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Assessment of Target Species in Saint Katherine Protectorate, Sinai, Egypt.

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Abstract: Sinai Peninsula has the geographical importance and uniqueness of being the meeting place of Asia and Africa. One hundred and twenty four species, belonging to 108 genera and 42 families were tabulated in Saint Katherine protectorate which is the only entirely terrestrial protectorate in Sinai peninsula. Forty-seven of the recorded species were the target species of medicinal plant conservation project, of which eleven endemic species. Asteraceae has the highest contribution of the total flora (15.3%), followed by Lamiaceae (10.5%), Caryophyllaceae (8.1%), Poaceae (7.3%) and each of Brassicaeae and Fabaceae (5.7%). With regard to their habitats, they could be arranged into 11 groups, of which rocky and stony are the most represented. Fortunately, two new enclosures were monitored for the first time in wadi Abu-Tweita. Thirty-five percent of the target species were found inside these two enclosures. Fifteen locations of soil characteristics supporting most of the target species at St. Katherine protectorate were analyzed. Significant differences in soil variables were detected among the 15 localities in several soil attributes, like pH, clay, Mg^{2+}, K^{+}, sand and gravel respectively. Forty-seven species were protected inside 48 permanent enclosures (37 old, 9 new and the two first-time monitored enclosures) were selected throughout St. Katherine protectorate to represent the different environmental habitats in fifteen locations. These species are 2 geophytes (*Adiantum capillus-veneris* and *Equisetum ramosissimum*), of which 50% is pluri-regional, 4 phanerophytes (*Cotoneaster orbicularis*, *Crataegus x sinaica*, *Moringa peregrine* and *Pistacia khinjuk*), of which 50% is pluri-regional and 25% is endemic, 5 therophytes (*Bufonia multiceps*, *Caylusea hexagyna*, *Plantago sinaica*, *Primula boveana* and *Silene linearis*) of which 40% is bi-regional, 20% is mono-regional and 20% is endemic and 36 chamaephytes, of which 30.6% is mono-regional, 27.8% is bi-regional, 25% is endemic and 8% is pluri-regional. The size distribution of 20 species among the target species approximate one of the 6 following size distributions: 1) More or less inverse J-shaped distribution, 2) Positively skewed distribution towards the small individuals, 3) More or less J-shaped distribution, 4) bell shaped distribution, 5) Bimodal size distribution and 6) stationary size distribution.

Key words: Saint Katherine, endemic, Sinai, SPIZE.

INTRODUCTION

With its high mountains and deep wadis in the southern Sinai Peninsula and its relatively unexplored desert ecosystem of wild plants, Saint Katherine Protectorate is as one of region's most amazing areas not only for its natural landscapes, but also for its medicinal plant diversity that has national and global interest.

The present study was carried out within the framework of " Medicinal Plant Conservation Project". A program for botanical conservation measures has been establishing in Saint Katherine Protectorate since 1998. This program includes the establishment of 37 enclosures in various areas to protect and monitor the endemic and threatened plant species in this protectorate. In addition, 9 new enclosures were established in 2003 for conserving some target species that were not included in the 37 old enclosures. Another two enclosures were monitored for the first time during this work. The plots of enclosures were chosen to represent the prevailing environmental variation associated with the distribution of the target species.

In the past few years, the Sinai peninsula has attracted a great deal of scientific attention both as a new axis of development of Egypt and as an important phytogeographic province. The recent socioeconomic and the tourist industry development of Sinai are based on previous evaluation of its natural resources (soil, water, animal and plant wild-life). Proper knowledge of these resources will help plan for the future development and conservation of its natural treasures. Studies dealing with the evaluation of these natural resources and monitoring of the changes taking place are needed, especially ecological studies[21].

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Most plant community classifications are based on soil characteristics, nature of soil surface and landform types[22]. Many studies have provided qualitative assessments of the distribution of plant species and associations in relation to physiographic factors in different areas of Sinai[37,15,4].

Management of an area to a large extent depends on condition of the vegetation[53]. Constant monitoring and studying of vegetation of an area is thus of utmost importance in order to provide the information on changes in condition of the area[53].

Few studies has been carried out on the size structure of plant species in Egypt, in general and in St. Katherine protectorate, in particular. According to Emslie[24], it is necessary to study woody vegetation at a size class as well as at a species level. As age class data are unreliable for savanna areas[35], analysis of population structure is restricted to size classes[47]. Size classes are considered to be better indicators of reproductive output than are age classes[55,34].

The structure of a population of plants can be described in terms of ages, sizes and forms of the individuals that compose it[27]. Since the fecundity and survival of plants is often much more closely related to size than to age[28,10,54,49], some authors[55,33,10] argued that it is better to classify the life history of plants by size rather than age which is the most widely used classification for organisms. Size differences may be directly or through differences in growth rates due to age differences, genetic variation, heterogeneity of resources, herbivores and competition[54].

The vegetation in St. Katherine protectorate has been subjected to disturbance through the human activities including "overgrazing, uprooting, tourism quarrying and over-exploitation". For example, rarity of these species may be due to regeneration slowly as *Thymus decussates*, drought as *Hypericum sinaicum*.

In Egypt, many shrub species are either endangered or vulnerable due to aridity conditions and human activities[3]. The continuous overgrazing, over-cutting and uprooting has led to the disappearance of pastoral plant communities, the paucity of trees and shrubs, the reduction of plant cover and soil erosion[32,56,29].

The present study is specifically interested in a) evaluating the degree of protection for the target species, b) developing a structural classification of some of the target species using species size (SPIZE) classes and c) assessing the ecological factors which affect the distribution and diversity of the recorded families with their species in Saint Katherine protectorate. Attention has also been paid to the relationship between the amount of boulders and stones, cobbles and surface gravels and the distribution of the plant species in the study area.

MATERIAL AND METHODS

Study Area: The Saint Katherine region is situated in the southern Sinai and is part of the upper Sinai massif[15]. It is located between 33° 55' to 34° 30' East and 28° 30' to 28° 35' North (Fig.1). Elevation ranges from 1300 to 8,530.18 ft. This region is characterized by outcrops of smooth granite uplifted to form several mountain peaks (e.g: Gebel Katherine 2642 m and Gebel Musa 2285 m)[46].

Forty seven species were protected inside 48 permanent enclosures (37 old, 9 new and 2 first time monitored enclosures during this work) were selected throughout St. Katherine protectorate to represent the different environmental habitats in fifteen localities. These localities are: Wadi Garagnia, Wadi Esbaiea, Wadi El-Fera'a, El-Monagh mountain, Wadi Abou Tweta, Wadi El Dair, Catherine mountain, Shaq Musa, Wadi El-Arbae'en, Musa's gorge, El- Ahmar mountain, Kahf El- Gola, Farsh Umm S'la, Wadi Zaghra and Musa's mountain. Cluster analysis of species with their habitats was performed by hierarchical cluster analysis (SPSS software, SPSS Inc. USA; Norusis,[42]).

Soil samples were collected from the surface of each location, or up to the rocks or hard pans in case of shallow. In each location, 3 soil samples were collected from 3 soil profiles (0 – 25cm). air dried, thoroughly mixed and passed through 2mm sieve to separate gravel and debris. Samples finer than 2mm were analyzed for soil texture and organic matter. The pH and electrical conductivity were determined in an

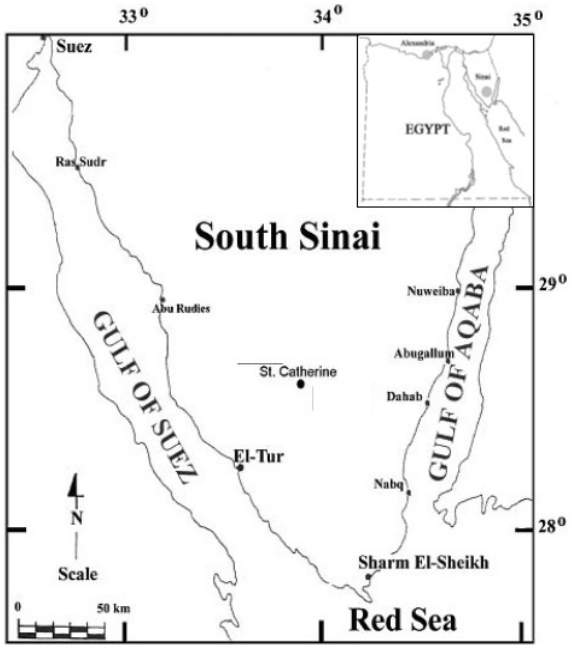

Fig. 1: Map of Egypt indicating the study area.

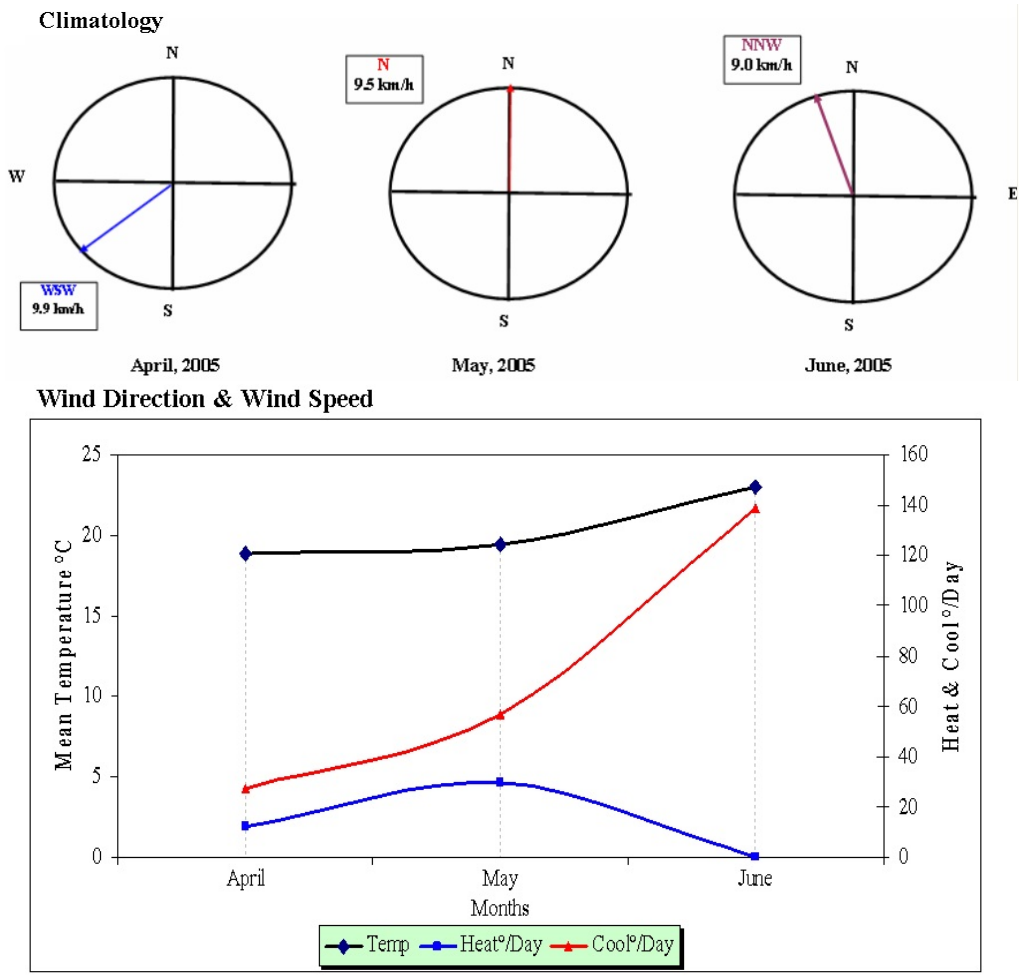

Fig. 2: Metrological data recorded at Saint Katherine protectorate from April to June 2005.

aqueous solution using a pH and a conductivity meter. Soil texture was determined by Bouyoucos hydrometer and soil organic carbon (loss on ignition) were estimated according to Allen *et al*.,[1]. Soil nutrients Ca^{+2}, K^{+}, Na^{+} and Mg^{+2} were determined using an atomic absorption spectrophotometer[31,1].

Plant specimens identification pended on the detailed examination and consultation of various flora of Sinai and adjacent regions. Nomenclature was updated according to Bolous[6-9], including also revision of many of the plant names. Voucher specimens for future reference of all plant taxa are kept at Ecological Research Unit, Collage of Science, Ain Shams University.

The population structure of twenty species was evaluated in terms of size distribution. For achieving this, the height and mean crown diameter of each individual in the whole locations was measured (based on 2-4 diameter measurements / ind.) and its volume was calculated as a cylinder. The volume estimates were then used to classify population into 10 size classes. The size classes (cm/ ind.) are (1≤10, 2=20, 3=30, 4=40, 5=50, 6=60, 7=70, 8=80, 9=90 and 10 ≥ 100), except for *Moringa peregrine* (m / ind.). The size index of each individual was calculated as the mean of its height and diameter[12,51].

Climate: The Sinai part of the Saharo-Arabian deserts[36,15] is characterized by an arid (>100 mm precipitation / year) to extremely arid climate with Mediterranean influences. Most of Sinai receives less than 50 mm annually with the southern Sinai massif receiving an average of 65 – 100 mm precipitation[15]. Saint Katherine is the coolest area in Sinai owing to its high elevation. The Saint Katherine area, in the southern Sinai, is characterized by a unique vegetation due to its geomorphological formations and altitudinal climatic variations Moustafa and Klopatek[38]. Temperature vary from a lowest mean temperature in January of 1.4°C to a highest mean temperature of

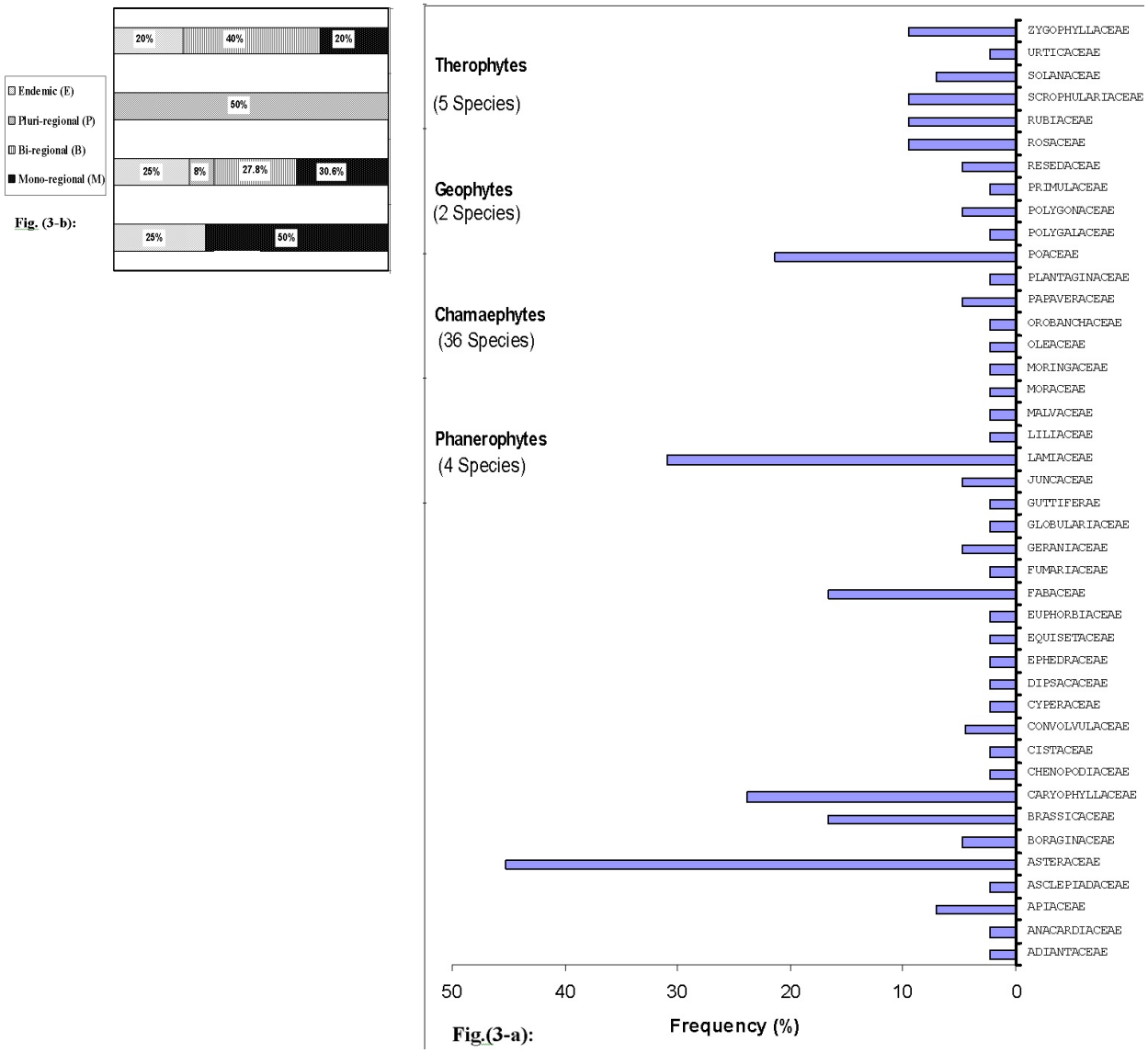

Fig. 3a: Frequency of the recorded families in relation to their species in Saint Katherine protectorate.
b: Layer diagram of chorotype spectrum and life form of the target species of S. Katherine protectorate.

30.8° and 31.8°C in June. During our work (2005), the temperature increased gradually from 18°C to 24°C. Variations in slope direction and soil type result in microhabitats that differ substantially in temperature (Fig.2). It reveals also, that the wind direction was western-south in April while in June, it became toward western-north direction.

RESULTS AND DISCUSSIONS

The study area which is a tiny section of Sinai (61.100 km^2 or 5.9% of Egypt) is the home of 124 species, belonging to 108 genera and 42 families. Forty seven of the recorded species were the target species of medicinal plant conservation project. Of which eleven endemic species showed in appendix 1.

Asteraceae has the highest contribution to the total flora (15.3%), followed by Lamiaceae (10.5%), Caryophyllaceae (8.1%), Poaceae (7.3%) and each of Brassicaeae and Fabaceae (5.7%) respectively (Fig.3-a).

With regard to their habitats, these species arranged into 11 groups of which rocky and stony are the most represented (Fig.4). The study area comprises a variety of highly diversified habitats including: stony, granite, wadis, caves(sheltered cliffs) and rock crevices. A group of species such as *Adiantum capillus-veneris,*

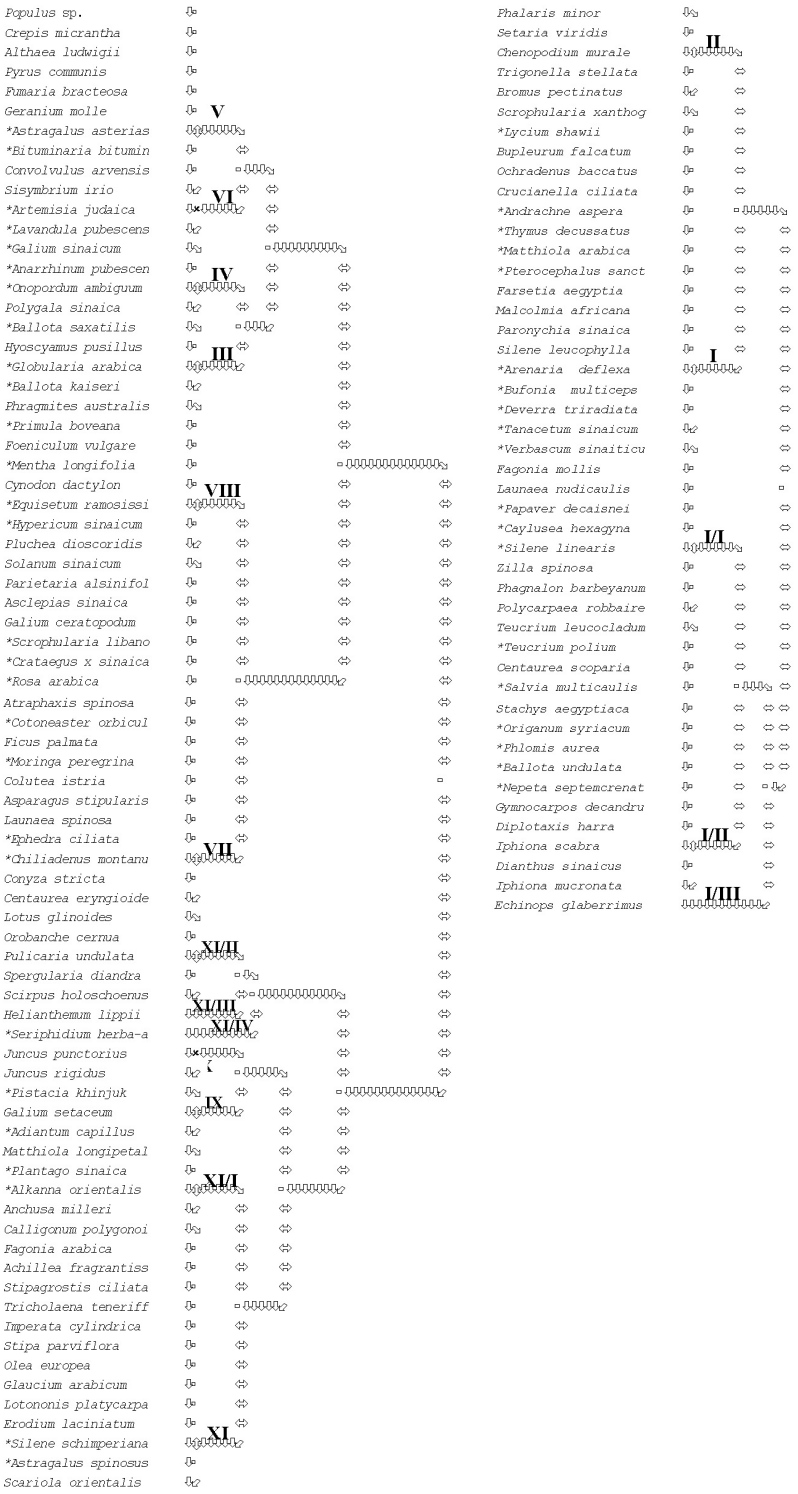

Fig. 4: Dendrogram showing the arrangement of plant species according to their habitats in the study area. Where I: stony, II: weed of cultivation, III: calcareous, IV: Granite, V: cultivated waste ground, VI: wadi bed & terraces, VII: rocky, VIII: moist ground, IX: sheltered cliffs, X: marshy places, XI: sandy, I/I: stony + sandy , I/II: stony wadis, I/III: stony granite, XI/I: sandy + rocky, XI/II: sandy + alluvial, XI/III: sandy + gravelly and XI/IV: sandy + stony + calcareous , see appendix (1).

Table 1: Mean (± standard deviation) of soil characteristics of 15 lacations at St. Catherine protectorate. The F-values and its probabilities are indicated. *P 0.05, **P 0.01 and ***P 0.001.

Loc.		Soil texture (%)					EC			Anion and Cations (Meq/L)				
No.	Locations	Gravel	Sand	Silt	Clay	pH	($mmhcm^{-1}$)	O.C.%	$CaCO_{3\%}$	Cl^-	Na^+	Mg^{++}	Ca^{++}	K^+
1	Wadi Garagnia	52.7±5.6	35.0±6.2	0.8±0.5	11.8±1.1	8.3±0.6	1.8±1.1	1.6±0.3	11.5±3.7	1.9±0.7	1.4±0.7	7.0±2.4	6.8±3.3	3.4±2.3
2	Wadi Esbaiea	64.7±2.3	28.7±1.9	0.9±0.2	5.1±3.9	7.7±0.3	0.3±0.2	1.1±0.1	4.0±0.2	3.3±0.8	0.7±0.2	3.7±2.0	5.3±2.0	0.6±0.2
3	Wadi El-Fera'a	47.0±11.2	38.9±8.3	1.6±0.6	12.4±4.9	8.2±0.2	1.0±0.9	0.8±0.2	11.0±4.8	1.5±0.3	0.7±0.3	4.8±2.5	4.7±1.6	0.7±0.4
4	El-Monagh mountain	38.8±3.3	40.8±4.4	2.5±0.1	15.7±1.2	7.8±0.3	0.2±0.1	1.0±0.1	13.0±1.4	2.5±0.7	1.1±0.1	2.5±0.7	4.0±0.2	0.4±0.3
5	Wadi Abou Tweta	53.3±10.8	33.6±8.5	0.9±0.6	10.9±5.3	8.2±0.1	1.0±0.7	1.4±0.6	10.0±6.4	1.6±0.4	0.8±0.3	3.9±2.8	4.4±1.2	1.2±0.5
6	Wadi El Dair	45.9±1.6	41.1±6.5	0.8±0.1	10.5±2.3	8.0±0.1	1.0±0.4	0.5±0.1	8.0±0.3	2.1±0.4	0.8±0.3	3.0±0.1	7.0±5.6	0.8±0.1
7	Catherine mountain	30.8±3.4	47.6±1.7	2.0±0.5	20.2±2.3	7.9±0.4	0.5±0.5	1.6±0.3	6.7±3.0	1.4±0.2	1.1±0.1	2.3±0.5	6.0±1.7	0.6±0.1
8	Shaq Musa	36.0±16.0	33.3±7.2	2.0±1.7	24.4±14.9	8.0±0.6	1.5±0.6	1.3±0.5	12.3±6.7	3.3±2.1	2.6±0.8	6.9±2.2	12.3±8.9	8.5±6.9
9	Wadi El-Arbae'en	50.9±20.8	36.3±13.3	1.4±1.0	10.7±7.7	7.6±0.2	0.6±0.5	1.1±0.3	8.7±5.4	2.2±1.4	1.0±0.5	4.2±2.5	3.8±1.3	0.6±0.3
10	Musa's gorge	33.1±10.5	41.9±6.5	1.5±0.6	20.4±4.4	7.8±0.2	0.8±0.7	1.2±0.2	10.3±2.3	2.0±0.7	1.3±0.3	3.8±1.8	4.2±1.7	0.9±0.5
11	El- Ahmar mountain	43.2±8.5	41.7±10.1	2.8±2.1	12.1±0.5	7.2±0.5	1.0±0.8	1.2±0.2	8.7±1.1	5.2±4.2	1.9±1.7	6.2±4.5	4.8±2.0	0.4±0.0
12	Kahf El- Gola	43.7±4.5	45.4±5.6	1.8±0.2	8.9±1.2	7.5±0.3	0.2±0.1	1.8±0.2	6.0±0.4	2.5±0.2	1.2±0.1	4.0±0.2	8.0±0.8	0.6±0.2
13	Farsh Umm S'la	37.8±22.4	30.7±3.3	1.2±0.7	11.9±0.7	8.0±0.4	1.4±1.1	1.1±0.2	11.0±1.4	1.8±0.1	1.4±0.4	5.5±2.1	5.5±4.9	1.0±0.1
14	Wadi Zaghra	34.1±4.3	63.9±5.8	0.4±0.1	5.5±1.2	7.7±0.3	0.4±0.3	1.9±0.2	2.0±0.1	2.3±0.2	1.3±0.2	5.0±0.2	4.0±0.7	1.2±0.1
15	Musa's mountain	47.9±11.3	38.6±6.6	1.7±0.4	12.3±7.9	7.7±0.3	1.2±0.6	1.2±0.5	8.3±4.7	1.5±0.3	1.3±0.7	6.1±3.5	5.4±1.8	0.6±0.4
	F value	1.95	1.99	1.31	2.43	3.02	0.56	1.76	1.22	1.86	1	2.26	0.78	2.07
	P	0.048*	0.043*	0.245	0.013**	0.003***	0.883	0.078	0.295	0.061	0.473	0.021*	0.688	0.035*

Galium setaceum and *Pistacia khinjuk* are very restricted to sheltered cliffs (caves). The same can be said about *Rosa arabica* with its group (VII) occurred in rocky habitat (see Appendix 1 and Fig.4).

Fortunately, two new enclosures (not recorded before) were monitored. They present in wadi Abu-Tuweita, coordinate Late. 28° 34' 013" N, Long 33° 53' 044" E, Alt. 1910 m.a.s.l; Late. 28° 34' 016" N, Long 33° 53' 043" E, Alt. 1882 m.a.s.l. The area of the 1st time monitored enclosure (1) was 20 m^2 with eight target species. These species are: *Deverra triradiata*, *Ephedra ciliate*, *Onopordum ambiguum*, *Phlomis aurea*, *Pistacia khinjuk*, *Rosa arabica*, *Silene schimperiana* and *Tanacetum* sinaicum. On the other hand, the area of the 1st time monitored enclosure (2) was 27 m^2 with 14 target species. Their species are: *Alkanna orientalis*, *Astragalus spinosus*, *Chiliadenus montanus*, *Cotoneaster orbicularis*, *Deverra triradiata*, *Echinops glaberrimus*, *Galium sinaicum*, *Phlomis aurea*, *Plantago sinaica*, *Salvia multicaulis*, *Scrophularia libanotica*, *Silene schimperiana*, *Tanacetum sinaicum* and *Teucrium polium*.

The character of the soil surface, altitudinal gradients and landform types provide microhabitats dominated by characteristic vegetation. Table (1) shows the results of 15 locations of soil characteristics supporting some of the target species at St. Katherine protectorate. Significant differences in soil variables were detected among the 15 localities in many soil attributes, e.g: pH, clay, Mg^{2+}, K^+, sand and gravel respectively. The soil of the study area generally has alkine pH, with a minimum of 7.2 in the location of Al-Ahmar mountain and a maximum of 8.3 in the location of Wadi garagnia in the study area. The silt % showed a wide range of variation in the different locations with a minimum of 0.4% in wadi Zaghra (that have highest % of sand) and a maximum of 2.8% in samples from Al-Ahmar mountain.

The soil of wadi Esbaiea has a gravely texture with least % of sand and clay in contrast to Catherine mountain which has least % of gravels (30.8±3.4). The soil electrical conductivity ($mmhcm^{-1}$) showed a wide range of variation in the different locations in St. Katherine protectorate with a maximum of 1.8 $mmhcm^{-1}$ in samples from wadi Garagnia and a minimum of 0.2 $mmhcm^{-1}$ in soil samples from both El-Monagh mountain and Kahf El-Gola sites.

$CaCO_3$ showed a maximum value of 13.0 % in soil samples from El-Monagh mountain and a minimum of 2.0% in soil samples from wadi Zaghra. With respect to anion and cations (Meq/L), in the different locations of St. Katherine protectorate, table 1, showed that soil samples taken from Shaq Musa has a maximum value in all the cations determined with a slight higher value of chlorine as an anion (3.3 Meq/L).

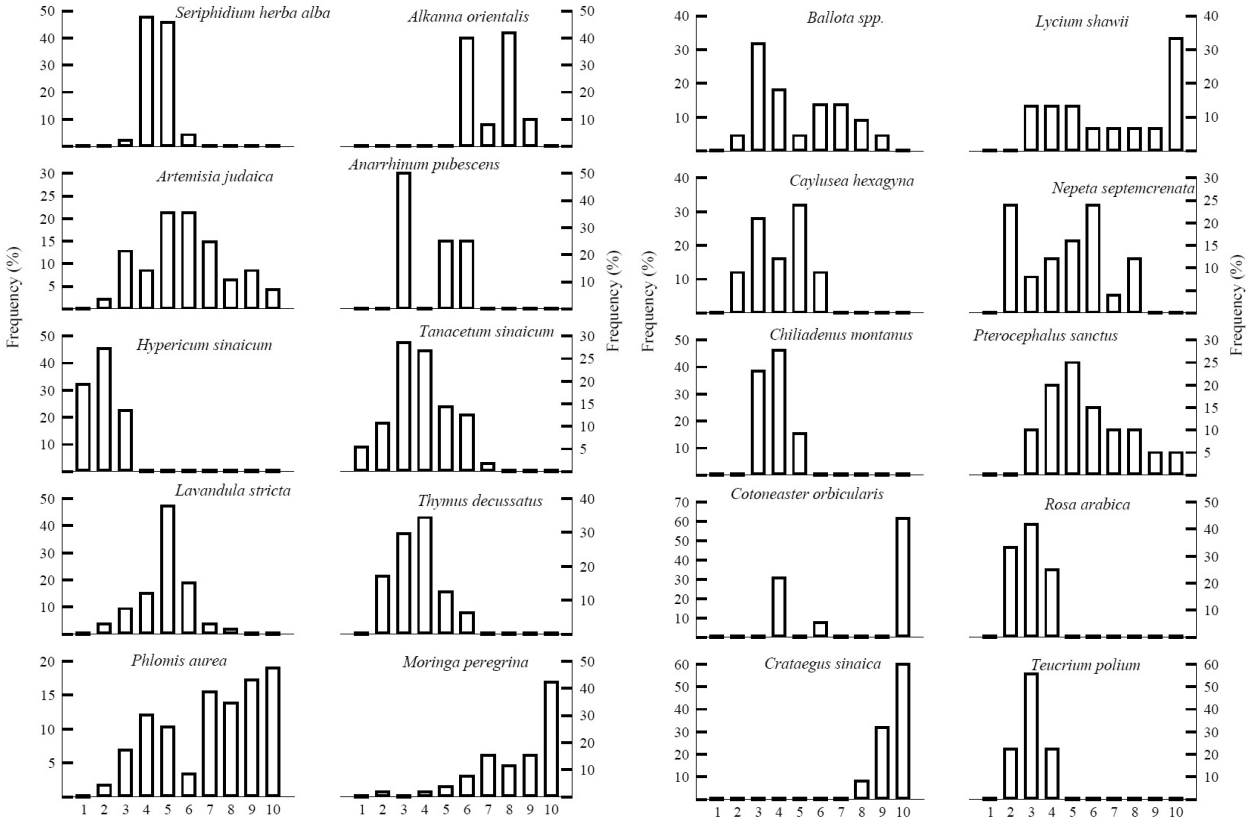

Fig. 5: The size-frequency distribution of some target species in St. Katherine Protecorate. The size classes (cm/individual) are (1<10, 2 = 20, 3 = 30, 4= 40, 5= 50, 6= 60, 7= 70, 8=80, 9 = 90 and 10> 100), except for *Moringa peregrina* and *Rosa arabica* (m/individual).

From table (1) and appendix (1), the species present only in a single locations were as follow: *Adiantum capillus-veneris, Arenaria deflexa* and *Mentha longifolia*; *Mathiola Arabica*; *Papaver decaisnei* and *Verbascum sinaiticum*; *Andrachne aspera*; *Astragalus asterias*; *Ballota* spp., *Deverra triradiata*, *Lycium shawii* and *Silene linearis*; *Galium sinaicum* and *Globularia arabica*; *Moringa peregrine*. Their locations are: wadi Garagnia, wadi El-Fera'a, wadi Abou Tweta, wadi El Dair, Catherine mountain, wadi El-Arbae'en, Farsh Umm S'la and wadi Zaghra respectively. The other species present in more than one location such as *Thymus decussates* which present in five locations named wadi El-Fera'a, wadi El-Arbae'en, El-Ahmar mountain, Farsh Umm S'la and Musa's mountain.

Wadi Garagnia, the location of *Adiantum capillus-veneris* tolerates the maximum pH (8.3), EC (1.8 $mmhcm^{-1}$) and Mg^{2+} (7.0 Meq/L). Wadi El-Dair, the location of *Anarrhinum pubescens* indicates the minimum % of organic carbon (0.5) while Shaq Musa, the location of *Cotoneaster orbicularis* occupy the maximum values of clay (24.4%) and all the cation fractions (Na^{+}: 2.6, Mg^{2+}: 6.9, Ca^{2+}: 12.3 and K^{+}: 8.5 Meq/L). *Hypericum sinaicum* occupy the slightly alkaline soil (pH: 7.5) at Kahf El-Gola with least value of EC (0.2 $mmhcm^{-1}$) in comparison with the other locations. *Moringa peregrina* occupy the sandy soil (63.9%) with minimum % of each of silt (0.4%), organic carbon (1.9%) and $CaCO_3$ (2.0%) at wadi Zaghra.

There are 47 target species recorded in 48 enclosures (37 old since 1998, 9 new since 2003 and two 1st monitored only during this work, 2005). These species are 2 geophytes (*Adiantum capillus-veneris* and *Equisetum ramosissimum*), of which 50% is pluri-regional, 4 phanerophytes (*Cotoneaster orbicularis*, *Crataegus x sinaica*, *Moringa peregrine* and *Pistacia khinjuk*), of which 50% are pluri-regional and 25% is endemic, 5 therophytes (*Bufonia multiceps*, *Caylusea hexagyna*, *Plantago sinaica*, *Primula boveana* and *Silene linearis*) of which 40% are bi-regional, 20% is mono-regional and 20% is endemic and 36 chamaephytes, of which 30.6% are mono-regional, 27.8% are bi-regional, 25% are endemic and 8% are pluri-regional (see appendix 1 and fig.3-b).

Table 2: Mean±SD of some demographic variables of the target species in Saint Katherine protectorate.

Species	Height (cm)	Diameter (cm)	Size index (cm)	Height/Diameter (cm)	Volume (m^3)	Area (m^2)
Alkanna orientalis	57.78±19.28	105.56±29.27	81.67±53.69	0.5±0.61	6.297±1.893	0.934±0.511
Anarrhinum pubescens	51.25±18.08	20.83±11.75	36.04±13.94	2.96±1.38	0.313±0.300	0.044±0.042
Artemisia judaica	54.71±20.92	57.18±29.68	55.94±23.09	1.14±0.50	0.996±0.982	0.324±0.295
Ballota sp.	49.09±9.25	37.95±8.69	43.52±7.88	1.57±0.58	0.596±0.673	0.159±0.189
Caylusea hexagyna	51.6±16.75	22.72±10.24	37.16±11.95	2.54±1.01	0.315±0.252	0.048±0.042
Chiliadenus montanus	40.77±8.62	27.44±10.01	34.1±6.58	1.63±0.53	0.201±0.133	0.066±0.055
Cotoneaster orbicularis	83.85±32.28	70±33.88	76.92±32.24	1.37±0.54	2.926±2.283	0.468±0.333
Crataegus sinaica	302.31±106.31	237.44±72.82	269.87±86.93	1.27±0.22	117.687±111.873	4.81±2.956
Hypericum sinaicum	14.97±13.56	13.42±6.63	14.2±8.21	1.26±1.00	0.027±0.044	0.018±0.017
Lavandula stricta	51.92±16.74	37.23±15.88	44.58±13.93	1.59±0.67	0.508±0.394	0.128±0.094
Lycium shawii	89±46.71	66.22±41.95	77.61±41.85	1.5±0.57	3.889±4.744	0.474±0.557
Moringa peregrina	1222.22±625.24	720.56±305.73	971.39±438.86	3.64±0.88	0.736±1.044	0.891±0.428
Nepeta septemcrenata	48.8±18.10	34.53±21.75	41.67±19.46	2.11±1.50	0.525±0.516	0.129±0.128
Phlomis aurea	80.68±33.11	48.61±29.05	64.64±28.86	2.03±1.04	2.01±0.226	0.25±0.029
Pterocephalus sanctus	59±28.40	47.42±19.19	53.21±21.97	1.3±0.57	1.054±1.420	0.204±0.174
Rosa arabica	306.67±59.90	310.74±39.85	308.7±42.59	0.99±0.16	129.019±58.671	7.691±1.865
Seriphidium herba alba	34.22±5.85	49.21±9.44	41.72±5.27	0.73±0.20	0.247±0.100	0.197±0.073
Tanacetum sinaicum	33.62±13.15	39.89±24.61	36.75±17.70	1.11±0.57	0.275±0.025	0.171±0.017
Teucrium polium	19.44±4.64	28.52±10.26	23.98±7.07	0.72±0.15	0.052±0.034	0.071±0.047
Thymus decussatus	18.63±6.54	44.01±19.20	31.32±11.56	0.47±0.18	0.081±0.021	0.18±0.015

Appendix 1 and fig. 4 reveal that the plant species can arranged according to their habitats into the following categories: stony, weed of cultivation, calcareous, granite, cultivated waste ground, wadi bed and terraces, rocky, moist ground, sheltered cliffs, marshy places and sandy. Further classification of stony and sand into stony + sand, stony wadis, stony granite, sandy + rocky, sandy + alluvial, sandy + gravelly and finally sandy + stony +calcareous respectively.

The diagrams illustrating the size distribution of the 20 examined target species approximate one of the 6 following size distributions (Fig.5):

1. More or less inverse J-shaped distribution (*Alkanna orientalis* and *Ballota* spp.);
2. Positively skewed distribution towards the small (young) individuals (*Anarrhinum pubescens, Chiliadenus montanus, Hypericum sinaicum, Rosa arabica, Teucrium polium* and *Thymus decussates*);
3. More or less J-shaped distribution (*Cotoneaster orbicularis, Cratagus sinaica Lycium shawii* and *Moringa peregrine*);
4. Approximately symmetrical (i.e. bell shaped) distribution (*Artemisia judaica*, *Lavandula stricta*, *Seriphidium herba alba* and *Tanacetum sinaicum*);
5. Bimodal size distribution (*Caylusea hexagyna* and *Nepeta septemcrenata*);
6. More or less stationary size distribution (*Phlomis aurea and Pterocephalus sanctus*).

With respective to *Thymus, Alkanna, Tecurium* and *Seriphidium*, the height to diameter ratio was less than unity (Table 2). This means that the diameters of these species exceed their heights and hence individuals of these species tend to expand horizontally rather than vertically.

Discusion: Sinai is a triangular area covering about 61.100 Km^2. The southern part of Sinai is relatively floristically rich compared to the rest of Sinai. In agreement with Danin[14,15] the nature of the soil surface is one of the most important factors influencing the floristic richness of the landforms along with the climatic variations due to orographic influences. The peninsula contains mountains in its southern sector that are a geological extension of the Red Sea Hills, with Mount Katherine as the highest point at 2642 m high. St. Katherine is the only entirely terrestrial protectorate in Sinai peninsula. It is a central area of plant geographical regions and has high

climatic, lithologic and edaphic diversity. These factors, together with prolonged influence of human activity, have led to the development of rich flora and diverse vegetation.

The existence of many habitats that are needed to support 124 species may be due to topographic features of the study area (Appendix 1 and Fig.4). The geomorphological structures are relatively small but the number of rock types is high. As a result, many soil types develop in small area[13] increasing the diversity of habitats.

The Saint Katherine mountains are a centre of endemism[57,52,40]. Danin[16] estimated 28 endemic species, 3.2 % of its total flora. About 50% of these species are found in the study area growing in the floristically rich landform types that have a wetter microclimate than other habitats of the Sinai. Previous work by Danin[17,16], Moustafa[39,40] and Boulos and Gibali[5] indicate that the Saint Katherine flora area is represented mainly by Irano-Turanian elements. Eleven endemic species among the forty seven target species are listed in appendix 1.

St. Katherine protectorate is among the most picturesque in the country. It is blessed with a variety of microhabitat types which is hardly matched by any other part of Sinai. Therefore, it is not surprising to find that this small fraction of Sinai houses of more than 124 plant species. In this context, Danin[15] reported that a counteracted type of vegetation dominated the study area with only 236 species, while El-Gazzar *et al*.,[21] reported 406 species from the same area. Danin[15] attributed the development of so many plant associations in the study area to the great variability of rock and soil types. Plant diversity changes have been related to several factors: spatial variability (de Pablo *et al*., 1982), seed bank and secondary succession (Peco *et al*., 1983) and meteorological variation between years[43].

Many studies[48,44] reported high species diversity due to substrate heterogeneity in some Mediterranean communities. These studies indicated that higher levels of species diversity were brought about by a local differentiation in soil properties around the individual plant. Since heterogeneity of environment allows satisfaction of the requirements of the diverse species within a community.

The composites (Asteraceae) and Lamiaceae followed by Caryophyllaceae and Poaceae had the highest contribution to the flora of the present study. This trend is somewhat similar to that of the pasture zone in north Libya[45]. Regarding the biological spectrum of the target species in the present study, chamaephytes are the most frequent (76.6%), followed by therophytes (10.6) and phanerophytes (8.5%). From the phytogeographical view point of these target species, the mono-regional chorotype is the most representative. This resembles the chorological data in Al-Jabal Al-Akhdar and also the endemic species in that mountain[45]. The concentration of the endemic species in the present study could be due to its peculiar physiographic and climatic comparing with the rest of Sinai. These mass of mountains is intensively rugged and dissected by a complicated system of deep wadis. Irregularities give rise to a high number of microhabitats, each with peculiar environmental conditions. These physiographic and climatic barriers have provided an excellent ecological refugia and contributed to restriction of many endemic taxa.

The Saint Katherine area has a variety of landform types: terraces, gorges, slopes, ridges, wadis and plains. Landform type and other elements such as elevation, soil physical characteristics (including soil texture and nature of surface), slope, aspect and topography all play an important role in determining the distribution of plant communities[2,15,40].

The highest % of clay and silt present in Shaq Musa and El-Ahmar mountain respectively. The airborne silt and clay that is trapped at the sand surface improve the moisture regime and enable the development of micro-biotic crust (Pers. Obs.). This result was in accordance with Danin *et al*.,[19] and Danin[18] who concludes this crust decreases sand mobility and promotes sand stabilization.

Size differences in plant populations may be caused directly or through differences in growth rates due to age differences, genetic variation, heterogeneity of resources, herbivores and competition[54].

In the present study, some species had inverse J-shaped distribution (*Alkanna orientalis* and *Ballota* spp.) or positively skewed (*Anarrhinum pubescens*, *Chiliadenus montanus*, *Hypericum sinaicum*, *Rosa arabica*, *Teucrium polium* and *Thymus decussates*) size distributions towards the small (i.e. young) individuals. These may represent rapidly growing populations with high reproductive capacity. Such distributions may indicate also a high juvenile mortality[28], but nevertheless they seem to represent long-term stability, since in most stable population one would expect an excess of juvenile over mature individuals[11,25,49].

Moreover, Gray[26] reported that the positively skewed distribution is indicative of a self-perpetuating species, with marked more frequency of the smaller (younger) size classes. Similar conclusion was made by Shaltout and Ayyad[49]. The bell-shaped size distribution of *Artemisia judaica*, *Lavandula stricta*, *Seriphidium herba alba* and *Tanacetum sinaicum* indicated comparable representation of the juvenile and mature individuals. If current situation continues, a reduction in population size of this species is expected in the future. Similar results were reported by Shaltout and Mady[50] in their study on the size distribution of *Lycium shawii* in central Saudi Arabia.

The J-shaped distribution of *Cotoneaster orbicularis, Cratagus sinaica, Lycium shawii* and *Moringa peregrine* indicated the dominance of mature individuals over the juvenile ones. This distribution characterizes a declining populations, because the population has a large proportion of larger individuals than smaller ones (i.e. limited regeneration capacity). This may indicate that the recruitment of these species is rare especially with respect to *Lycium shawii* and *Moringa peregrine* as they represented only in one location, wadi El-Arbae'en and wadi Zaghra respectively.

Bimodal size distribution may result from initially unimodal size distribution when there is discontinuous variation in exponential growth rates among individuals. Sources of discontinuous variation may be genetic and /or environmental heterogeneity, or dominance-and-suppression competition. Such competition may be considered asymmetric because the resulting negative effects are experienced only by the smaller plants[30].

It is recommended that the target species present only in one location as *Adiantum capillus-veneris, Arenaria deflexa*, *Mentha longifolia*, *Mathiola arabica*, *Papaver decaisnei*, *Verbascum sinaiticum andrachne aspera*, *Astragalus asterias*, *Ballota* spp., *Deverra triradiata*, *Lycium shawii*, *Silene linearis*, *Galium sinaicum*, *Globularia arabica* and *Moringa peregrine*, must be evaluated seasonally rather than annually.

The positively skewed size distribution indicated the relative preponderance of small sized individuals of *Anarrhinum pubescens, Chiliadenus montanus, Hypericum sinaicum, Rosa arabica, Teucrium polium* and *Thymus decussates* may be due to their presence in more than two locations. Contrarily, the J-shaped size distribution of *Cotoneaster orbicularis, Cratagus sinaica Lycium shawii* and *Moringa peregrine* may be due to their presence only in one or at maximum two locations. The study area needs further studies for assessing the regeneration capacity of the endemic and endangered of noteworthy, rare and threatened species in terms of natality, mortality, survival and growth rates.

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Appendix (1): List of the recorded families with their species, vernacular names, Habitats and life form (LF) and chorotype (CH) of the target species(*) of Saint Katherine protectorate. Note: The number follows the species name indicates location number in which it is present.

Family	Species	Vernacular	Habitats	*LF	*CH
ADIANTACEAE	**Adiantum capillus-veneris* L.[1]	كسيرة البئر	Sheltered cliffs	*Ge	*ME, IT&ES
ANACARDIACEAE	**Pistacia khinjuk* Stocks var. *glabra* Schweinf. [1st time recorded (1)]	بطم	Sheltered cliffs	*Ph	*IT
APIACEAE	*Bupleurum fakatum* L. subsp. *exaltatum* (M. Bieb.) H. Wolff var. *linearifolium*		Stony		
	**Deverra triradiata* Poir[9]	زجوح	Stony		
	Foeniculum vulgare subsp. *piperitum* (Ucria) Cout.	شمر	Moist ground		
ASCLEPIADACEAE	*Asclepias sinaica* (Boiss.) Muschl.	حرجل بري	Rocky		
ASTERACEAE	*Achillea fragrantissima* (Forssk.) Sch. Bip.	جيسوم	Sandy		
	**Artemisia judaica* L. [2,6]	بعيتران	Wadi beds & terraces	*Ch	*SA
	Centaurea eryngioides Lam.	لحية البدن	Rocky		
	Centaurea scoparia Sieber ex Spreng.	بركان	Stony wadis		
	**Chiliadenus montanus* (Vahl) Brullo. [1,6,9]	هنيده	Rocky	*Ch	*SA
	Conyza stricta Willd.,	حليبه	Rocky		
	Crepis micrantha Czerep		Cultivated waste ground		
	Echinops glaberrimus DC.	كعر -شدق)شوك الجمل(	Stony granite		
	Iphiona mucronata (Forssk.) Asch. & Schweinf.,	ظفره	Stony wadis		
	Iphiona scabra DC.		Stony wadis		
	Launaea nudicaulis (L.) Hook. F.,	حوه	Stony, sandy & alluvial		
	Launaea spinosa (Forssk.) Sch. Bip. Ex Kuntze,	كياك	Rocky		
	**Onopordum ambiguum* Fresen.[1st time recorded (1)]	الخشرف	Granite	*Ch	*SA&IT
	Phagnalon barbeyanum Asch. & Schweinf.		Sandy & stony		
	Pluchea dioscoridis (L.) DC.,	البرنوف	Moist ground		
	Pulicaria undulata (L.) C. A. Mey.	نشاث	Sandy & alluvial		
	Scariola orientalis (Boiss.) Soják	يحكيس	Sandy		
	**Seriphidium herba-alba* (Asso.) Sojak [3,7,8]		Sandy,stony&calcareous	*Ch	*IT
	**Tanacetum sinaicum* (fresen.)Delile ex Bremer &Humphries[5, 7,8,9,10,11,13]	مر	Stony	*Ch	*IT
BORAGINACEAE	**Alkanna orientalis* (L.) Boiss.[1,2]	الليبيد	Sandy&rocky wadis	*Ch	*ME&IT
	Anchusa milleri Willd.	كحلة	Sandy&rocky wadis		
BRASSICACEAE	*Diplotaxis harra* (Forssk.) Boiss.	حاره	Sandy & stony		
	Farsetia aegyptia Turra,	جربه	Stony		
	Malcolmia africana (L.) R. Br. in W. T. Aiton		Stony		
	**Matthiola arabica* Boiss.[3]	خمخم	Stony	*Ch	*SA
	Matthiola longipetala subsp. *bicornis* (Sm.) P. W. Ball,		Sandy & rocky		
	Sisymbrium irio L.	السليج	Cultivated waste ground		
	Zilla spinosa subsp. *spinosa* (L.) Prrantl in Engl. & Pran	زله	Stony & sandy		
CARYOPHYLLACEAE	**Arenaria deflexa* Decne [1]		Stony	*Ch	*ME
	**Bufonia multiceps* Decne. [3,4,5]	عدمه	Stony	*Th	*Endemic
	Dianthus sinaicus Boiss.	صمه	Stony wadis		
	Gymnocarpos decandrus Forssk	جرد	Stony wadis		
	Paronychia sinaica Fresen.		Stony		

	Polycarpaea robbairea (Kuntze.) Greuler & Bardit.,		Sandy & stony		
	**Silene leucophylla* Boiss. [1st time recorded (2)]	اللزيقة	Stony	*Ch	*Endemic
	**Silene linearis* Decne.[9]	وسبى	Sandy & stony	*Th	*SA & SU
	**Silene schimperiana* Boiss.[1st time recorded (1&2)]	وسبيه	Sandy	*Ch	
	Spergularia diandra (Guss.) Boiss.		Sandy & alluvial		
CHENOPODIACEAE	*Chenopodium murale* L.	لسان الطير	Weed of cultivation		
CISTACEAE	*Helianthemum lippii* (L.) Dum. Cours.	رجرج -رقروق	Sandy & gravelly		
CONVOLVULACEAE	*Convolvulus arvensis* L.	العليق	Cultivated waste ground		
	Cuscuta planiflora Ten.	الحامول	Parasitic on plants		
CYPERACEAE	*Scirpus holoschoenus* L.	ديس	Sandy & Alluvial		
DIPSACACEAE	**Pterocephalus sanctus* Decne [1,3, 10,.11]	علده	Stony	*Ch	*SA&IT
EPHEDRACEAE	**Ephedra ciliata* Fischer & C. A. Mey. [1st time recorded (1)]		Rocky	*Ch	*ME
EQUISETACEAE	**Equisetum ramosissimum* Desf.[9]	حجينه	Moist ground	*Ge	
EUPHORBIACEAE	**Andrachne aspera* Spreng. [6]	عود العقرب	Stony	*Ch	*IT,SA&SU
FABACEAE	**Astragalus asterias* subsp. *radiatus* (Butt.) Greuter [7]		Cultivated waste ground	*Ch	
	**Astragalus spinosus* (Forssk.) Muschl. [1st time recorded (2)]	قتاد أو كتاد	Sandy	*Ch	*IT & SA
	**Bituminaria bituminosa* (L.) C. H. Stirt. [4,6]	جيتيت	Cultivated waste ground		
	Colutea istria Mill.,	يسر	Rocky		
	Lotononis platycarpa (Viv.) Pic. Serm.,	عدرس	Sandy		
	Lotus glinoides Delile	قطب	Sandy & alluvial		
	Trigonella stellata Forssk		Weed of cultivation		
FUMARIACEAE	*Fumaria bracteosa* Pomel		Cultivated waste ground		
GERANIACEAE	*Erodium laciniatum* subsp. *pulverlentum* (Boiss.) Batt. & Trab.		Sandy		
	Geranium molle L.		Cultivated waste ground		
GLOBULARIACEAE	**Globularia arabica* Jaub. & Spach.[13]	زريقه	Calcareous	*Ch	*ME & SA
GUTTIFERAE	**Hypericum sinaicum* Boiss.[8,12]	ركيج	Moist ground	*Ch	*Endemic
JUNCACEAE	*Juncus punctorius* var. *punctorius* L.f.	ثمور	Marshy places		
	Juncus rigidus Desf.		Marshy places		
LAMIACEAE	**Ballota kaiseri* Tackholm [9,12]	غصة	Calcareous	*Ch	*Endemic
	**Ballota saxatilis* C. Presl [9]		Calcareous	*Ch	*ME
	**Ballota undulata* (Fresen.) Benth.[9]		Stony wadis	*Ch	*ME
	**Lavandula pubescens* Decne. [6]	عطان	Wadi beds & terraces	*Ch	*SA & SU
	**Mentha longifolia* (L.) Huds. subsp. *schimperi* (Briq.) Briq.[1]	حبق	Moist ground	*Ch	*ES,IT&ME
	**Nepeta septemcrenata* Benth[.1,8,9,10,11,12]	زيتيه	Stony wadis	*Ch	*Endemic
	**Origanum syriacum* subsp. *sinaicum* (Boiss.) Greater & Burdet.[5,9,10,12]	زعتر	Stony wadis	*Ch	*Endemic
	**Phlomis aurea* Decne.[1,3,8,9,11,13]	زهيره	Stony wadis	*Ch	*Endemic
	**Salvia multicaulis* Vahl. [5,13]	برديقوش -مرديقوش	Stony wadis	*Ch	*IT & ME
	Stachys aegyptiaca Pers.	رغل	Stony wadis		
	Teucrium leucocladum Boiss.		Stony wadis		
	**Teucrium polium* L. [7,9]	جعده	Stony wadis	*Ch	*IT&ME
	**Thymus decussatus* Benth. [3,9,11,13,15]	زعيتران	Stony	*Ch	*Endemic
LILIACEAE	*Asparagus stipularis* Forssk	عقول بري	Rocky		
MALVACEAE	*Althaea ludwigii* L.	الخطمية	Cultivated waste ground		
MORACEAE	*Ficus palmata Forssk.*	حماط	Rocky		
MORINGACEAE	**Moringa peregrina* (Forssk.) Fiori. [14]	لبان	Rocky	*Ph	*SU
OLEACEAE	*Olea europea* L. var. *europea*	زيتون	Sandy		
OROBANCHACEAE	*Orobanche cernua* Reut.	الهالوك	Sandy & alluvial		
PAPAVERACEAE	*Glaucium arabicum* Fresen.	النعمان	Sandy		
	**Papaver decaisnei* Elkan.[5]	قريعية	Stony & sandy	*Ch	
PLANTAGINACEAE	**Plantago sinaica* (Barneoud) Decne.[9,13]	لسان الحمل	Sandy & rocky	*Th	*ME
POACEAE	*Bromus pectinatus* Thunb.,		Weed of cultivation		
	Cynodon dactylon (L.) Pers.,	نجيل	Moist ground		
	Imperata cylindrica (L.) Raeusch.,	الحلفا	Sandy		
	Phalaris minor Retz..		Weed of cultivation		
	Phragmites australis (Cav.) Trin. ex Steud.,	الحجنه	Moist ground		
	Setaria viridis (L.) P. Beauv.,	ذيل الفأر	Weed of cultivation		
	Stipa parviflora Desf.		Sandy		
	Stipagrostis ciliata (Desf.) de Winter		Sandy		
	Tricholaena teneriffae (L. f.) Link		Sandy		
POLYGALACEAE	*Polygala sinaica* Botsch.	هيكل	Granite		
POLYGONACEAE	**Atraphaxis spinosa* L. var. *sinaica* (Jaub & Spach.) Boiss.[10,13]	سراس	Rocky	*Ch	*IT
	Calligonum polygonoides L. subsp. *comosum* (L,Her) Soskov	ارطى	Sandy		

PRIMULACEAE	**Primula boveana* Duby [1,8,12]	خس الجبل ـلباغ	Moist ground	*Th	
RESEDACEAE	**Caylusea hexagyna* (Forssk.) M. L. Green	دنابه	Sandy & stony	*Th	*SA & SU
	Ochradenus baccatus Delile	جارتى ـعنرس	Stony		
ROSACEAE	**Cotoneaster orbicularis* Schltdl. [8,9]	ثوحط	Rocky	*Ph	
	**Crataegus x sinaica* Boiss. [1,5,7,8,9,15]	زعرور	Rocky	*Ph	*Endemic
	Pyrus communis L.	الكمثري	Cultivated waste ground		
	**Rosa arabica* Crep. [5,8,9,12]	ورد برى	Rocky	*Ch	*Endemic
RUBIACEAE	*Crucianella ciliata* Lam.,	عشد	Stony		
	Galium ceratopodum Boiss.	بسيسة	Rocky		
	Galium setaceum Lam.	بسيسة	Sheltered hillsides		
	**Galium sinaicum* (Delile ex Decne) Boiss. [13]	عشمه ـبسيسه	Granite	*Ch	*SA
SCROPHULARIACEAE	**Anarrhinum pubescens* Fresen. [6,13]	ارفيجه	Granite	*Ch	*Endemic
	**Scrophularia libanotica* Boiss.		Rocky	*Ch	*ME
	Scrophularia xanthogolssa Boiss.	قرطم	Sandy		
	**Verbascum sinaiticum* Benth. [5]	خرماع	Sandy & stony	*Ch	*IT,SA&SU
SOLANACEAE	*Hyoscyamus pusillus* L.	صوفيره	Calcareous		
	**Lycium shawii* Roem. & Schult. [9]	عوسج	Stony	*Ch	*SA&SU
	Solanum sinaicum Boiss	عنب الديب	Rocky		
URTICACEAE	*Parietaria alsinifolia* Delile		Rocky		
ZYGOPHYLLACEAE	*Fagonia arabica* var. *arabica* L.	حلوة الجمل	Sandy		
	Fagonia mollis var. *hispida* Zohary	شكاعة	Stony & sandy		
	Peganum harmala L.	حرملان	Cultivated waste ground		
	Populus sp.	الحور	Cultivated waste ground		