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Ecological Prominence of *Juniperus phoenicea* L. Growing in Gebel Halal, North Sinai, Egypt

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ABSTRACT

Identifying diversity, distribution, and habitats of interest species is an important task for developing conservation and restoration programs. *Juniperus phoenicea* has suffered immense destruction and degradation over the last few decades on the anticlines of North Sinai. Therefore, this study evaluated the ecological status of *J. phoenicea* assemblages in Gebel Halal, and analyzed floristic composition, distribution and species diversity in different habitats. Germination treatments Juniper seeds were also considered. The results showed that the surveyed area of Gebel Halal harbors 73 plant species including 50 medicinal plant species representing 69% of the recorded species, of which 17 species were found only in the mountainous area. Soils of gorge habitats are the richest soil in organic matter (2.22%), and silt and clay content (17.19%). These conditions support dense vegetation of *J. phoenicea* assemblages associated with many sub-shrubs, shrubs and annuals. Mean canopy cover of *J. phoenicea* at gorge habitats is 14.21% (±6.45 SD, ±3.73 SE), and mean diameter is 3.53 m (±1.29 SD, ±0.74 SE). The study area showed also assemblages of *Acacia pachyceras* at wadi habitats; *Anabasis articulata*, *Ballota undulata* and *Lycium shawii* at slope habitats. Associated species include *Zygophyllum dumosum*, *Chiliadenus montanus* and *Globularia arabica*. Ecological characterization and floristic composition were most influenced by climatic and edaphic factors. Isolated patches of the remnant assemblages of *Juniperus phoenicea* persist in gorges (220-400m altitude) growing on fractures of smooth-faced limestone outcrops of Gebel Halal. Assemblages of *J. phoenicea* are considered local threatened endemic Mediterranean type mainly due to human disturbances. The results of the preliminary germination experiments showed low germination percentages when seeds were shaken with gravel and coarse sand for 15 minutes (20%), and when seeds were soaked in concentrated acids for 5 or 10 minutes (10%). In conclusion, the ecological conditions for *J. phoenicea* indicated that it is an endangered species. Immediate protection of the remaining *J. phoenicea* trees and future restoration programs should be the priority for conservation strategies of this endemic assemblage type. The anticlines of North Sinai that harbor *J. phoenicea* assemblages should be listed as a priority habitat in the national conservation plan.

Keywords: Floristic composition, Gebel Halal, *Juniperus phoenicea*, Sinai anticlines, Species richness.

INTRODUCTION

Junipers grow in semiarid and arid regions (Gardner and Fisher, 1996; Gauquelin *et al*., 1999; El-Bana *et al*., 2010). Isolated plant populations in a few areas are more susceptible to climate change and human pressure that can threaten their resources and habitats. Consequences might be the loss of biodiversity of associated floras and faunas, including the genetic diversity of the species populations (Thompson, 1999). These negative effects are of special concern when target communities are rich in endemic, endangered, vulnerable, and rare species (Abd El-Wahab *et al*., 2004). Therefore, identifying the geographical range and environmental requirements of rare target species or habitats represents an important tool in conservation planning and biodiversity monitoring.

Juniper (Family Cupressaceae) is a dioecious, coniferous shrub growing in temperate and subtropical regions of the northern hemisphere. The genus is taxonomically complex, consisting of around 80 species (Thomas *et al*., 2007). Due to its former widespread distribution Juniper is associated with a rich folklore and diverse ethnobotanical uses, including medicinal, veterinary and culinary uses. Juniper is found in a wide range of open habitats, at varying altitudes and growing in a wide range of soil types (Cooper *et al*., 2012). In the Mediterranean regions; *Juniperus* can survive under extremely harsh conditions of extreme drought with lots of climatic fluctuations (Piotto and Di Noi, 2003).

Juniperus phoenicea L., commonly known in Arabic as Ar'ar and in English as Phoenician Juniper, is a shrub or small cypress-like tree with erect branches. Leaves are of two kinds, spreading needle-like and imbricated scale-like. Fruits are glossy, reddish-brown, 6-14 mm across, 3-9 seeded (Täckholm, 1974). In Egypt, it is a very rare species recorded only in the anticlines of Halal, Maghara, and Yi'allaq (Täckholm, 1974; Abd El-Wahab *et al*., 2008; El-Bana *et al*., 2010; Youssef *et al*., 2014). It is a native species to the coastal sites of the Mediterranean basin and extends into the mountains of western Arabia (Zohary, 1973).

It has a characteristic aromatic bitter taste and aromatic odor; generally Bedouins are using the plant extract as a drink for treating diabetes. Dry leaves are used to cure mild skin inflammations for babies; dilator for urinary tracts, laxative, intestinal disinfectant, emmenagogue and helping in childbirth by increasing the contraction of the uterus, diaphoretic, sedative and for diarrhea (Batanouny *et al*., 1999). The mixture of leaves and berries is used as an oral hypoglycemic agent, whereas the leaves are used against bronco-pulmonary disease and as a diuretic (Ramdani *et al*., 2013). The essential oil of *J. phoenicea* shows strong

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antimicrobial activity (Ramdani *et al*., 2013). In Jordan traditional medicine, it is used for treatment of variety of diseases such as diarrhea, gout and poor appetite, eliminating gastrointestinal bacteria and parasites (Qnais *et al*., 2005).

Several studies reported the importance of active contents of leaves and berries of *J. phoenicea* grown in Mediterranean region including Morocco (Ait Ouazzou *et al*., 2012), Egypt (El-Sawi *et al*., 2007), Tunisia (Bouzouita *et al*., 2008), Algeria (Mazari *et al.*, 2010; Bekhechi *et al*., 2012), Canary Islands and Madeira (Adams *et al*., 2009), and Portugal (Cavaleiro *et al*., 2001). For most of the desert plants soil moisture and rainfall are major factors influencing seed germination and successful seedling establishment (Harper and Benton, 1966: Freas and Kemp, 1983; Agami, 1986). Freas and Kemp (1983) discussed the importance of innate dormancy, water-controlled dormancy, and seed dispersal to the long-term survival of desert annual species. Germination trials of some native plant species particularly threatened and medicinal species in Sinai have been done by several studies (e.g., Moustafa *et al*., 1996; Zaghloul, 1997; Zaghloul *et al*., 2010; Moustafa *et al*., 2015), however there is a lack of knowledge about germination of *J. phoenicea*. In Egypt, *J. phoenicea* is restricted to the strongly folded area (Frontal folds) Gebel Halal, G. Maghara and G. Yi'allaq. The plant is very rare and new seedlings are not observed in the sites of its growth. The assemblages of *J. phoenicea* in the North Sinai are considered a Mediterranean-type subjected to ecological effects as wind, erosion and drought. In addition recently, this threatened type has almost completely been destroyed over the last few decades due to severe human impacts including over-grazing, over-collecting, and quarrying activities (Fig. 1).

This study aims to evaluate the geographical distribution, ecological status, floristic composition and diversity pattern of existing assemblages of *J. phoenicea* in G. Halal. This is of great conservation concern since G. Halal is rich in medicinal and threatened species and should be listed as priority habitats in the national conservation strategy.

Figure (1): Threatened *Juniperus phoenicea* trees at Gebel Halal showing signs of cutting.

MATERIALS AND METHODS

Study Area

The anticlines of North Sinai include Gebel (mountain) Yi'allaq (1090 m above sea level), G. Halal (892 m a.s.l), and G. Maghara (735 m a.s.l) (Fig. 2). The anticline fold system of North Sinai is a part of Cretaceous Syria arc that extends from the Palmyra folds of Syria to the desert west of the Nile. The North Sinai folds have NE-SW orientation and include both large folds such as G. Halal, G. Maghara, and G. Yi'allaq; and small folds such as G. Libni (463 m a.s.l). These anticlines are characterized by large outcrops of smooth-faced limestone and dolomite. The syncline valleys are filled with sand-covered alluvium. This study was carried out in G. Halal. The asymmetric doubly plunging anticline of Gebel Halal is structurally simpler than the Gebel Maghara and G. Yi'allaq structures. Gebel Halal anticline has a gentle northwestern flank dipping at about 15° NW and a steep southeastern flank that is mostly vertical to overturned (Moustafa, 2010). It is characterized by large outcrops of smooth-faced limestone, whereas G. El-Maghara and G. Yi'allaq have fissured rocks with limestone and dolomite outcrops (Danin, 1972). North Sinai, as a desert region, belongs to arid climate with hot summer, mild winter and annual rainfall of 20 – 100 mm (Ayyad and Ghabour, 1986). During winter average temperature reaches 19.8ºC during the day and 8.3ºC during the night. The precipitation reaches about 62.2 mm, which represents 60% of the annual precipitation. In spring, the average temperature varies between 23.57ºC and 11.13ºC; and precipitation reaches 25.2 mm. Average wind speed in this season is 9.6 m/sec (Saleh, 2013).

Vegetation Survey

Six sites were surveyed at the northern and eastern side of Gebel Halal. The geographical locations of these sites (Table 1) were recorded using a global positioning system (GPS, Trimble model, Trimble Navigation Limited, Sunnyvale, California, USA). At each site, 5 quadrats (10 x 10m) were selected randomly for qualitative (3 quadrats) and quantitative measurements (2 quadrats). At each quadrat, identified plant species and their abundance (the number of individual of each species) were recorded.

Minimum and maximum canopy diameters of each species were measured. Average diameter (D) and canopy cover of plant species were calculated. The canopy cover was calculated using the formula for a circle area {πr2}, where r was taken to be half of the canopy average diameter. The total plant cover of each quadrat was estimated. Species identification and their growth forms followed Täckholm (1974) and Boulos (1999 – 2005). Importance of plant species as medicinal or fodder followed Boulos (1983), Batanouny *et al.* (1999), and Abd El-Wahab *et al*. (2008). The ratio of species/genera and genera/family were estimated (Ayyad *et al*., 2000). Species richness (the total number of species in each quadrat), Margalef's index (based on species richness), Shannon Index and Pielou's evenness index (based on species relative abundance) were applied to assess biodiversity.

According to Magurran (1988), the Margalef index was calculated from the formula:

$$D_{Mg} = (S-1)/\ln N$$

(Where S is the number of species and N is the total number of individuals)

The Shannon index from the formula:

$$H' = -\sum_{i=1}^{n} pi \times \ln pi$$

(Where pi is the proportion of individuals found in the i^{th} species)

Pielou's evenness index from the formula:

$$E = H'/H_{max}$$

(Where H_{max} is the maximum diversity possible and equal "ln S").

Soil analysis

At each quadrat one surface soil sample was collected as a mixture from zero to 20 cm in depth. Soil samples were air-dried and sieved through a 2-mm sieve to obtain representative sub-samples (fine soil) for physical and chemical analyses and to exclude large gravels that are relatively less reactive (Robertson et al. 1999). The large particles (>2 mm) were weighed as a gravel percentage. Soil fraction analysis was obtained using dry sieving (particle-size distribution), and hygroscopic moisture was measured (Gee and Bauder, 1986). Soil pH was measured in a 1:2.5 soil-water extract. Soil electric conductivity was measured in a 1:1 soil-water extract. Soil organic matter (%) was estimated by using the loss on ignition method. Soil chemical analyses were conducted following the methods of Sparks *et al*. (1996).

Germination treatments

Seeds of *Juniperus phoenicea* were collected from different sites in North Sinai anticlines. Average seed weight, number of seeds per cone, and number of seeds in kilogram were estimated. Preliminary germination experiments were carried out under laboratory conditions and in growth chamber to determine germination behavior. Germination treatments of *J. phoenicea* seeds include manual shaking with gravel and coarse sand for 5, 10 and 15 minutes; immersing in boiling water for 5, 10 and 15 minutes; soaking in concentrated hydrochloric acid (HCl) for 5, 10 and 15 minutes; soaking in concentrated sulphuric acid (H_2SO_4) for 5, 10, and 15 minutes; and rinsing (washing) by tap water for 8, 12 and 24 hours.

Data treatment

Descriptive statistics include mean, standard deviation (SD) and standard error (SE) of vegetative parameter (abundance, diameter and canopy cover, and total plant cover) and diversity indices (species richness, Shannon-Winner index, Pielou's evenness index, and Margalef's index) in each habitat and plant assemblage. Pearson correlations were used to determine how abundance, diameter and canopy cover, total plant cover, and diversity indices are related. Cluster analysis of vegetation structure was tested statistically using average linkage of Bray-Curtis distance calculated from differences in abundance, cover, and average diameter of 33 plant species (Cophenetic correlation= 0.94).

The one-way ANOVA procedure was used to determine whether differences exist among the mean values of plant cover, and diversity indices of different assemblages. Statistical analyses of the data were carried out using SPSS software (Statistical package for social sciences, version 21, IBM Corp. Released 2012). Cluster analysis was carried out using F diversity software (Casanoves *et al*., 2010).

RESULTS

General description of *Juniperus phoenicea* assemblages

Assemblages of *Juniperus phoenicea* were recorded in three sites at gorge habitat (220-400 m altitude). The total plant cover at stands supporting *J. phoenicea* assemblage varies between 11.5% and 22.6%. The canopy cover of *Juniperus* trees varies between 7.1 and 19.63% with mean value of 14.21% (6.45 ±6.45 SD, ±3.73 SE). Canopy diameter of *Juniperus* trees varies between 2 m and 5 m. The mean canopy diameter is 3.53 m (±1.29 SD, ±0.74 SE).

Seedlings or young individuals were not recognized

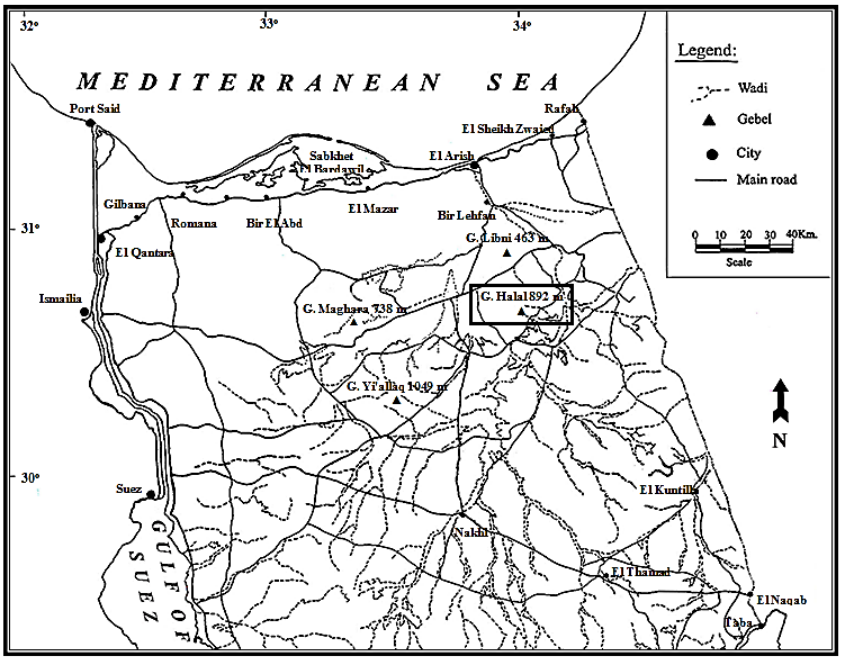

Figure (2): Location map of North Sinai showing the study area of Gebel Halal.

in all surveyed sites. Almost all the trees of *J. phoenicea* are suffering from overcollection and overcutting for wood and medicinal uses. Associated species of this assemblage include *Chiliadenus montanus, Ballota undulata* and *Schismus arabicus.* Soil of gorge habitats is the richest in organic matter (2.22%), and silt and clay content (17.19%). These conditions support dense many vegetation of *J. phoenicea* assemblages associated with sub-shrubs, shrubs and annuals. *J. phoenicea* trees were not recognized below the elevation of 200m a.s.l. either in wadi or channel habitats.

Soils of wadi and channel habitats are lower in content of organic matter and gravel than soils of gorge habitat. Statistical analysis of different soil properties showed high significant variations between different habitats (Table 1).

Table (1): Habitat type, altitude and the geographic location of the six main sites at Gebel Halal.

Sites	Habitat	GPS	pH	EC dS m^{-1}	Gravel %	Coarse sand %	Medium Sand %	Fine Sand %	Silt & clay %	organic matter %
1	Wadi	N:30° 47.227' E:33° 58.802' Altitude: 143m	8.21	3.04	1.42	19.18	30.83	44.72	5.28	1.11
2	Channel	N:30° 45.447' E:34° 01.069' Altitude: 173m	8.43	2.06	1.17	18.59	23.38	49.33	8.7	1.23
3	Gorge	N:30° 44.072' E:34° 02.067' Altitude: 224m	8.89	1.86	2.02	13.17	32.54	47.95	6.34	1.49
4	Gorge	N:30° 43.539' E:34° 01.703' Altitude: 311m	8.88	1.84	3.17	21.28	26.89	41.45	10.38	2.11
5	Gorge	N:30° 43.428' E:34° 01.571' Altitude: 289m	8.33	2.06	12.88	13.38	19.33	36.51	17.19	2.22
6	Slope	N:30° 43.335' E:34° 01.853' Altitude: 362m	8.64	1.97	5.27	24.56	29.94	38.98	6.52	1.99
F			22.02*	36.5*	18.2*	7.68*	5.32*	7.32*	17.23*	19.32*

**p*-value <0.001

Seed germination treatments of *J. phoenicea*

The results of the preliminary germination experiments showed difficulties in germination of *Juniperus* seeds. Most of treatments such as soaking or washing seeds in tap water or boiling water were failed to germinate *Juniperus seeds.* Low germination percentages were obtained in treatments of shaking seeds with gravel and coarse sand for 15 minutes (20%), and soaking seeds in concentrated hydrochloric acid for 5 minutes or sulfuric acid for 5 or 10 minutes (10%) (Table 2).

Table (2): Germination treatments of *Juniperus phoenicea*.

Treatment	Germination Percentage
Control	0
Manual shaking for 5, 10, 15 min	0, 0, 20
Boiling water for 5, 10, 15 min	0
Cooling of seeds for 7, 14, 21 day	0
Soaking in conc. HCL for 5, 10, 15 min.	10, 0, 0
Soaking in conc. H2SO4 for 5, 10, 15 min.	10, 10, 0
Soaking in tap water for 24, 36, 72 hour	0
Washing under tap water for 8, 12, 24 h	0

Floristic composition

Based on field survey of different habitats, G. Halal harbors 73 plant species. The identified plant species belong to 31 families and 68 genera (Appendeix 1). The ratio of genera to families and species to genera are 2.19 and 1.07 respectively. Compositea is the largest family in the study area with 11 species. Analyzing floristic composition of G. Halal showed high abundances of perennials (74%), whereas annuals represented 26% of the recorded species. Shrubs and sub-shrubs are about 48% whereas trees are about 4% (Fig. 3)

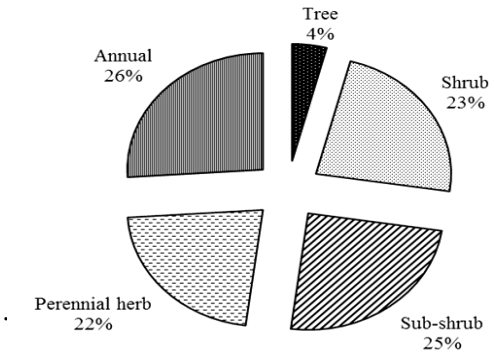

Figure (3): Growth forms of recorded plant species in Gebel Halal

Gebel Halal harbors 50 medicinal plant species representing about 69% of the recorded species (Appendeix 1) Medicinal plants growing only in the mountainous area (17 species) include *Acacia pachyceras* var. *najdensis*, *Asclepias sinaica*, *Ballota arabica*, *Juniperus phoenicea*, and *Lavandula pubescens*. The other medicinal plants such as *Acacia tortilis*, *Anabasis arabica*, *Artemisia monosperma*, *Cleome amblyocarpa*, and *Panicum turgidum* are growing also in the Mediterranean coastal area. Fifteen species are grazed or collected as fodder for livestock animals. The most common fodder plants are *Acacia pachyceras*, *Acacia tortilis*, *Globularia arabica*, *Zilla spinosa*, and *Tamarix nilotica*.

Vegetation and plant diversity of different habitats

Distribution of plant species and their canopy cover at different habitats showed that Gebel Halal is characterized by two main tree species with the highest canopy cover (15-30%); *Acacia pachyceras* at wadis and *J. phoenicea* at gorges. *Heliotropium ramosissimum* and *Artemisia monosperma* at wadis and *Fagonia scabra*, *Acacia pachyceras* and *Lycium shawii* at channels have intermediate values of canopy cover (2-7%). Most of the other recorded species have canopy cover values less than 1% (Table 3). The mean value of total plant cover in G. Halal is about 19.6%. The total plant cover varies between (35.63%) at wadis and 3.47% at slopes. Channels and gorges were close to each other in total plant cover (Fig. 4A).

The highest species richness was recorded at channels (10 species/100m^2) followed by gorges (8.67 species/100m^2) and slopes (6.67 species/100m^2). On the other hand, wadis showed the lowest value of richness diversity (Fig. 4B). The results of Pielou's evenness index showed that slopes and gorges are higher in species diversity than wadis and channels. Shannon index showed also that slopes have the highest value of species diversity in the study area. However, Margalef's index showed that gorge habitats are more diverse than channels and slopes (Fig. 5). Pearson correlation between total plant cover and plant diversity indices at Gebel Halal showed significance relationships between richness index and Shannon index, and between richness index and Margalef's index. The other relationships were not significant (Table 4).

Plant assemblages

Cluster analysis using average linkage of Bray-Curtis distance method based on differences in abundance, cover, and average diameter of 33 species showed that vegetation clusters of G. Halal has six distinguished assemblages (Fig. 6). Assemblage (I) showed high cover value of *Acacia pachyceras* at wadi habitats (Table 5).

Three assemblages were characterized by dominance of *Juniperus phoenicea* (II. IV, V). Assemblage II represents a pure vegetation of Juniperus phoenicea. Assemblages IV and V were characterized by high species richness of associated species such as *Lycium shawii* and *Chiliadenus montanus* in assemblage IV, and *Fagonia scabra*, *Ballota undulata*, *Globularia arabica*, *Fagonia mollis* and *Zygophyllum dumosum* in assemblage V. Two assemblages (III and V) were characterized by dominance of shrubs and sub-shrubs.

Table (3): Canopy cover% of some recorded species at different habitats and their mean values for the total study area of Gebel Halal.

Species	Stydy area	Wadi	Channel	Gorge	Slope
Acacia pachyceras O. Schwartz var. najdensis (Chaudhry) Boulos	28.03	43.85	4.32		
Anabasis articulata (Forssk.) Moq.	0.17		0.14		0.19
Artemisia monosperma Delile	1.51	1.51			
Asclepias sinaica (Boiss.) Muschl.	0.16		0.16		
Asparagus aphyllus L.	0.04			0.04	
Asparagus stipularis Forssk.	0.23			0.15	0.32
Asphodelus viscidulus Boiss.	0.24	0.31	0.22	0.21	
Astragalus spinosus (Forssk.) Muschl.	0.01		0.01		
Ballota undulata (Fresen.) Benth.	0.93			0.52	1.35
Caylusea hexagyna (Forssk.) M. L. Green	0.10			0.10	
Chiliadenus montanus (Vahl) Brullo.	0.54		0.19	0.89	
Cleome amblyocarpa Barratte & Murb.	0.13	0.13			
Cornulaca monacantha Delile	0.79	0.79			
Cymbopogon schoenanthus (L.) Spreng.	0.03			0.03	
Diplotaxis harra (Forssk.) Boiss.	0.53	1.42		0.06	0.10
Echinops galalensis Schweinf.	0.2		0.02	0.26	0.33
Fagonia mollis Delile	0.61		1.25		0.40
Fagonia scabra Forssk.	6.78		13.43		0.13
Globularia arabica Jaub.&Spach.	0.24			0.24	
Gymnocarpos decander Forssk.	0.09		0.05		0.12
Heliotropium ramosissimum (Lehm.) Sieb. ex. A. DC.	6.28	6.28			
Juniperus phoenicea L.	14.21			14.21	
Launaea capitata (Spreng.) Dandy	0.25	0.25			
Lycium shawii Roem.&Schult.	2.47		3.55		0.32
Morettia canescens Boiss.	0.26				0.26
Nitraria retusa (Forssk.) Asch.	0.24			0.24	
Reaumuria hirtella Jaub. & Spach	0.33	0.29		0.31	0.38
*Retama raetam (*Forssk.) Webb&Berthel	0.28		0.28		
Schismus arabicus Nees	0.57		0.07	1.07	
Stachys aegyptiaca Pers.	0.22		0.10	0.29	
Tamarix nilotica (Ehrenb.) Bunge	0.33			0.33	
Thymelaea hirsuta (L.) Endl.	0.13		0.05	0.21	
Urginea maritime (L.) Baker	0.76			0.18	1.05
Zygophyllum dumosum Boiss.	0.54		0.19		0.89

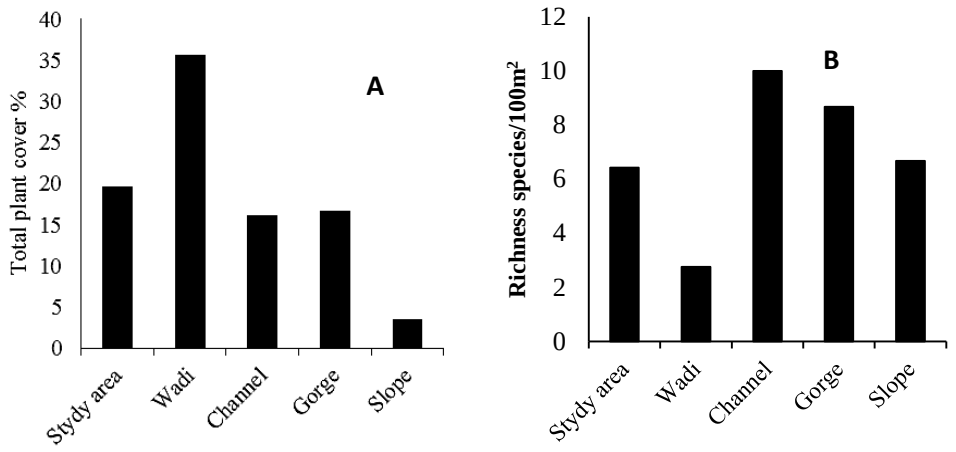

Figure (4): Mean of total plant cover (A) and richness (B) at different habitats of Gebel Halal.

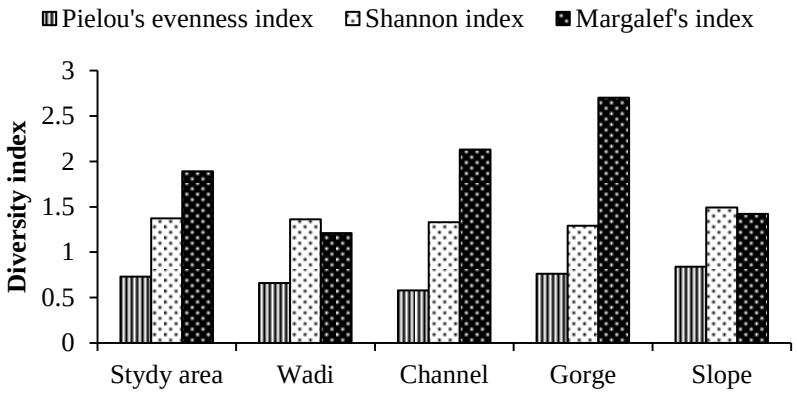

Figure (5): Mean values of different species diversity indices at different habitat and for the total study area of Gebel Halal.

Table (4): Pearson correlation between total plant cover and plant diversity indices at Gebel Halal.

Variable (1)	Variable (2)	n	Pearson	p-value
Total plant cover	Richness	12	-0.47	0.1194
	Pielou's evenness index	8	-0.60	0.1192
	Shannon index	9	-0.05	0.8900
	Margalef's index	8	-0.64	0.0890
Richness	Pielou's evenness index	8	-0.39	0.3457
	Shannon index	9	0.84	0.0044
	Margalef's index	8	0.83	0.0113
Pielou's evenness index	Shannon index	8	0.35	0.3885
	Margalef's index	8	-0.12	0.7859
Shannon index	Margalef's index	8	0.68	0.0625

Assemblage III showed dominance of *Heliotropium ramosissimum*, and was located at wadi and slope habitats. Associated species in this assemblage were *Ballota undulata*, *Urginea maritime*, *Artemisia monosperma* and *Zygophyllum dumosum*. The other assemblage (V) was characterized by *Anabasis articulata*, *Ballota undulata* and *Lycium shawii*, and was located mainly at slope habitats (Table 5).

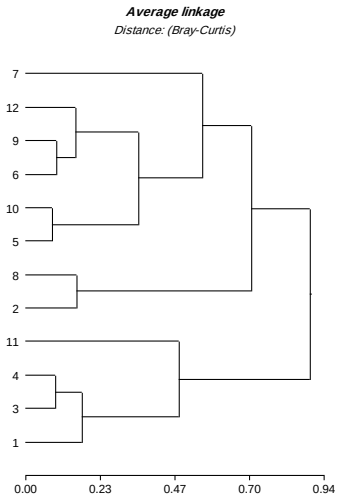

Figure (6): Cluster dendrogram of the 12 plots based on abundance, canopy cover and average canopy of 33 plant species recorded in Gebel Halal. Plots grouped using average linkage of Bray-Curtis dissimilarities (Cophenetic correlation = 0.94).

DISCUSSION

The characterization of the ecological status, the analysis of species diversity and the delimitation of the geographical distribution of habitats and plant populations of interest, particularly isolated ones are fundamental in conservation biology (Scott *et al*., 2001; Otto *et al*., 2012). According to Danin (1986) and Moustafa (1990), flora of G. Halal belongs mainly to three main phytogeographical territories; Saharo-Arabian, Irano-Turanian and Mediterranean. Phytogeographical relations have a significant influence on species diversity as they largely determine the stock of species available in the past and present for inhabiting the study area (Danin, 1986). *Juniperus phoenicea* populations are a clear example of marginal or border populations in relation to the overall plant distribution area of the Mediterranean region (Danin, 1999), a factor commonly associated with regression dynamics due to climatic stress (Eriksson, 1996). The situation of population regeneration of J. phoenicea in North Sinai anticlines is limited to a few habitats with wetter soils, where population decline is associated with drought (Fisher, 1997). This study evaluated the ecological status of Juniper assemblages in G. Halal and analyzed their floristic composition, distribution, and species diversity at different habitats. *Juniperus phoenicea* has a high ecological value in relation to its soil-retaining ability, and it can be taken as a keystone

Table 5: Plant assemblages of Gebel Halal and their habitats, total plant cover, diversity, and canopy cover of plant species.

Variable	**Plant Assemblages**					
Assemblage	**I**	**II**	**III**	**IV**	**V**	**VI**
Plot	1,3,4	11	2,8	5,10	6,9,12	7
Habitat	wadi	gorge	wadi, slope	channel, gorge	channel, gorge, slope	slope
Total plant cover%	43.85	15.92	9.26	11.07	15.32	1.106
Richness species/100m^2	1	1	9	10.5	10	4
Pielou's evenness index	-	-	0.68	0.68	0.72	0.95
Shannon index	-	-	1.50	1.62	1.60	1.32
Margalef's index	-	-	1.39	2.47	1.98	1.44
Canopy cover% of plant species						
Acacia pachyceras O. Schwartz var. najdensis (Chaudhry) Boulos	43.85			5.94	2.69	
Anabasis articulata (Forssk.) Moq.			0.05		0.14	0.33
Artemisia monosperma Delile			1.51			
Asclepias sinaica (Boiss.) Muschl.				0.16		
Asparagus aphyllus L.				0.04		
Asparagus stipularis Forssk.			0.10	0.12	0.36	
Asphodelus viscidulus Boiss.			0.31	0.02	0.31	
Astragalus spinosus (Forssk.) Muschl.					0.01	
Ballota undulata (Fresen.) Benth.			2.32	0.22	0.81	0.38
Caylusea hexagyna (Forssk.) M. L. Green					0.10	
Chiliadenus montanus (Vahl) Brullo.				0.84	0.24	
Cleome amblyocarpa Barratte & Murb.			0.13			
Cornulaca monacantha Delile			0.79			
Cymbopogon schoenanthus (L.) Spreng.					0.03	
Diplotaxis harra (Forssk.) Boiss.			0.76		0.06	
Echinops galalensis Schweinf.			0.33		0.14	
Fagonia mollis Delile			0.70		0.83	0.08
Fagonia scabra Forssk.					6.78	
Globularia arabica Jaub.&Spach.				0.13	0.36	
Gymnocarpos decander Forssk.					0.09	
Heliotropium ramosissimum			6.28			
Juniperus phoenicea L.		15.92		7.07	19.63	
Launaea capitata (Spreng.) Dandy			0.25			
Lycium shawii Roem.&Schult.				3.83	3.26	0.32
Morettia canescens Boiss.			0.6			
Nitraria retusa (Forssk.) Asch.				0.24		
Reaumuria hirtella Jaub. & Spach			0.34	0.31		
*Retama raetam (*Forssk.) Webb&Berthel					0.28	
Schismus arabicus Nees				0.57		
Stachys aegyptiaca Pers.				0.21	0.25	
Tamarix nilotica (Ehrenb.) Bunge				0.33		
Thymelaea hirsuta (L.) Endl.				0.13		
Urginea maritime (L.) Baker			1.97		0.16	
Zygophyllum dumosum Boiss.			1.33	0.25	0.29	

species for the associated rare, vulnerable and endangered flora (Boulos and Gibali, 1993).

Ecological characterization and floristic composition of G. Halal were most influenced by climatic and edaphic factors. Gorge habitats with the richest soil in organic matter and silt and clay content (17.19%) support high diversity and dense vegetation of *J. phoenicea* assemblages associated with many sub-shrubs, shrubs and annuals. Variation in the average plant cover is also recognized reflecting the climatic and mainly the aridity conditions of the area. The differences in rock types and elevation among North Sinai anticlines reflect serious limitation on recruitment of *J. phoenicea* due to moisture availability (El-Bana *et al*., 2010). Only low germination percentages of *J. phoenicea* seeds were obtained when the seeds were shacked with gravel and coarse sand for 15 min, or soaked in concentrated sulfuric acid for 5 and 10 min. Seeds of *J. phoenicea* are sensitive to a strong desiccation and that there is no known effective pre-treatments will improve germination but the suggested cold stratification of naked seed at +3°C or +4°C for 30 days (Piotto and Di Noi, 2003).

Gebel Halal has six distinguished plant assemblages. Isolated assemblages of *J. phoenicea* were recognized in gorge habitats (220-400m altitude). These assemblages have many species in common with G. Maghara and G. Yi'allaq in North Sinai (Boulos, 1960; Danin *et al*., 1985; Abd El-Wahab *et al*., 2008; Kamel *et al*., 2008; El-Bana *et al*., 2010). Associated species in *J. phoenicea* assemblages include *Lycium shawii, Chiliadenus montanus, Fagonia scabra, Ballota undulata, Globularia arabica, Fagonia mollis* and *Zygophyllum dumosum*. Similar findings were obtained by previous ecological survey (e.g. Gazar *et al*., 2000; El-Bana *et al*., 2010; Yousef *et al*., 2014). Assemblage of *J. phoenicea* is considered local threatened endemic Mediterranean type mainly due to immense destruction and degradation over the last few decades on the anticlines of North Sinai including over-grazing, over-collecting and quarrying activities. Our results fit with the general findings that human disturbance is a strong driver of isolated patches of the remnant assemblages of *Juniperus phoenicea* in the anticlines of North Sinai (Abd El-Wahab *et al*., 2008; El-Bana *et al*., 2010; Yousef *et al*., 2014).

As a result of the impact of continuity of human disturbance and aridity in the study area, the conservation of *J. phoenicea* in northern Sinai must have an urgent priority, particularly at G. Halal that harbors the largest populations of *J. phoenicea* in North Sinai anticlines (Danin *et al*., 1985; El-Bana *et al*., 2010; Youssef *et al*., 2014). Populations of *J. phoenicea* at G. Halal are ecologically more valuable in terms of maintaining their associated flora since populations of some associated species are vulnerable as well (Abd El-Wahab *et al*., 2008; Boulos and Gibali, 1993). Global climate changes resulting in alternation of wet and dry climate episodes (Kusky and El-Baz, 2000) will also affect North Sinai anticlines by increasing temperatures and aridity, many of the juniper stands at lower altitudes will probably disappear in the future due to increasing environmental stress and lack of regeneration causing a local loss of biodiversity (Otto *et al*., 2012).

Although there is a lack of comparative studies of richness patterns for all main habitats of the anticlines (Abd El-Wahab *et al*., 2008; El-Bana *et al*., 2010), we can show that the remaining *J. phoenicea* patches represent high biodiversity spots in G. Halal within the recognized local biodiversity hotspot of the North Sinai anticlines. The ecological conditions for *J. phoenicea* indicated that it is an endangered species. Immediate protection of the remaining *J. phoenicea* trees and future restoration programs should be the priority for conservation strategies of this endemic assemblage type. The anticlines of North Sinai that harbor *J. phoenicea* assemblages should be listed as a priority habitat in the national conservation plan

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Appendix (1): Species list of Gebel Halal and their growth form and importance.

Family	Species	Growth form	Importance
Asclepiadaceae	*Asclepias sinaica* (Boiss.) Muschl.	shrub	medicinal
	Pergularia tomentosa L.	sub-shrub	medicinal
Boraginaceae	*Heliotropium ramosissimum* (Lehm.) Sieb. ex. A. DC.	sub-shrub	medicinal
Capparaceae	*Cleome amblyocarpa* Barratte & Murb.	annual	medicinal
Caryophyllaceae	*Gymnocarpos decander* Forssk.	sub-shrubt	
	Gypsophila capillaris (Forssk.) C. Chr.	annual	medicinal
	*Herniaria hirsuta*L.	annual	medicinal
	Paronychia arabica (L.) DC.	annual	medicinal
Chenopodiaceae	*Agathophora alopecuroides* (Delile) Fenzl ex Bunge	sub-shrub	medicinal
	Anabasis articulata (Forssk.) Moq.	shrub	medicinal
	Bassia muricata (L.) Asch.	annual	medicinal
	Cornulaca monacantha Delile	sub-shrub	medicinal
	Haloxylon scoparium Pomel	shrub	medicinal
	Salsola longifolia Forssk.	sub-shrub	
Compositae	*Achillea fragrantissima* (Forssk.)Sch.Bip.	sub-shrub	medicinal
	Artemisia monosperma Delile	sub-shrub	medicinal
	Atractylis mernephthae Asch.	annual	
	Centaurea pallescens Delile	annual	
	*Chiliadenus montanus (*Vahl) Brullo.	shrub	medicinal
	Echinops galalensis Schweinf.	perennial herb	
	Echinops spinosus L.	perennial herb	medicinal
	Iphiona scabra DC.	shrub	
	Launaea capitata (Spreng.) Dandy	annual	
	Senecio glaucus L. subsp. *coronopifolius* (Maire) C. Alexander	annual	medicinal
	Senecio glaucus L. subsp. *glaucus*	annual	medicinal
Convolvulaceae	*Convolvulus lanatus* Vahl.	sub-shrub	
Cruciferae	*Diplotaxis harra* (Forssk.) Boiss.	perennial herb	medicinal
	Farsetia aegyptia Turra	shrub	medicinal
	Morettia canescens Boiss.	perennial herb	
	Zilla spinosa (L.) Prantl	Shrub	medicinal
Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad.	perennial herb	medicinal
Cupressaceae	*Juniperus phoenicea* L.	tree	medicinal
Dipsacaceae	*Pterocephalus plumosus* (L.) Coult.	annual	
Ephedraceae	*Ephedra alata* Decne.	shrub	medicinal
Euphorbiaceae	*Andrachne telephioides* L.	perennial herb	
	Chrozophora tinctoria (L.) Raf.	annual	
	Euphorbia retusa Forssk.	perennial herb	medicinal
Globulariaceae	*Globularia arabica* Jaub. & Spach.	shrub	medicinal
Graminae	*Cymbopogon schoenanthus* (L.) Spreng.	perennial herb	medicinal
	Panicum turgidum Forssk.	sub-shrub	medicinal
	Schismus arabicus Nees	annual	
	Stipagrostis scoparia (Trin.&Rupr.) de Winter	perennial herb	medicinal
Juncaceae	*Juncus rigidus* Desf.	perennial herb	medicinal
Labiatae	*Ballota undulata* (Fresen.) Benth.	perennial herb	medicinal
	Salvia aegyptiaca L.	sub-shrub	medicinal
	Stachys aegyptiaca Pers.	sub-shrub	medicinal
	Teucrium polium L.	sub-shrub	medicinal
Leguminosae	*Acacia pachyceras* O. Schwartz var. *ital*(Chaudhry) Boulos	tree	medicinal
	Acacia tortilis (Forssk.) Hayne	tree	medicinal
	Astragalus spinosus (Forssk.) Muschl.	shrub	
	*Retama raetam (*Forssk.) Webb & Berthel	shrub	medicinal
Liliaceae	*Asparagus stipularis* Forssk.	shrub	medicinal
	Asphodelus viscidulus Boiss.	annual	
	Urginea maritima (L.) Baker	perennial herb	medicinal
Malvaceae	*Malva parviflora* L.	annual	medicinal
Molluginaceae	*Telephium sphaerospermum* Boiss.	annual	
Neuradaceae	*Neurada procumbens* L.	annual	
Nitrariaceae	*Nitraria retusa* (Forssk.) Asch.	Shrub	medicinal
Peganaceae	*Peganum harmala* L.	perennial herb	medicinal
Resedaceae	*Caylusea hexagyna* (Forssk.) M. L. Green	annual	
	Reseda orientalis (Müll. Arg.) Boiss.	annual	

Continue Appendix 1: Species list of Gebel Halal and their growth form and importance.			
Scrophulariaceae	*Scrophularia syriaca* Benth.	sub-shrub	
	Verbascum fruticulosum Post	perennial herb	
Solanaceae	*Lycium Shawii* Roem.& Schult.	shrub	medicinal
Tamaricaceae	*Reaumuria hirtella* Jaub. & Spach	sub-shrub	medicinal
	Tamarix nilotica (Ehrenb.) Bunge	shrub	medicinal
Thymelaceae	*Thymelaea hirsuta* (L.) Endl.	shrub	medicinal
Umbellifera	*Deverra tortuosa* (Desf.) DC.	sub-shrub	medicinal
	Eryngium glomeratum Lam.	perennial herb	
Zygophyllaceae	*Fagonia arabica* L.	sub-shrub	medicinal
	Fagonia mollis Delile	sub-shrub	medicinal
	Fagonia scabra Forssk.	perennial herb	
	Zygophyllum dumosum Boiss.	shrub	medicinal