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Plant Communities Associated with Egyptian Endemic Flora

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DESPITE the numerous studies that have addressed the natural and ruderal vegetation of the Egyptian habitats in a certain regions, a few studies have dealt with the vegetation of the whole country, but no study has accounted for the plant communities associated with the endemic plants of Egypt. The present study aims at deign distribution for the endemic taxa using grid map analysis, analyzing their vegetation, depicting the prevailing plant communities associated with them and assessing the role of the edaphic and environmental factors that affect these communities. Six hundred and nineteen stands were investigated to recognize the plant communities associated with the Egyptian endemic flora from 2018 to 2023. The application of TWINSPAN on the cover estimates of 1026 species (21 endemics and 1005 associated) led to the recognition of 8 vegetation groups at the 4th level of classification. The vegetation groups are named as follows: I: *Echinops taeckholmianus*, II: *Malva parviflora*, III: *Origanum syriacum* subsp. *sinaicum*, IV: *Ifloga spicata* subsp. *elbaensis*, V: *Allium roseum*, VI: *Arthrocnemum macrostachyum*, VII: *Atractylis carduus* var. *marmarica* and VIII: *Atractylis carduus* var. *marmarica*- *Anabasis articulata*. Soil analysis showed that most of the soils are alkaline and non-saline according to pH values. Four cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and four anions (Co_3^{--}, HCO_3^{-}, SO_4^{--} and Cl^{-}) were determined for each species as soluble salts. The majority of soil samples had sandy to loamy sandy textures. Soil samples are characterized by low content of organic matter.

Keywords : Endemism, Egypt, Grid map analysis, Multivariate analysis, Plant communities.

Introduction

Over the last 100 years, the trends in plant biodiversity loss have been a major source of concern (Khapugin et al., 2020; Knapp et al., 2021). The loss of biodiversity has serious economic and social costs. Despite every effort to maintain the diversity of plants, the situation remains alarming today (Cronk, 2016). In general, types of communities are distinguished mainly on the basis of features of the plants, including their structure, and the floristic composition of the vegetation. Characteristics of the habitat are, however, also taken into account (Zahran & Willis, 2009). The spatial distribution of plant species and communities over a small geographic area in desert ecosystems is related to heterogeneous topography and landform patterns (Kassas & Batanouny, 1984).

The concept of endemism is apparently simple, but it is actually problematic (Thompson, 2020). In biology and ecology, the meaning of endemic is similar to precinctive (i.e., restricted to a precinct or place and found nowhere else). Nevertheless, the precinct is often delimited on a case-by-case basis using artificial criteria such as geopolitical borders, which are variable in extent and often biologically irrelevant. The term ‘endemic’ is context-dependent and applied over various scales: continental endemic, local endemic or narrow endemic (Lavergne et al., 2004; Coelho et al., 2020), and may be considered to include the ecological requirements of the species and degree

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of habitat specificity (Boakes, 2010; Beck et al., 2014; Fithian et al., 2014). An endemic species is defined as a species restricted to a particular geographic region due to many factors such as isolation, and response to abiotic conditions (Lima et al., 2020). It has special importance since they inhabit particular habitats that are restricted to a specific area due to climate change or natural environment destruction (Carmona et al., 2019). In addition, most of these species have high economic and ecological values (El-Khalafy et al., 2023; Shaltout et al., 2023). In North Africa, the highest endemic species was in Morocco (17%), followed by Algeria (7.9%), Libya (7.3%), Egypt (3.5 %) and Tunisia (1.7 %) (Boulos, 1997).

The term "endemism" refers to the spatial scale at which a particular taxon is restricted to a certain location (Laffan & Crisp, 2003). Most of these species are included in the Red Data List as they are potentially threatened due to their small and unique habitat specificity and distribution ranges (Crisp et al., 2001; El-Khalafy et al., 2021a, b). Egypt is home to 41 endemic taxa belonged to 36 genera and 20 families. Endemic taxa are critical constituents in the flora of most regions in the world. Most of these species have threatened within the last years as a result of numerous reasons such as environmental conditions and human activities (El-Khalafy et al., 2021a; El-Khalafy, 2023).

Based on the red list categories of (IUCN), the distribution of endemic species should be recorded and documented periodically to evaluate their population status. Grid maps are used as a basic vegetation data base; they are simplified from vector-based vegetation maps (Nakagoshi et al., 1998). The grid map technique was developed in geography. Grid maps can show both continuously varying attributes without boundaries (e.g. gradients, physiognomy, temperature), and discontinuous attributes with boundaries (vegetation, soil, land use) in the same unit. Before more advanced computing systems such as geographic information systems (GIS) became popular, data for grid maps could be easily computerized and analyzed statistically (Driese et al., 1997). It was shown that the grid mapping method is most effective for revealing new locations of rare and protected plants (Kiselyova et al., 2017). In order to establish an effective conservation program for a plant species, we should have enough knowledge of its biology and ecology. It is widely accepted today that the primary strategy for nature conservation is the establishment and maintenance of a system or network of protected areas, but it is not sufficient in a changing world (Huntley, 1999). The first step in any conservation program for target species is to establish a baseline of available information before other activities are initiated. The process of gathering this information is sometimes referred to as an ecogeographical survey or study (Maxted et al., 1995), which is considered central to all issues of conservation and a key requirement in the development of any conservation strategy (Ouédraogo, 1997).

Despite the numerous studies that have addressed the natural and ruderal vegetation of the Egyptian habitats in a certain regions, a few studies have dealt with the vegetation of the whole country, but no study has accounted for the plant communities associated with the endemic plants of Egypt's. The study of relationship between endemic species and other associated is very important. It was necessary to work on studying the taxonomic, phytosociological and biological characteristics of endemic plants and others. In general, types of communities are distinguished mainly on the basis of features of the plants, including their structure, the floristic composition of the vegetation and characteristics of the habitat (Zahran & Willis, 2009). So, the present study aims at deign distribution for the endemic taxa using grid map analysis, analyzing their vegetation, depicting the prevailing plant communities associated with them and assessing the role of the edaphic and environmental factors that affect the communities.

Materials and Methods

Study area

Egypt is located in the north–eastern portion of Africa and extends beyond the Isthmus and Gulf of Suez into Asia to the Sinai Peninsula. Approximately, it is located between longitudes 25° and 37° E and latitudes 22° and 32° N. It measures roughly 1100km in length from north to south and 1230km in width from east to west. Egypt's territory is almost one million square kilometers, and it mostly resembles a square (Fig. 1). Egypt is bound by the Mediterranean Sea to the north, Sudan to the south, the Libya to the west, and the Red Sea, the Gulf of Aqaba, and Palestine to the east (Embabi, 2018). Egypt lies in the tropical and subtropical arid climate because its southern part is crossed by the cancer Tropic. Egypt is divided in to four geographical regions: Western Desert including the Mediterranean coastal belt (681,000km²), Eastern Desert (223,000km²), Nile Land including Nile Valley and the Delta (25,000km²) and Sinai Peninsula (61,000km²). The Nile Land includes several islands in the main stream of the River and its Delta branches. Fayium depression (1700km²) is connected to the Nile region by a principal irrigation canal called Youssef Sea (Zahran & Willis, 2009; Embabi, 2018).

Grid map analysis

Most of the endemic taxa were distributed on a grid map using ArcGIS 10.3 software. This was performed in 3 steps: **1-** opening shapefile of the country on ArcGIS software, **2-** searching shipnet in data management tools, then choosing gride size 400/400 m^2 and the number of rows and columns from options and **3-** putting all the plant species coordinates on excel sheet as x.y. columns representing the latitudes and longitudes, then convert it to comma-separated values (CSV) format and click add file to ArcGIS.

Investigated stands

Six hundred and nineteen stands were investigated to recognize the plant communities associated with the Egyptian endemic flora. The majority of these stands were carried out through numerous field visits to many locations all over Egypt from spring 2018 to Spring 2023. These field trips were conducted to Nile Delta, Saint-Catherine Protectorate (SKP), Matrouh, Sharm El-Sheikh, Alexandria, Western and Eastern Mediterranean Coast, Wadi El-Natroun, Assiut and Aswan for collecting the endemic taxa in Egypt and recording the associated flora with them (Fig. 1). Some of the examined stands covering as much as possible the different landforms of Egypt, especially Saint Katharine and Gabel Elba, were gathered from available literature such as (Hatim, 2013; El-Khalafy, 2018; Shaltout et al., 2018; Abutaha et al., 2020). Plant cover of each species was recorded according to Braun Blanquet scale (Mueller-Dombois & Ellenberg, 1974). The associated species with endemic taxa were determined depending on the highest qui-square values. These values were conducted using CAP 4.1.

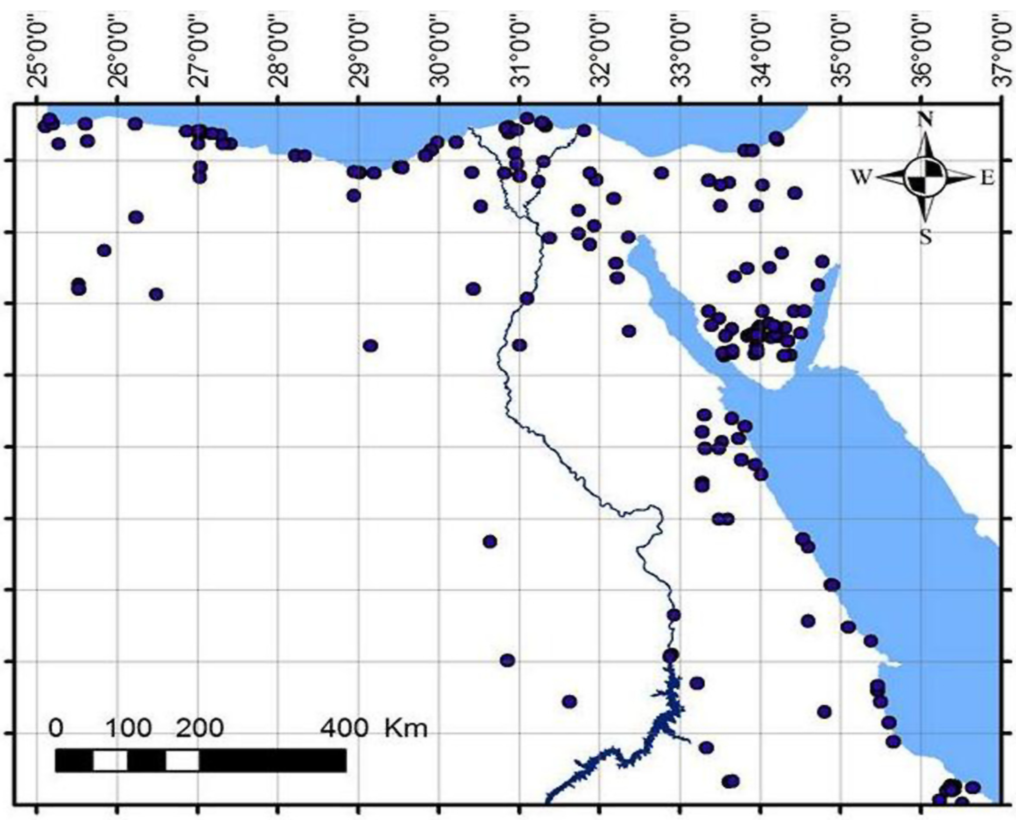


Fig. 1. Map of Egypt showing the main geomorphic regions of Egypt and field visits during the present study

Data analysis

Multivariate analysis

Two trends of multivariate analysis were applied in the present study: classification and ordination. Both trends have their merits in helping to understand vegetation and environmental phenomena. The two–way indicator species analysis (TWINSPAN), as a classification technique, and detrended correspondence analysis (DECORANA), as an ordination technique (Hill, 1979 a, b), were applied to the matrix of presence/absence estimates of 1005 species associated with the endemic species in 619 stands. The most significant new feature is that the program first constructs a classification of samples, and then uses this classification to obtain a classification of a species according to their ecological performance (Hill, 1979b; Gauch & Whittaker, 1981). These analyses were conducted using CAP 4.1.

Statistical analysis

A Simple linear correlation coefficient (r) was calculated to assess the type of relationship between the spatial variations in the estimated soil variables and the endemic taxa. These analyses were conducted using CANOCO 4.5 and SPSS 20 softwares (SPSS, 2012).

Soil analysis

Three randomly distributed soil samples of 22 endemic taxa (Table 1) were collected as profiles (0-50cm depth) from the zones of active roots of different plants, brought to the laboratory in plastic bags, spread over paper sheets for air drying, passed through 2mm sieve to separate gravel and debris, and packed in plastic bags until analysis. Soil texture was determined by the Bouyqucous hydrometer method, whereby the percentages of clay, silt and sand were calculated (Allen et al., 1986). Soil extracts were prepared as 1:5 (w/v) soil / distilled water extract to measure Electrical Conductivity (EC), pH, carbonates, bicarbonates, chloride, sulphates, nitrates, nitrites, phosphorus, calcium, magnesium, sodium and potassium. Soil reaction (pH) was estimated using a glass electrode pH-meter (r (Jenway 3020, Cole-Parmer, Staffordshire, UK). EC (dSm^{-1}) and total dissolved salts (TDS) (ppm) were assessed using a direct indicating conductivity bridge using a conductivity meter. Total organic matter was determined by loss on ignition at 550°C (Parkinson & Quarmby, 1974), and calcium carbonate was estimated using Bernard's calcimeter (Betremieux, 1948). Carbonates and bicarbonates were estimated by titration against 0.01N HCl using phenolphthalein and methyl orange as indicators, respectively (Allen et al., 1986). Sulphates were determined using the gravimetric with the ignition of residue method (Harrison & Perry, 1986). Chlorides were estimated by direct titration against silver nitrate using 5% potassium chromate as the indicator (Kolthoff & Stenger, 1947; APHA, 1981; Hazen, 1989). Ca^{+2} and Mg^{+2} were determined by titration, while Na^{+} and K^{+} were measured using a flame photometer (Corning 410 BWB, Sherwood Scientific Ltd., Cambridge, UK). For the determination of some available nutrients, soil extracts using 2.5% v/v glacial acetic acid were prepared. Total nitrogen was determined using Micro-Kjeldahl apparatus (VELP UDK 130, VELP Scientifica Srl, Usmate Velate, Italy). Molybdenum blue and Indo-phenol blue methods were applied for the determination of P and N respectively using Spectrophotometer at 700 nm and 660 nm, respectively. Fe, Zn, Mn, and Cu concentrations were determined using atomic absorption (GBC 932 AA, GBC Scientific Equipment Ltd., Dandenong, Australia). Flame photometer was used for the determination of K. All these procedures are outlined by Jackson (1960), Bear (1975) and Allen et al. (1986).

Results

Grid map Distribution

Sinai region is the richest region in endemic taxa (12 families and 19 taxa), followed by the Western Mediterranean region (8 families and 12 taxa), Nile region (including Delta, Valley and Faiyum: 6 families and 8 taxa), Eastern Desert (3 families and 3 taxa), Gebel Elba (2 families and 2 taxa), finally Oases, Eastern Mediterranean and Libyan desert regions (each of 1 family and 1 taxon) (Figs. 2, 3, Table. 1 and Appendix 1).

Associated species with endemic taxa

A total of 1026 species (21 endemic species and 1005 species associated with them) belonging to 89 families and 475 genera were recorded. *Astragalus* was the most represented genus (4.2%), followed by *Centaurea* and *Euphorbia* (each of 13 taxa = 2.8%) . The most associated species with endemic taxa depending on the highest chi-squared values are presented in Table 2. The highly significant pairs of associations are: *Allium mareoticum* with *Ajuga iva* and *Adonis dentata*, *Anthemis microsperma* with *Anacyclus alexandrinus* and *Allium mareoticum*, *Atractylis carduus* var. *marmarica* with *Asphodelus* *macrocarpus* and *Anabasis articulata*, *Bromus aegyptiacus* with *Symphotrichum squamatum* and *Atriplex leucoclada, Echinops taeckholmianus* with *Carthamus glaucus* and *Cyperus capitatus*, *Ifloga spicata* subsp. *elbaensis* with *Cenchrus setigerus* and *Euphorbia arabica*, *Pancratium arabicum* with *Pancratium maritimum* and *Erodium laciniatum*, *Silene schimperiana* with *Silene oreosinaica*, *Sonchus macrocarpus* with *Senecio desfontainei* and *Glebionis coronaria*, *Thesium humile* var. *maritima* with *Diplotaxis simplex* and *Asphodelus ramosus*, and *Veronica anagalloides* subsp. *taeckholmiorum* with *Ranunculus sceleratus* and *Mentha longifolia*.

Multivariate analysis of the sampled stands

The application of TWINSPAN on the cover-abundance of 1026 species in 619 stands led to the determination of 8 vegetation groups at the 4th classification level (Fig. 4a). The application of DECORANA on the same set of data indicates reasonable segregation among these groups along the ordination plane of axes 1 and 2 (Fig. 4b). The vegetation groups are named after the first and occasionally the second dominant species (the species that have the highest presence percentage) as follows: I: *Echinops taeckholmianus*, II: *Malva parviflora*, III: *Origanum syriacum* subsp. *sinaicum*, IV: *Ifloga spicata* subsp. *elbaensis*, V: *Allium roseum*, VI: *Arthrocnemum macrostachyum*, VII: *Atractylis carduus* var. *marmarica* and VIII: *Atractylis carduus* var. *marmarica*- *Anabasis articulata*. The following is a brief description of these vegetation groups (Table 3).

Group I: *Echinops taeckholmianus*. It comprises 7 stands (1.1% of the total stands) and 19 species including 3 endemics (*Echinops taeckholmianus*, *Sonchus macrocarpus* and *Pancratium arabicum*). It represents the stands of sand dunes in the Eastern Mediterranean (Baltim). The dominant species are *Echinops taeckholmianus* (P= 100%, RC= 9.9%), *Cyperus capitatus* (P= 85.7%, RC= 8.5%), *Plantago notata* (P= 85.7%, and *Silene succulenta* (P= 85.7%).

Group II: *Malva parviflora*. It comprises 40 stands (6.5% of the total stands) and 323 species including 3 endemics (*Sonchus macrocarpus*, *Thesium humile* var. *maritima* and *Atractylis carduus* var. *marmarica*). It represents the stands of the Western Mediterranean (From Alexandria to Matrouh). The dominant species are *Malva parviflora* (P= 70%, RC= 2.9%), *Reichardia tingitana* (P= 65%, RC= 2.6%), *Emex spinosa* (P= 60%), *Chenopodium murale* (55%) and *Cynodon dactylon (*P= 52.5%).

Group III: *Origanum syriacum* subsp. *sinaicum*. This is the largest vegetation group. It comprises 503 stands (81.3% of the total stands) and 549 species including 12 endemic taxa. It represents the stands of Sinai region. The dominant species are *Origanum syriacum* subsp. *sinaicum* (P= 24.9%, RC= 1.1%), *Hyoscyamus boveanus* (P= 23.3%, RC=1%), *Artemisia judaica* (P= 18.5%), *Zilla spinosa* (P= 18.1%) and *Fagonia mollis* var. *mollis* (P= 17.9%).

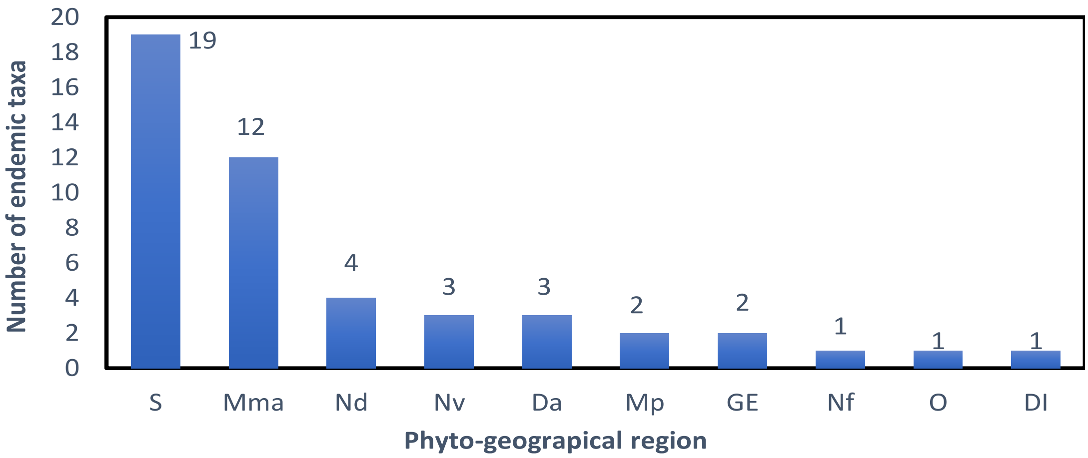


Fig. 2. Number of endemic taxa in the Egyptian flora in relation to National phyto geographical regions [The phytogeographical regions are abbreviated as follows: S: Sinai Peninsula, Mma: Western Mediterranean, Nd: Nile Delta, Nv: Nile Valley, Da: Eastern desert, Mp: Eastern Mediterranean, GE: Gebel Elba region, Nf: Nile Faiyum, O: Oases and DI: Libyan desert]

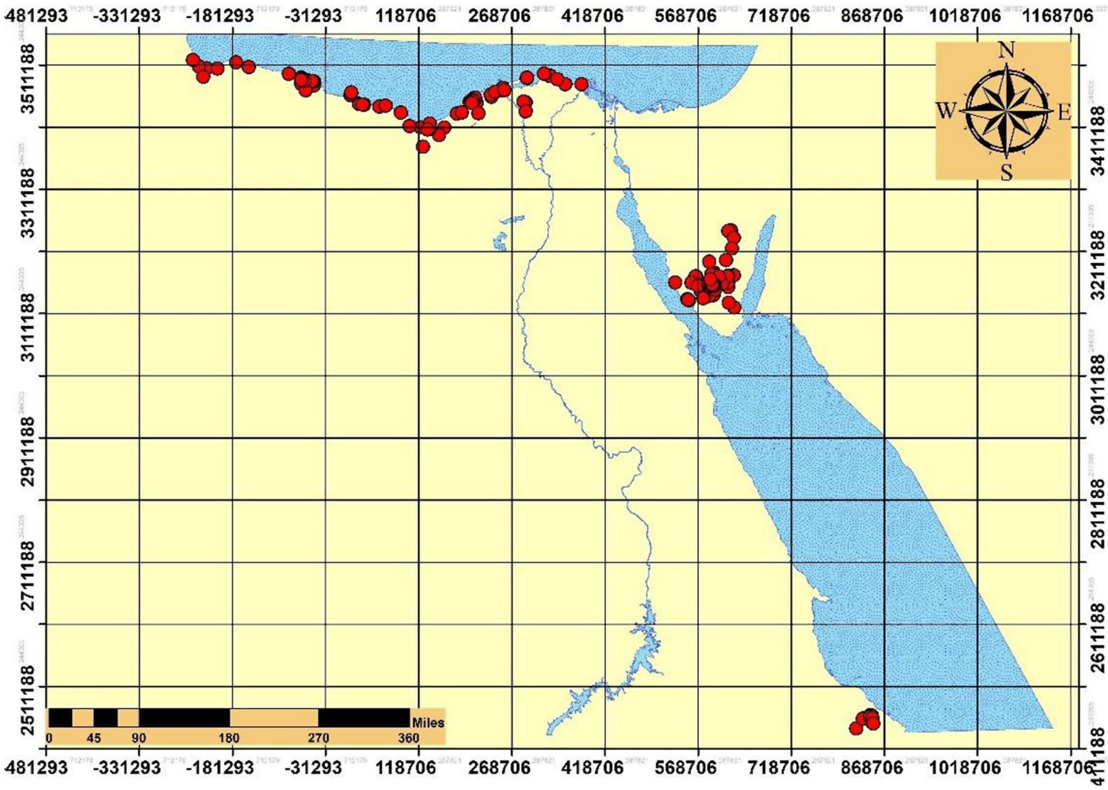


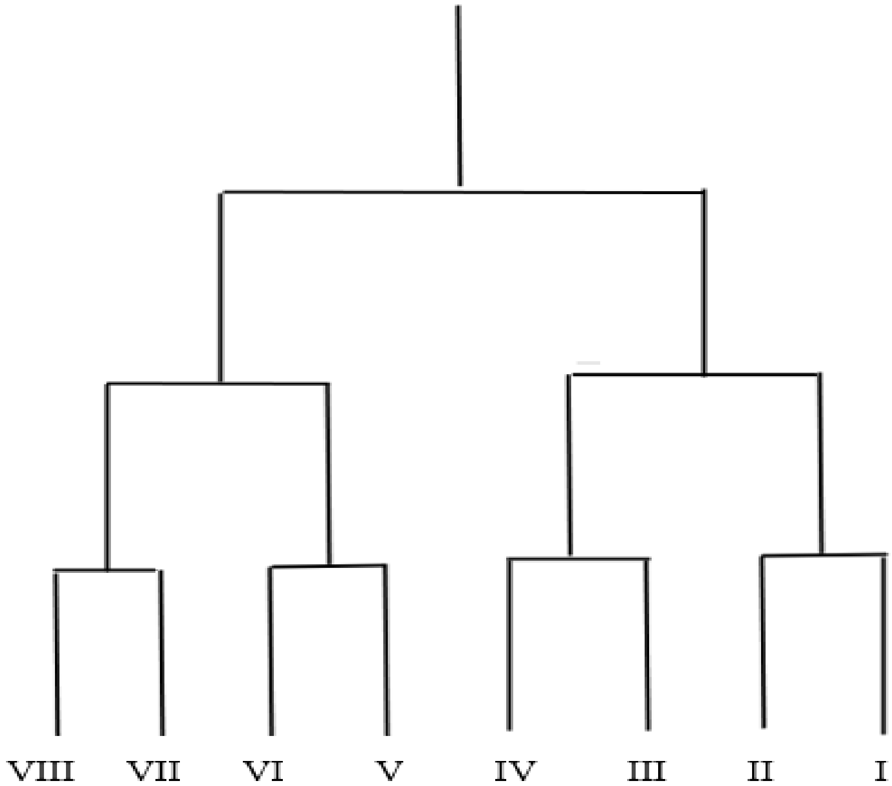
Fig. 3. Grid map distribution of endemic taxa recorded in the present study

TABLE 1. Soil samples of endemic taxa and their location

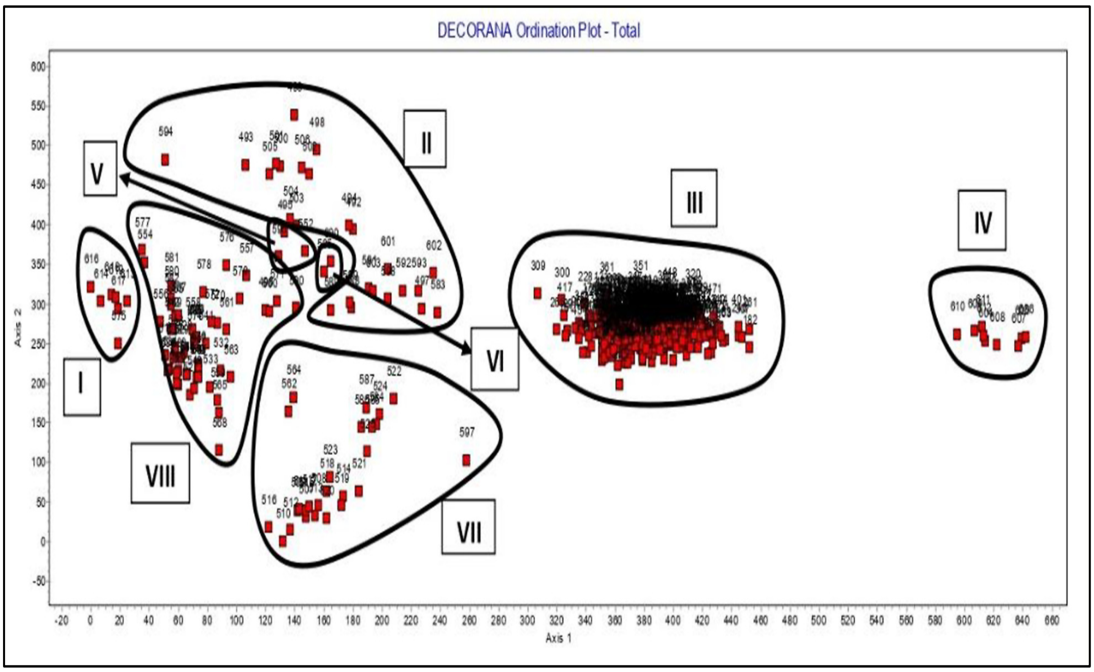
Code	Species	Location
1	*Allium mareoticum*	El-Dabaa, Matrouh
2	*Anarrhinum forskaohlii* subsp. *pubescens*	El-Gebel Al-Ahmar, SKP
3	*Anthemis microsperma*	Omayed, Alamin
4	*Atractylis carduus* var. *marmarica*	Omayed, Alamin
5	*Ballota kaiseri*	Abo Hamman, SKP
6	*Bromus aegyptiacus*	Lake Mariut, Alexandria
7	*Bufonia multiceps*	Wadi Gebal, SKP
8	*Echinops taeckholmianus*	El-Hammad, Baltim
9	*Hyoscyamus boveanus*	Abu Tewita, SKP
10	*Ifloga spicata* subsp. *elbaensis*	Gebel Elba
11	*Micromeria serbaliana*	El-Gebel Al-Ahmar, SKP
12	*Origanum syriacum* subsp. *sinaicum*	Zawatieen, SKP
13	*Pancratium arabicum*	Keliopatra, Matrouh
14	*Polygala sinaica* var. *sinaica*	Farsh Elias, SKP
15	*Primula boveana*	El-Garginhia, SKP
16	*Rosa arabica*	Wadi El-Arbain, SKP
17	*Silene leucophylla*	W. El-Faraa, SKP
18	*Silene oreosinaica*	Shag Musa, SKP
19	*Silene schimperiana*	Shag Talaa, SKP
20	*Sonchus macrocarpus*	lake Mariut, Alexandria
21	*Thesium humile* var. *maritima*	Ajeeba, Matrouh
22	*Veronica anagalloides s*ubsp. *taeckholmiorum*	Qallin, Kagrelsheikh

TABLE 2. The most five associated species with endemic taxa depending on chi square value [Values are significant at P ≤ 0.05 (*) and P ≤ 0.01 (**)]

Endemic taxa	Associated species	df	Chi square (%)
Allium mareoticum	*Ajuga iva*	2	25.0**
	Adonis dentata		14.7**
Anarrhinum forskaohlii subsp. *pubescens*	*Alkanna orientalis*	60	9.8
	Aerva javanica var. *bovei*		8.1
Anthemis microsperma	*Anacyclus alexandrinus*	10	134.4**
	Allium mareoticum		61.6**
Atractylis carduus var. *marmarica*	*Asphodelus macrocarpus*	55	327.5**
	Anabasis articulata		194.9**
Ballota kaiseri	*Achillea fragrantissima*	41	17.8
	Astragalus hamosus		12.9
Bromus aegyptiacus	*Symphotrichum squamatum*	5	177.3**
	Atriplex leucoclada		114.6**
Bufonia multiceps	*Ballota undulata*	30	5.4
	Anthemis melampodina		6.4
Echinops taeckholmianus	*Carthamus glaucus*	7	220.2**
	Cyperus capitatus		190.3**
Hyoscyamus boveanus	*Haloxylon salicornicum*	116	13.3
	Capsella bursa-pastoris		11.0
Ifloga spicata subsp. *elbaensis*	*Cenchrus setigerus*	8	481.9**
	Euphorbia arabica		412.8**
Origanum syriacum subsp. *sinaicum*	*Mentha longifolia*	124	26.2
	Alkanna orientalis		24.6
Pancratium arabicum	*Pancratium maritimum*	4	137.9**
	Erodium laciniatum		67.2**
Polygala sinaica var. *sinaica*	*Chrozophora tinctoria*	28	10.6
	Glaucium arabicum		9.0
Primula boveana	*Euphorbia peplis*	28	7.0
	Papaver rhoeas		6.8
Rosa arabica	*Hypericum sinaicum*	27	17.2
	Adiantum capillus-veneris		11.5
Silene leucophylla	*Nauplius graveolens*	61	13.8
	Scandix stellata		12.11
Silene oreosinaica	*Cleome amblyocarpa*	60	9.9
	Mentha longifolia		7.0
Silene schimperiana	*Silene oreosinaica*	39	262.8**
	Hyoscyamus pusillus		17.8
Sonchus macrocarpus	*Senecio desfontainei*	20	245.9**
	Glebionis coronaria		143.6**
Thesium humile var. *maritima*	*Diplotaxis simplex*	10	336.5**
	Asphodelus ramosus		280.5**
Veronica anagalloides subsp. *taeckholmiorum*	*Ranunculus sceleratus*	1	154.3**
	Mentha longifolia		154.3**



(a)



(b)

Fig. 4. Dendrogram of the 8 vegetation groups derived after application of TWINSPAN classification technique (a), cluster segregation of the 8 vegetation groups along axes 1 and 2 using DECORANA (b)

TABLE 3. Vegetation groups of the studied endemic taxa and their associated species and their percentage in different geographic regions

Veg. group	No. of stands	Geographic region (%)			1st dominant	P %	2nd dominant	P%
		Sinai	Gebel Elba	Meditt. + Nile				
I	7	-	-	100	*Echinops taeckholmianus*	100	*Cyperus capitatus*	85.7
II	40	-	-	100	*Malva Parviflora*	70	*Reichardia tingitana*	65
III	503	97.6	-	2.4	*Origanum syriacum* subsp. *sinaicum*	24.9	*Hyoscyamus boveanus*	23.3
VI	11	-	81.8	18.2	*Ifloga spicata* subsp. *elbaensis*	81.8	*Zygophyllm simplex*	81.8
V	3	-	-	100	*Allium roseum*	100	*Asphodelus macrocarpus*	100
VI	2	-	-	100	*Arthrocnemum macrostachyum*	100	*Suaeda pruinosa*	100
VII	17	-	-	100	*Atractylis carduus var. marmarica*	94.1	*Thymelaea hirsuta*	76.5
VIII	36	-	-	100	*Atractylis carduus* var. *marmarica*	94.4	*Anabasis articulata*	91.7

Group IV: *Ifloga spicata* subsp. *elbaensis*. It comprises 11 stands (1.8% of the total stands) and 414 species. It represents the stands of Gebel Elba. The dominant species are *Ifloga spicata* subsp. *elbaensis* (P= 81.8%, RC= 0.7%), *Zygophyllum simplex* (P= 81.8%, RC=0.7%), *Reichardia tingitana* (P= 81.8%), *Chenopodium murale* (P= 81.8%), *Aizoon canariense* (P=81.8%), *Lycium shawii* (P=81.8%) and *Asphodelus tenuifolius* (P= 81.8 %).

Group V: *Allium roseum*. It comprises 3 stands (0.5% of the total stands) and 84 species including 4 endemic species (*Thesium humile* var. *maritima* and *Atractylis carduus* var. *marmarica*, *Anthemis microsperma* and *Allium mareoticum*). It represents the high-elevation areas of El-Alamin (Omayed) and Matrouh (Ajeeba). The dominant species are *Allium roseum* (P= 100%, RC= 2.3%), *Asphodelus macrocarpus* (P= 100%, RC= 2.3%), *Thymelaea hirsuta* (P= 100%), *Artemisia herba-alba* (P=100%), and *Salvia deserti* (P= 100%).

Group VI: *Arthrocnemum macrostachyum*. It comprises 2 stands (0.3% of the total stands) and 44 species including one endemic species only (*Sonchus macrocarpus*). It represents the salt marches of Burg El-Arab, Alexandria. The dominant species are *Arthrocnemum macrostachyum* (P= 100%, RC= 2.4%), *Suaeda pruinosa* (P= 100%, RC= 2.4%), *Erodium ciconium* (P= 100%), *Bassia muricata* (P=100%), *plantago albicans* (P=100%), *Salsola tetrandra* (P=100%), *Zygophyllum album* (P=100%) and *Salvia deserti* (P= 100%).

Group VII: *Atractylis carduus* var. *marmarica*. It comprises 36 stands (5.8% of the total stands) and 37 species. It represents the non-saline depressions in the El-Alamin region (El-Hammam and Burg El-Arab). The dominant species are *Atractylis carduus* var. *marmarica* (P= 94.1%, RC= 9.1%), *Thymelaea hirsuta* (P= 76.5%, RC= 7.4%), *plantago albicans* (P= 64.7%), *Anabasis articulata* (P=58.8%) and *Deverra tortuosa* (P= 52.7%).

Group VIII: *Atractylis carduus* var. *marmarica- Anabasis articulata*. It comprises 17 stands (2.7% of the total stands) and 50 species. It represents the non-saline depressions along Mediterranean coastal strip. The dominant species are *Atractylis carduus* var. *marmarica* (P= 94.4%, RC= 8.1%), *Anabasis articulata* (P= 91.7%, RC= 7.9%), *Echiochilon fruticosum* (P= 91.7%), *Gymnocarpos decandrum* (P=88.9%), *plantago albicans* (P= 86.1%), *Noaea mucronata* (P= 83.3%) and *Helianthemum Lippii* (P= 83.3%).

The multivariate analysis of 21 endemic taxa recorded in 619 stands led to classification of these taxa into seven communities according to the habitat and phytogeographic regions (Fig. 5). The first community (A) represents hot deserts and sandy rocky areas in Gebel Elba, and dominated by *Ifloga spicata* subsp. *elbaensis*, while the second one (B) represents sandy rocky habitats in mountainous regions in SKP, and include 11 endemic species: *Anarrhinum forskaohlii* subsp. *pubescens*, *Ballota kaiseri*, *Bufonia multiceps*, *Hyoscyamus boveanus*, *Origanum syriacum* subsp. *sinaicum*, *Polygala sinaica* var. *sinaica*, *Primula boveana*, *Rosa arabica*, *Silene leucophylla*, *Silene oreosinaica* and *Silene schimperiana*. The third community (C) represents canal and drainage canal ditches regions in Nile and Mediterranean regions, and dominated by *Veronica anagalloides* subsp. *taeckholmiorum*, while the fourth (D), which dominated by *Sonchus macrocarpus* and *Anthemis microsperma* and fifth (E) which dominated by *Atractylis carduus* var. *marmarica* and *Echinops taeckholmianus,* communities represent sandy regions in Mediterranean. The sixth and seventh communities represent coastal sand dunes in the Mediterranean region, and dominated by *Allium mareoticum, Bromus aegyptiacus, Pancratium arabicum* and *Thesium humile* var. *maritima,* respectively.

Soil analysis

The soil samples of twenty-two endemic taxa were analyzed (Tables 4, 5). PH values showed that most of the soils are alkaline and non-saline, where pH ranges from 8.9 in soils of *Thesium humile* var. *maritima* to 6.8 in soils of *Polygala sinaica* var. *sinaica*. EC values range from 0.2 to 12.6ds/m^{-1}. It reached the maximum value in soils of *Veronica anagalloides* subsp. *taeckholmiorum*, while its minimum value was recorded in soils of *Bufonia multiceps*. Four cations (Ca^{++}, Mg^{++}, Na^+ and K^+) and four anions (Co_3^{--}, HCO_3^-, SO_4^{--} and Cl^-) were determined for each species as soluble salts. The soils that occupied by *Veronica anagalloides* subsp. *taeckholmiorum* had the highest values of Ca^{++}, Mg^{++}, $Na^{+,}$ Cl^-, and SO_4^{--} (43, 24, 80.3, 14 and 132.8 meq^{-1}, respectively), while those of *Ifloga spicata* subsp. *elbaensis* had the lowest values (0.05, 0.03, 0.04, 0.04 and 0.02meq^{-1}, respectively). The soils occupied by *Primula boveana* had the highest values K^+ and HCO_3^- (5.8 and 16.8meq^{-1}, respectively), while that of *Ifloga spicata* subsp. *elbaensis* had the lowest (0.04 and 0.3meq^{-1} respectively).

Sodium absorption ratio had maximum value in soils of *Veronica anagalloides* subsp. *taeckholmiorum* (13.9), while its minimum value in that of *Ifloga spicata* subsp. *elbaensis* (0.2). The majority of soil samples had sandy to loamy sandy textures. The percentage of sand fraction ranges from 74- 99%, silt from 0.5-17.1 %, and clay from 0.5 to 8.2 %. Soil samples are characterized by low content of organic matter. It ranged from 0.1% in soils of six species to 5.3% in soils of *Veronica anagalloides* subsp. *taeckholmiorum*. It was observed that the coastal plants are characterized by high content of $CaCO_3$. It reached its maximum value in soils of *Thesium humile* var. *maritima* and *Pancratium arbicum* (17.3%, 12.6% respectively), while its minimum value was recorded in soils of *Ifloga spicata* subsp. *elbaensis* (1.1%) (Table 4).

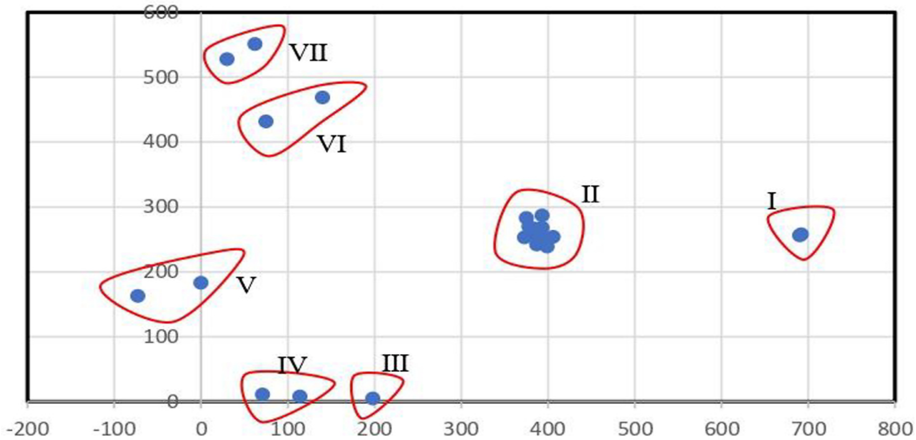


Fig. 5. Ordination of the studied endemic taxa in relation to each other

TABLE 4. Soil analysis of the recorded endemic taxa. EC: electric conductivity, SP: saturation percentage and SAR: sodium absorption value

Sample No.	pH	EC (dS m^{-1})	Soluble salts (meq/L)								SAR	TDS (ppm)	Gravel (%)	Particle size distribution [%]			SP	Organic matter	$CaCO_3$
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}				Sand	Silt	Clay	%		
1	7.9	4.7	23.0	5.0	20.0	1.7	0.0	2.0	3.6	44	5.3	3027	2.7	97	1.0	2.0	26	2.7	2.8
2	8.5	0.8	5.8	1.2	16.9	0.5	0.0	4.4	2.3	17.7	9.0	538	3.2	98	1.0	1.0	23	2.6	5.4
3	8.0	1.9	9.0	0.8	7.5	0.7	0.0	7.0	9	2	3.4	1235	0.1	95	3.0	2.0	27	0.7	4.6
4	7.9	1.3	5.4	0.8	4.4	0.8	0.0	5.0	5.4	1	2.5	838	4.6	99	0.5	0.5	20	0.1	1.7
5	8.2	0.9	5.0	0.8	1.7	0.6	0.0	6.2	1.9	0.01	1.0	570	38.7	96	2.0	2.0	25	0.5	1.6
6	7.8	1.9	9.0	1.8	4.7	1.7	0.0	8.8	3.6	4.7	2.0	1184	0.1	90	6.0	4.0	30	1.7	3.7
7	7.0	0.2	1.2	1.0	0.5	0.2	0.0	1.0	1.5	0.4	0.4	147	0.0	89	7.0	4.0	38	0.1	3.7
8	8.2	0.9	3.4	1.0	3.5	1.4	0.0	5.0	2.7	1.6	2.3	570	0.0	97	2.0	1.0	29	0.5	2.5
9	8.1	3.7	20.0	8.0	8.4	2.6	0.0	7.0	2.2	29.8	2.3	2381	33.5	93	3.0	4.0	28	0.4	4.2
10	7.3	0.7	0.05	0.03	0.04	0.04	0.03	0.3	0.04	0.02	0.2	470	55.9	86.4	13.1	0.5	52	0.1	1.1
11	7.1	1.6	15.2	0.7	1.6	0.8	0.0	3.2	1.8	0.8	1.25	410	0.0	97.5	1.5	1.0	28	0.3	1.8
12	7.8	1.0	4.0	1.0	3.4	0.6	0.0	3.0	3.6	2.3	2.1	659	0.0	89	5.0	6.0	29	2.1	2.1
13	8.2	2.2	3.2	1.4	16.0	0.7	0.0	2.0	13.7	5.6	10.6	1389	0.0	99	0.5	0.5	18	0.1	12.6
14	6.8	0.8	4.8	1.4	1.7	0.5	0.0	1.2	2.9	4.2	0.9	486	0.0	96.5	2.0	1.5	27	0.4	4.0
15	8.1	2.1	21.0	2.0	25.3	5.8	0.0	16.8	3.6	33.8	7.5	1350	42.6	91	5.0	4.0	24	0.1	3.1
16	8.0	0.9	3.8	0.8	3.4	0.2	0.0	3.8	3.1	1.2	2.2	582	23.1	94	3.0	3.0	28	0.2	2.1
17	8.5	1.7	10.0	1.6	4.3	0.5	0.0	4.6	10.3	1.5	1.8	1107	0.0	88	7.0	5.0	35	1.0	3.8
18	7.9	0.6	3.2	0.6	1.8	0.4	0.0	3.4	1.8	0.8	1.3	403	65.5	97	2.0	1.0	26	0.2	1.8
19	8.2	0.7	3.0	1.0	2.1	0.7	0.0	4.2	1.6	1	1.5	467	0.0	95	3.0	2.0	24	1.2	2.7
20	7.7	1.8	14.2	0.6	3.2	1.7	0.0	7.8	4.3	7.6	1.2	1152	24.8	98	0.5	1.5	33	1.1	8.9
21	8.9	0.9	1.0	2.3	1.3	0.2	0.0	1.4	1.6	1.8	5.4	640	1.8	74.4	17.1	8.2	54	0.1	17.3
22	7.9	12.6	43.0	24.0	80.3	0.4	0.0	1.0	14	132.8	13.9	10064	65.9	74	12.0	14.0	54	5.3	3.1

TABLE 5. Percentages of available nutrients in soil samples of the studied endemic taxa

Species	Available levels of nutrients (p.p.m)						
	N	P	K	Fe	Zn	Mn	Cu
Allium mareoticum	1.6	26	116	0.88	0.41	0.07	0.12
Anarrhinum forskaohlii subsp. *pubescens*	2.4	21	118	0.65	0.34	0.04	0.17
Anthemis microsperma	2.1	26	120	1.87	0.43	0.19	0.21
Atractylis carduus var. *marmarica*	2.0	18	120	0.23	0.23	0.08	0.21
Ballota kaiseri	1.7	21	128	0.32	0.36	0.98	0.22
Bromus aegyptiacus	3.1	21	112	1.65	0.32	0.04	0.21
Bufonia multiceps	1.7	23	120	0.10	0.23	0.27	0.43
Echinops taeckholmianus	2.4	18	121	0.32	0.54	0.10	0.23
Hyoscyamus boveanus	1.1	18	121	0.09	0.31	0.11	0.17
Ifloga spicata subsp. *elbaensis*	1.3	14	103	1.01	0.11	0.04	0.15
Micromeria serbaliana	2.2	22	110	1.35	0.25	0.20	0.40
Origanum syriacum subsp. *sinaicum*	2.6	19	121	1.10	0.28	0.09	0.13
Pancratium arabicum	1.5	21	119	1.10	0.11	0.22	0.07
Polygala sinaica var. *sinaica*	1.3	20	112	1.10	0.17	0.16	0.31
Primula boveana	1.3	16	121	1.09	0.09	0.27	0.45
Rosa arabica	2.2	20	125	0.34	0.45	0.11	0.23
Silene leucophylla	1.6	17	116	1.02	0.12	0.21	0.08
Silene oreosinaica	2.0	21	109	1.43	0.26	0.22	0.34
Silene schimperiana	1.8	20	121	1.05	0.21	0.27	0.12
Sonchus macrocarpus	1.6	24	121	1.60	0.22	0.32	0.04
Thesium humile var. *maritima*	1.4	23	110	0.64	0.31	0.04	0.11
Veronica anagalloides subsp. *taeckholmiorum*	4.6	9	431	3.60	2.43	1.32	0.76

Regarding the available nutrients and heavy metals, the soils that occupied by *Veronica anagalloides* subsp. *taeckholmiorum* has the highest values of N, K, Fe, Zn, Mn, and Cu (4.6, 431, 3.6, 2.43, 1.32 and 0.76ppm, respectively), but the lowest of P (9ppm). The soils of *Anarrhinum forskaohlii* subsp. *pubescens*, *Bromus aegyptiacus* and *Thesium humile* var. *maritima* are characterized by low values of Mn (0.04 ppm), that of *Hyoscyamus boveanus* is characterized by low value of N (1.05ppm), that of *Ifloga spicata* subsp. *elbaensis* is characterized by the low value of K (103ppm), that of *Bufonia multiceps* is characterized by the low value of Fe (0.10ppm), that of *Primula boveana* is characterized by the low value of Zn (0.09ppm), and that of *Sonchus macrocarpus* is characterized by the low value of Cu (0.04ppm) (Table 5).

Relationship between the soil variables and endemic species distribution

The arrow length of CANOCO ordination expresses the relative importance of a certain soil variable. It is clear that the soil variables such as: pH, organic matter, magnesium, calcium carbonate, bicarbonates and sulphates are the most effective environmental variables in the distribution of endemic species. (Fig. 6). *Thesium humile* var. *maritima* (21) correlated with high gradients of calcium carbonate; and with moderate gradients of pH. *Silene* species (18,19,20) correlated with high gradients of sand fraction and Phosphorous. *Bromus aegyptiacus* (6) and *Ifloga spicata* subsp. *elbaensis* (10) correlated with high gradients of N, Fe, Ca^+, CO_3^{--}, Cl^- and HCO_3^-, while other taxa were correlated with high gradients of other parameters of soil analysis.

Discussion

Grid map distribution

Records of the present study indicate that the number of endemic taxa had the maximum value in southern Sinai, as it includes 13 endemics (31.7%). On the other hand, the endemics were poor in each of Gebel Elba (4.9%), Oases and Western Mediterranean (2.4%). Thirty-five endemic taxa (85.4%) occur in one phytogeographical region (Steno-endemics) which are most represented in

Sinai (16 taxa = 45.7% of total steno-endemics), while less represented in Gebel Elba (2 taxa = 5.7%) and Oases (1 taxon = 2.9%). The richness of the Sinai region with steno-endemics is probably due to the extensive mountainous massive in this region, which prevents the dispersal of seeds for long distances. Specifically, the most important endemism region in Egypt is the Southern Sinai's SKP (Zohary, 1973). This is because of its humid climate and physiographic characteristics that define particular microhabitats that serve as havens in arid regions (Danin, 1999; Moustafa et al., 2001; Khedr, 2006; Mosallam, 2007). The high-elevation rock surfaces and the coolest climate in Egypt are characteristics of SKP region, that aid in the restriction and limitation of rare and endemic taxa. (Moustafa & Klopatek, 1995; Moustafa et al., 2001). Similarly, the northeastern Mediterranean belt and mountains in North Sinai (e.g., Gebel El-Halal) promote the establishment of endemic taxa. The distribution of these taxa is mainly determined by the Mediterranean coastal influence and geomorphological isolation in the mountainous regions (Abd El-Wahab et al., 2008). Additionally, the extensive mountainous massif of SKP, which is home to numerous microhabitats, is responsible for the region's rich plant diversity. The high elevations in this region hinder the dispersal process of propagules, a situation which often tends to increase endemic and near-endemic species (Shaltout et al., 2020).

Multivariate analysis

The application of TWINSPAN on the cover estimates of 1026 species including 21 endemic species recorded in 619 stands, led to the recognition of 8 vegetation groups at the 4th level of classification (**I:** *Echinops taeckholmianus*, **II:** *Malva parviflora*, **III:** *Origanum syriacum* subsp. *sinaicum*, **IV:** *Ifloga spicata* subsp. *elbaensis*, **V:** *Allium roseum* and **VI:** *Arthrocnemum macrostachyum*, **VII:** *Atractylis carduus* var. *marmarica* and **VIII:** *Atractylis carduus* var. *marmarica*). The diversity of plant communities generated from multivariate analysis (community diversity) supports the previous conclusions of the plant communities that characterize the different zones and habitat diversity of endemic taxa in Egypt. The results in the present study are different from most previous studies because it related to only the endemic species and its associated species all over Egypt. Bidak et al. (2013) studied the status of the wild medicinal plants in the Western Mediterranean coastal region and recognized 5 vegetation groups at the 3rd level of the classification. Their results partially agreed with the present study in the associated codominant species in different groups such as *Thymus capitatus*, *Matthiola longipetala* sub sp. *livida* and *Zygophyllum album*.

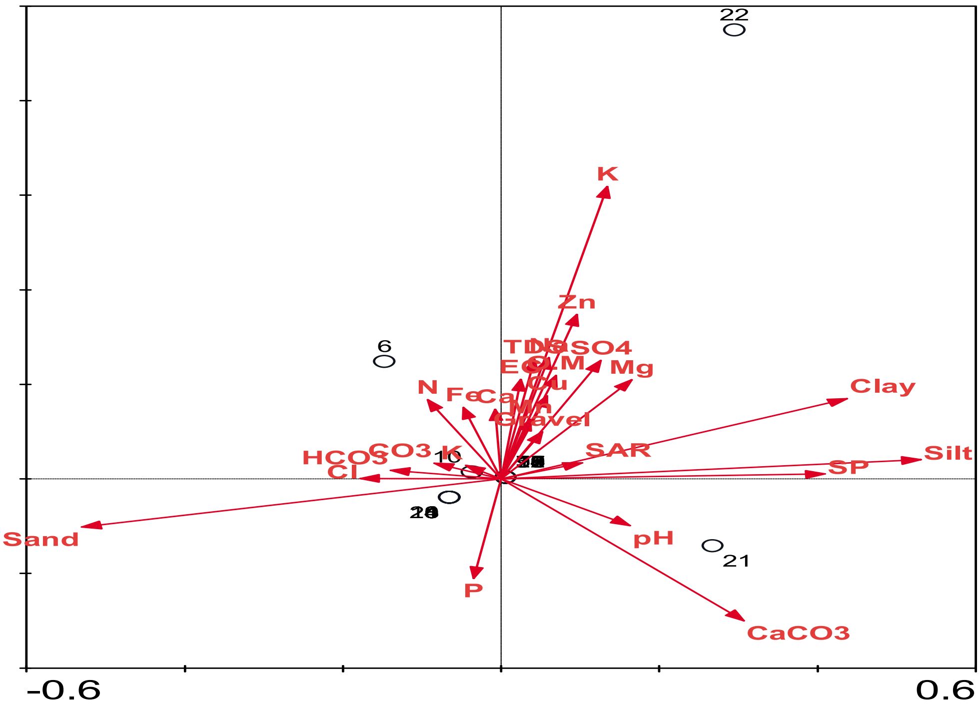


Fig. 6. CANOCO ordination plot for the edaphic variable (represented by arrows). Numbers represented endemic species (Table 1)

El-Amier & Abd El-Gawad (2017) described the plant communities-environment interactions of the international coastal highway from Port-Said to Abu-Qir, through Deltaic Mediterranean Coast. They recognized four communities (*Silybum mariannum*, *Mesembryanthemum crystalinum*, *Hordeum murinum-Senecio glaucus*, *Cakile maritima-Senecio glaucus communities*), while the present study recognized only one community (*Echinops taeckholmianus* community) along the same road. Also, Shaltout et al. (2020) studied the vegetation diversity along the altitudinal and environmental gradients in the main wadi beds in the mountainous region of South Sinai and recognized 4 vegetation groups at the 3rd level, while the present study recognized only one vegetation group in SKP that dominated by *Origanum syriacum* subsp. *sinaicum*. In addition, Abutaha et al. (2020) described seven woodland communities in Gebel Elba. *Ifloga spicata* subsp. *elbaensis* wasn't recorded in this survey. This disagreed with the present study that yielded one vegetation group in Gebel Elba which dominated by *Ifloga spicata* subsp. *elbaensis* and *Zygophyllm simplex*. In addition, Zaghloul (1997) and Shaltout et al. (2020) reported that vegetation variables and plant cover were positively correlated with altitude. These studies indicate that higher levels of species diversity were brought about by local differentiation in soil properties around individual plants, since environmental heterogeneity allows satisfaction of the requirements of diverse species within a community.

On the other hand, the present study recognized vegetation groups similar to that of the previous studies such as: 1-Abd El-Wahab et al. (2006) studied the vegetation and environment of Gebel Serbal in South Sinai and recognized seven main plant communities, *Origanum syriacum* subsp. *sinaicum* was recorded as codominant species in group VI. This agreed with the present study in SKP that yielded one large vegetation group dominated by *Origanum syriacum* subsp. *sinaicum* and *Hyoscyamus boveanus*. 2- Ahmed et al. (2015) studied the flora and vegetation of the different habitats of the western Mediterranean region and yielded 6 vegetation groups (*Calamagrostis arenaria-Echinops spinosus*, *Arthrocnemum macrostachyum-Suaeda monoica*, *Anabasis articulata- Lysimachia arvensis*, *Asphodelus aestivus-Plantago albicans*, *Asphodelus aestivus-Echinops spinosus*, *Cynodon dactylon-Polypogon monspliensis communities*). This study agreed with the present study which yielded three vegetation groups along the western Mediterranean region (*Arthrocnemum macrostachyum-Suaeda pruinosa*, *Atractylis carduus* var. *marmarica-Thymelaea hirsute*, *Atractylis carduus* var. *marmarica-Anabasis articulata communities*). 3- Heneidy et al. (2021) studied the vegetation in intra-city railway habitats in Alexandria and recognized six vegetation groups (communities) at the 3rd level of classification (*Urospermum picroides*, *Chenopodium murale*, *Malva parviflora*, *Cynodon dactylon*, *Hordeum leporinum*, *Sonchus oleraceus communities*). The present study agreed with them in one vegetation group in the same area which is dominated by *Malva Parviflora*. 4- Heneidy et al. (2022) studied the vegetation in archeological sites and relict landscapes in Alexandria city and recognized 4 vegetation groups (communities) at the 3rd level (*Chenopodium murale*, *Glebionis coronaria* community, *Reichardia tingitana* community, *Emex spinosa* communities). This study agreed with the present study in group II that dominated by *Malva Parviflora*.

Soil analysis

Soil has played an essential role in plant existence and distribution. Soil characteristics often play an essential role in determining plant community distributions. To assess the relevance of soil to species distribution, physical, chemical, and mineralogical analyses have been employed to determine soil criteria (Guo et al., 2003). The remarkable differences often observed in plant cover for different soil types in adjacent areas have naturally led to explain these phenomena in terms of the physical or chemical properties of the soil, or the physiological characteristics of the plants (Proctor & Woodell, 1975). Heavy metals are serious pollutants in natural environments due to their toxicity, persistence and bioaccumulation problems (El-Nemr, 2003). The concentration of heavy metals in the soil samples of the endemic taxa in the present study had the following sequence: K > P > N > Fe > Zn > Cu > Mn. The soil of Saint Katherine Protectorate (SKP) is characterized by a low to medium content of essential nutrients, slightly alkaline, sand to loamy sand in texture and has a low content of soluble salts. Such results agreed with Omar (2012), Omar (2017a, b, c), Omar et al. (2017), Shaltout et al. (2020), Omar & Elgammal (2021a, b, c, d, e, f, g, h, i).

It was observed that *Pancratium arabicum* and *Thesium humile* var. *maritima* have the maximum values of $CaCO_3$. This is due to the restriction of these species to Mediterranean sand dunes near the sea shores. Our results agreed with that of Zuo et al. (2008) who reported that the amount of soil organic carbon, total nitrogen and very fine sand were lower in gazed sandy dunes. The sand dunes habitat is affected by the leached salts from the salt marshes located to the south, and the waterways crossing the sand dunes leading to the salinization of the soil. The salt spray has a paramount effect on this habitat. It lies in the leeward side, where there is a chance for the precipitation of salty droplets due to the decrease in wind velocity (Batanouny, 1999). Soils of *Pancratium arabicum* that characterized coastal sand dunes have the highest values of sand, $CaCO_3$ pH, Mg and Ca. *Ifloga spicata* subsp. *elbaensis* is distributed in high-elevated wadis in Gebel Elba region. This taxon is characterized by a low value of pH and EC values. In addition, the values of soluble salts in its soil were relatively low. At higher elevations, orographic precipitation decreases the pH and EC. This negative relationship between precipitation and soil pH results in favorable soil conditions for plant growth at higher wadis (Abutaha et al., 2020).

Conclusion

The present study aims at deign distribution for the endemic taxa using grid map analysis, analyzing their vegetation, depicting the prevailing plant communities associated with them and assessing the role of the edaphic and environmental factors that affect the communities. The application of TWINSPAN on the cover estimates of 1026 species (21 endemic species and 1005 associated) in 91 stands led to the recognition of 8 vegetation groups at the 4th level of classification. Grid map distribution showed that Sinai region is the richest region in endemic taxa, while Eastern Mediterranean and Libyan desert regions are the lowest. Soil analysis showed that that most of the soils are alkaline and non-saline according to PH values. Four cations (Ca++, Mg++, Na+ and K+) and four anions (Co3 --, HCO3-, SO4-- and Cl-) were determined for each species as soluble salts. The majority of soil samples had sandy to loamy sandy textures. Soil samples are characterized by low content of organic matter.

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References

Abd El-Wahab, R.H., Zaghloul, M.S., Moustafa, A.A. (2006) Vegetation and Environment of Gebel Serbal, South Sinai, Egypt. *CATRINA*, **1**(2), 9-20.

Abd El-Wahab, R.H., Zaghloul, M.S., Kamel, W.M., Moustafa, A.R. (2008) Diversity and distribution of medicinal plants in North Sinai, Egypt. *African Journal of Environmental Science and Technology,* **2**(7), 157–171.

Abutaha, M., El-Khouly, A., Jurgens, N., Oldeland, J. (2020) Plant communities and their environmental drivers on an arid mountain, Gebel Elba, Egypt. *Vegetation Classification and Survey*, **1**, 21-36.

Ahmed, D., Shaltout, K., Hosni, H., El-Fahar, R. (2015) Flora and vegetation of the different habitats of the western Mediterranean region of Egypt. *Taeckholmia*, **35**(1), 45-76.

Allen, S.E., Grimshaw, H.M., Parkinson, J.A., Quarmby, C. (1986) "*Chemical Analysis of Ecological Materials*". Blackwell Scientific Publications, Oxford, 565p.

APHA, American Public Health Association (1981) *Standard methods for the examination of water and waste water, 15 ed.* Amer. Pup. Heal. Assoc., New York, 1134p.

Batanouny, K.H. (1999) The Mediterranean coastal dunes in Egypt: an endangered landscape. *Estuarine, Coastal and Shelf Science*, **49**(1), 3-9.

Bidak, L., Heneidy, S., Shaltout, K., Al-Sodany, Y.

(2013) Current status of the wild medicinal plants in the Western Mediterranean coastal region, Egypt. *Journal of Ethnobiology and Ethnomedicine*, **120**, 566-584.

Bear, F.E. (1975) "*Chemistry of the Soil*". Oxford & IBH Publishing Co., New Delhi, 515p.

Beck, J., Böller, M., Erhardt, A., Schwanghart, W. (2014) Spatial bias in the GBIF database and its effect on modeling species' geographic distributions. *Ecological Informatics*, **19**, 10–15.

Betremieux, R. (1948) *Traité de Chemié Vegetable*. Publié sous la direction de Brunel, Id 342. Espiau. P et Larguier, M. (Eds.).

Boakes, E.B. (2010) Distorted views of biodiversity: spatial and temporal bias in species occurrence data. *PLoS Biology*, **8**(6), e1000385. https://doi.org/10.1371/journal.pbio.1000385.

Boulos, L. (1997) Endemic Flora of the Middle East and North Africa. In: "*Reviews in Ecology: Desert Conservation and Development*", Barakat, H.N. and Hegazy, A.K. (Eds.), pp. 229-260. Metropole, Cairo.

Carmona, E.C., Ortiaz, A.C., Musarella, C.M. (2019) Introductory chapter: Endemism as basic element for the conservation of species and habitats. In: "*Endemic Species*", E.C. Carmona (Ed.), pp. 1–7. IntechOpen, London, https://doi.org/10.5772/intechopen.84950.

Coelho, N., Gonçalves, S., Romano, A. (2020) Endemic plant species conservation: Biotechnological approaches. *Plants*, **9**(3), 345. https://doi.org/10.3390/plants9030345

Crisp, M.D., Laffan, S., Linder, H.P., Monro, A. (2001) Endemism in the Australian flora. *Journal of Biogeography*, **28**(2), 183–198.

Cronk, Q. (2016) Plant extinctions take time. *Science*, **353**(6298), 446-447.

Danin, A. (1999) Desert rocks as plant refugia in the Near East. *Botanical Review*, **65**(2), 93–170.

Driese, K.L., Reiners, W.A., Merrill, E.H., Gerow, K.G. (1997) A digital land cover map of Wyoming, USA: a tool for vegetation analysis. *Journal of Vegetation Science*, **8**, 133-146.

El-Amier, Y.A., Abd El-Gawad, A.M. (2017) Plant communities along the international coastal highway of Nile delta, Egypt. *Journal of Agricultural Science*, **1**, 117-131.

El-Khalafy, M. (2018) Red list of the endemic and near endemic plant species in Egypt. *M.Sc Thesis,* Tanta University, Tanta, Egypt.

El-Khalafy, M.M. (2023) Biodiversity characteristics of endemic taxa in Egyptian flora. *Ph.D. Thesis,* Botany Department, Faculty of Science, Tanta University, Tanta, 483p.

El-Khalafy, M.M., Shaltout, K.H., Ahmed, D.A. (2021a) Updating and assessing plant endemism in Egypt. *Phytotaxa*, **502**(3), 237-258.

El-Khalafy, M.M., Ahmed, D.A.., Shaltout, K.H., Al-Sodany, Y.M., Haroun, S.A. (2021b) Re-assessment of the endemic taxa in the egyptian Flora. *African Journal of Ecology*, **59**(3), 784-796.

El-Khalafy, M.M., Ahmed, D.A., Shaltout, K.H., Haroun, S.A., Al-Sodany, Y.M. (2023) Ethnobotanical importance of the endemic taxa in the Egyptian flora. *Journal of Ecology and Environment*, **47**, 13. https://doi.org/10.5141/jee.23.044

El-Nemr, A. (2003) Assessment of heavy metals pollution in surface muddy sediments of Lake Burullus, southeastern Mediterranean, Egypt. *Egyptian Journal of Aquatic Biology and Fisheries*, **7**(4), 67-90.

Embabi, N.S. (2018) Geographic regions of Egypt. In: "*Landscapes and Landforms of Egypt. World Geomorphological Landscapes*", N.S. Embabi (Ed.), pp. 3–13. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-65661-8_1

Fithian, W., Elith, J., Hastie, T., Keith, D.A. (2014) Bias correction in species distribution models: Pooling survey and collection data for multiple species. *Methods in Ecology and Evolution*, **6**(4),424–438.

Gauch, H., Whittaker, R., (1981) Hierarchical Classification of Community Data. *Journal of Ecology*, **69**(2), 537-557.

Guo, Y., Gong, P., Amundson, R. (2003) Pedodiversity in the United States of America. *Geoderma*, **117**(1-2), 99–115.

Harrison, R., Perry, R. (1986) "*Handbook of Air Pollution Analysis*". 2nd ed., Champman and Hall, London.

Hatim, M. (2013) An inventory of available phytosociological data of Sinai and field survey of some under-sampeled area. *M.Sc. Thesis*. Tanta University, Tanta, 218p.

Hazen, A. (1989) On the determination of chloride in water. *American Journal of Chemistry*, **II**, 409.

Heneidy, S.Z., Halmy, M.W., Toto, S.M., Hamouda, S.K., Fakhry, A.M., Bidak, L.M., et al. (2021) Pattern of urban flora in intra-city railway habitats (Alexandria, Egypt): A conservation perspective. *Biology*, **10**(8), 698. https://doi.org/10.3390/biology10080698

Heneidy, S.Z., Al-Sodany, Y.M., Bidak, L.M., Fakhry, A.M., Hamouda, S.K., Halmy, M.W., et al. (2022) Archeological sites and relict landscapes as refuge for biodiversity: Case study of Alexandria city, Egypt. *Sustainability*, **14**(4), 2416.

Hill, M.O. (1979a) *DECORANA–A FORTRAN program for detrended correspondence analysis and reciprocal averaging*. Cornell University Ithaca N.Y, 90p.

Hill, M.O. (1979b) TWINSPAN–A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University Ithaca N.Y, 52p.

Huntley, B. (1999) Species distribution and environmental change. In: "*Ecosystem Management. Questions for Science and Society*", Maltby E., Hodgate M., Acreman M. & Weir A. (Eds.), pp. 115-129. Royal Holloway, University of London, Institute for Environmental Research, Egham.

Jackson, M.L. (1960) "*Soil Chemical Analysis*". Prentice-Hall, Inc. Inglewood Cliffs, N.T., 498p.

Kassas, M., Batanouny, K. (1984) *Plant ecology*. In: "*Sahara Desert*", Cloudsley-Thompson, J.J. (Ed.), Pergamon Press, Oxford, 348p.

Khapugin, A.A., Kuzmin, I.V., Silaeva, T.B. (2020) Anthropogenic drivers leading to regional extinction of threatened plants: Insights from regional Red Data Books of Russia. *Biodiversity and Conservation*, **29**, 2765–2777.

Khedr, A. (2006) Regional Patterns of Rarity and Life History Elements in the flora of Egypt. *Taeckholmia*, **26**, 141-160.

Kiselyova, L.L., Parakhina, E.A., Silaeva, Z.G. (2017) Efficiency of grid mapping method for detecting new locations of rare plants (on the example of Southeastern part of Orel region). *Geoinformatical and cartographical methods and technologies*, **23**(2), 209-219.

Knapp, W.M., Frances, A., Noss, R., Naczi, R.F., Weakley, A., Gann, G., et al. (2021) Vascular plant extinction in the continental United States and Canada. *Conservation Biology*, **35**(1), 360-368.

Kolthoff, I.M., Stenger, V.A. (1947) "*Volumetric Analysis*". 2nd ed., pp. 242-245. Outfy Interscience Publishers, New York.

Laffan, S. Crisp, M. (2003) Assessing endemism at multiple spatial scales, with an example from the Australian vascular flora. *Journal of Biogeography,* **30**(4), 511-520.

Lavergne, S., Thompson, J.D., Garnier, E., Debussche, M. (2004) The biology and ecology of narrow endemic and widespread plants: A comparative study of trait variation in 20 congeneric pairs. *Oikos*, **107**(3), 505–518.

Lima, R.A., Souza, V.C., De Siqueira, M.F., Steega, H.T. (2020) Defining endemism levels for biodiversity conservation: tree species in the Atlantic Forest hotspot. *Biological Conservation*, **252**, a108825. https://doi.org/10.1101/2020.02.08.939900

Maxted, N., van Slageren, M.W., Rihan, J.R. (1995) *Ecogeographic surveys*. In: "*Collecting Plant Genetic Diversity*", Guarino, L., Ramanatha Rao, V. & Reid, R. (Eds.), pp. 255-285. CAB International, Wallingford.

Mosallam, H.A. (2007) Assessment of target species in Saint Katherine Protectorate, Sinai, Egypt. *Journal of Applied Sciences Research*, **3**(6), 456-469.

Moustafa, A.R., Klopatek, J.M. (1995) Vegetation and landforms of the Saint Catherine area, Southern Sinai, Egypt. *Journal of Arid Environment*, **30**(4), 385–395.

Moustafa, A., Zaghloul, M., El-Wahab, R., Shaker, M. (2001) Evaluation of plant diversity and endemism in Saint Catherine Protectorate, South Sinai, Egypt. *Egyptian Journal of Botany*, **41**(1), 121-139.

Mueller-Dombois, D., Ellenberg, H. (1974) "*Aims and Methods of Vegetation Ecology*". New York: Wiley.

Nakagoshi, N., Hikasa, M., Koarai, M., Goda, T., Sakai, I. (1998) Grid map analysis and its application for detecting vegetation changes in Japan. *Applied vegetation science*, **1**(2), 219-224.

Omar, K. (2012) Vegetation, soil and grazing analysis in Saint Katherine Protectorate, South Sinai, Egypt. *International Journal of Environment and Biodiversity*, **3**(2), 80–92.

Omar, K. (2017a) *Anarrhinum pubescens*. The IUCN Red List of Threatened Species 2017: e.T84119796A84119800.

Omar, K. (2017b) *Bufonia multiceps*. The IUCN Red List of Threatened Species 2017: e.T84119945A84119949

Omar, K. (2017c) *Rosa arabica*. The IUCN Red List of Threatened Species 2017: e.T84120072A84120074.

Omar, K., Elgamal, I. (2021a) *Ballota kaiseri*. The IUCN Red List of Threatened Species: e.T184589206A184589211.

Omar, K., Elgamal, I. (2021b) *Micromeria serbaliana*. The IUCN Red List of Threatened Species 2021: e.T184589270A184589325.

Omar, K., Elgamal, I. (2021c) *Silene leucophylla*. The IUCN Red List of Threatened Species 2021: e.T184588883A184588988.

Omar, K., Elgamal, I. (2021d) *Silene oreosinaica*. The IUCN Red List of Threatened Species 2021: e.T184589013A184589032.

Omar, K., Elgamal, I. (2021e) *Silene schimperiana*. The IUCN Red List of Threatened Species 2021: e.T184589181A184589187.

Omar, K., Elgamal, I. (2021f) IUCN red list and species distribution models as tools for the conservation of poorly known species: a case study of endemic plants *Micromeria serbaliana* and *Veronica kaiseri* in South Sinai, Egypt. *Kew Bulletin*, **76**(3), 477–496.

Omar, K., Elgamal, I. (2021g) Assess the extinction risk of mountain endemic plants in Egypt under the current climatic condition: a case study of endemic *Silene* species. *European Journal of Biology and Biotechnology*, **2**(5), 34-47.

Omar, K., Elgamal, I. (2021h) Conservation of challenging endemic plant species at high risk of extinction in arid mountain ecosystems: a case study of *Rosa arabica* Crép. in Egypt. *Journal of Mountain Science*, **18**(10), 2698-2721.

Omar, K., Elgamal, I. (2021i) Can we save critically endangered relict endemic plant species? A case study of *Primula boveana* Decne ex Duby in Egypt. *Journal for Nature Conservation*, **61**, 126005.

Omar, K., Elgammal, I., Shalof, A., Mehana, S., Abdelbaset, F. (2017) 2017 *Final Report, community-based conservation of threatened plants Silene schimperiana and Polygala sinaica var. sinaica.* Conservation assessment for endemic species in Egypt. The Ruffor Foundation, London, 92p.

Ouédraogo, A.S. (1997) Conservation and use of forest genetic resources. In: *Proceedings of the XI World Forestry Congress,* Antalya, 13-22 October 1997. FAO, Rome: 173-188p.

Parkinson, J., Quarmby, C. (1974) "*Chemical Analysis of Ecological Materials*". Blackwell Scientific Publications. Blackwell Scientific Publications, 368p.

Proctor, J., Woodell, S. (1975) *The Ecology of Serpentine Soils*. In: "*Advances in Ecological Research*", Volume 9, pp 255–366. Academic Press, Cambridge, MA, USA.

Shaltout, K., Ahmed, D., Diab, M., El-Khalafy, M. (2018) Re-assessment of the near-endemic taxa in the Egyptian Flora. *Taeckholmia*, **38**(1), 61-83.

Shaltout, K.H., Al-Sodany, Y.M., Eid, E.M., Heneidy, S.Z., Taher, M.A. (2020) Vegetation diversity along the altitudinal and environmental gradients in the main wadi beds in the mountainous region of South Sinai, Egypt. *Journal of Mountain Science*, **17**, 2447–2458.

Shaltout, K.H., Ahmed, D.A., Al-Sodany, Y.M., Haroun, S.A., El-Khalafy, M.M. (2023) Cultural Importance Indices of the Endemic Plants in Egypt.

Egyptian Journal of Botany, **63**(2), 649-663.

SPSS (2012) *IBM. SPSS statistics for windows*: IBM crop. Armonk, NY. USA.

Thompson, J.D. (2020) "*Plant Evolution in the Mediterranean: Insights for Conservation*". Oxford University Press, USA, 304p.

Zaghloul, M.S. (1997) Ecological studies on some endemic plant species in South Sinai, Egypt. *M.Sc. Thesis*, University of Suez Canal, Ismailia. 279p.

Zahran, M., Willis, A. (2009) "*The Vegetation of Egypt*", 2: pp. 221-249. Plant and Springer Science Business Media B.V., London.

Zohary, M. (1973) "*Geobotanical Foundations of the Middle East*". Gustav Fischer Verlag, Stuttgart, 739p.

Zuo, X., Zhao, H., Zhao, X., Zhang, T., Guo, Y., Wang, S., Drake, S. (2008) Spatial pattern and heterogeneity of soil properties in sand dunes under grazing and restoration in Horqin Sandy Land, Northern China. *Soil and Tillage Research*, **99**(2), 202-212.

المجتمعات النباتية المصاحبة للأنواع المتوطنة في الفلورا المصرية

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تناولت العديد من الدراسات الغطاء النباتي الطبيعي للموائل المصرية في مناطق معينة، ولكن لم تتناول أي دراسة المجتمعات النباتية المصاحبة للنباتات المتوطنة في مصر ككل. ولذلك تهدف الدراسة الحالية إلى دراسة توزيع الأنواع النباتية المتوطنة باستخدام نظام الخريطة الشبكية، والكساء الخضري، وتحديد المجتمعات النباتية السائدةالمصاحبة لها، كما تم تقييم دور العوامل البيئية التي تؤثر على هذه المجتمعات. تم اختيار 619 موقعا لتحديد المجتمعات النباتية المصاحبة للنباتات المتوطنة المصرية في الفترة من 2018 - 2023. وقد أدى تطبيق طرائق التحليل العددي الحديثة (TWINSPAN) على قيم الغطاء لـ 1026 نوعًا (21 نوعًا مستوطنًا و1005 أنواعًا مصاحبة) إلى التعرف على 8 مجموعات نباتية في المستوى الرابع من التقسيم. وتم تسميتها طبقا للنبات السائد الأول في كل مجموعة. وقد أظهرت نتائج تحليل التربة أن معظمها قلوية وغير مالحة حسب قيم الرقم الهيدروجيني. تم تحديد أربعة كاتيونات (الكالسيوم، الماغنسيوم، الصوديوم، والبوتاسيوم)، وأربعة أنيونات (الكلوريدات، الكربونات، البيكربونات، والكبريتات) لكل نوع كأملاح قابلة للذوبان. تباينت غالبية عينات التربة من رملية إلى رملية طينية، كما تميزت بمحتوى منخفض من المواد العضوية.