewed and continually diminishing permanent plant cover. Nature has also turned a dark side on the arid zones with more years of scanty rains and an ever increasing temperature resulting from the many destructive modern ways of life, over exploitation and industrialization.

In the State of Qatar, many desire that those concerned will reintroduce this magnificent tree into many sandy depressions and seek to protect it in the hope of its natural regeneration. Perhaps, Al Ghaf which is described as tolerant of drought and salinity may be used in future restoration programs of coastal and inland areas with high soil alkalinity. The species is reputed to have a tolerance to high pH of up to 9.5 and high temperatures (up to 50° C under shade).

It is not known why the species has stopped regenerating locally. Whatever the reasons are, there is no doubt that those who lived in and around Al Ghafat depression and frequented the area with their browsing animals in the past have intentionally or non-intentionally maintained this vital resource. One reason given, and possibly relates to the whole country, is the heavy exploitation of underground water lowering the water table. On coastal areas of countries as small as the State of Qatar, this would have resulted in the intrusion of seawater. This species has been successfully grown in 50% sea water but it does not occur locally on the coastline areas. This needs to be further investigated testing local provenance.

From the studies carried out in this undertaking, the species has other benefits. It has been shown to have effective action against bacterial and fungal strains. It might be beneficial to extend the studies on its antimicrobial activities in view of the value of new medical source.

It is also possible to introduce Al Ghaf in the local agri-system by growing it in established farms with fodder and vegetable crops. Equally, the species is a magnificient handsome tree which can be introduced as an avenue tree in all major cities rather than using an introduced species such as *Conocarpus* that requires a high demand on the limited water resource, produces tons of tough leaf litter and is reputed to cause hay fever.

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