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Vegetation analysis and soil characteristics of five common desert climbing plants in Egypt

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Abstract: This study aimed to characterise Egyptian desert vine flora and compare it with that of deserts in other continents, such as Australia and North America. Specifically, 5 common climbing desert plants (*Citrullus colocynthis*, *Cocculus pendulus*, *Cucumis prophetarum*, *Pergularia tomentosa*, and *Periploca angustifolia*) were selected for this study. The floristic composition, vegetation heterogeneity, and chorological affinities of the associated species of the studied climbing plants were quantitatively analysed. In general, Leguminosae, Convolvulaceae, Cucurbitaceae, and Asclepiadaceae are the most species-rich families of the climbing plants in Egypt. The comparison of all desert climbing plants in Egypt to those found in the deserts of other continents (specifically, the Australian, Sonoran, and Chihuahuan deserts) revealed the same dominant plant families. The chorological analysis of the associated flora indicated the abundance of the Saharo-Arabian chorotype within the major growth forms. Classification of the vegetation associated with the 5 climbing plants yielded 4 vegetation groups, each linked to 1 or more of the studied climbing plants. Both DCA and CCA were used to assess the soil-vegetation relationships; results indicated that gravel, coarse sand, Na^+, SO_4^{-2}, Cl^-, and NO_3^- were the most important factors for the distribution of the vegetation patterns of the studied desert vines.

Key words: Egypt, floristic diversity, multivariate analysis, distribution patterns, vines, desert vegetation, CCA

Introduction

Climbing plants are an interesting but much neglected group. This group consists of plants that are rooted in the ground but need support for their weak stems, and both herbaceous (vines) and woody (lianas) climbing plants can be found. Climbers are a conspicuous feature of all forests and compete actively with trees for light and space (Richards, 1952). Their high abundance is an important physiognomic feature differentiating tropical from temperate forests (Gentry, 1991). Climbing plants are treated as an ambiguous growth form in most floristic studies of arid ecosystems; for this reason, our knowledge about the abundance of climbing plants is rather poor and has been difficult to obtain (Rundel & Franklin, 1991).

On the basis of the most obvious climbing technique, climbers have previously been distinguished (Nabe-Nielsen, 2001; Solórzano et al., 2002) to include: 1) twining using stems, branches,

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or petioles; 2) climbing using tendrils, including leaf tendrils; 3) scrambling, often assisted by hooks to avoid slipping; and 4) using adventitious roots. Each has a wide range of architectural expression, although closely related species tend to develop similar climbing attributes (Hegarty, 1991). Flowering plant families that are particularly rich in climbing species include Bignoniaceae, Vitaceae, Leguminosae, Convolvulaceae, Menispermaceae, and Hippocrateaceae. In some genera, all of the species are climbers (e.g. *Serjania*), whereas others include species of vines, shrubs, and trees (e.g. *Bauhinia*). There are also numerous species that grow as climbers when crowded, but are free-standing shrubs or trees if they fail to encounter mechanical supports (e.g. species of *Croton*).

Recently, interest in the flora and ecology of climbing plants (vines and lianas) has increased. Particularly in desert areas, however, the incidence, flora, phytogeography, and ecology of both woody and herbaceous climbing plants are poorly known (Parsons, 2005) with the only detailed studies being the accounts of Molina-Freaner & Tinoco-Ojanguren (1997) and Molina-Freaner et al. (2004) for the central Sonoran Desert in Mexico. They described the abundance, distribution, and morphological characteristics of vines in desert plant communities. In the Sonoran and Chihuahuan deserts, Krings (2000) studied the phytogeographical characterisation of the vine flora of 2 lower North American desert regions as a biogeographical framework for further ecological inquiry into desert vegetation. Similarly, Parsons (2005, 2006) investigated the presence of vine species in the 6 Australian deserts.

The complete phytogeographical analysis of Egyptian flora (including climbers) is still being documented. There have been a few attempts to analyse the phytogeographical implications of species distribution patterns, including the investigation by El Hadidi et al. (1996) of the weed flora in the farmlands of Egypt, including those of the Nile area, Mediterranean coast, and oases; Abd El-Ghani & El-Sawaf's exploration of the agroecosystem of Egypt (2004); and research carried out by El-Husseini et al. (2008) on the order Tubiflorae in Egyptian flora.

Egypt, and the greater Sahara region in general, has scanty studies on climbing plants. The present study therefore encompasses a selection of the most commonly distributed species in Egypt in an attempt to provide baseline information on climbing plants in an arid ecosystem. This study aims to identify the geographical distribution patterns of climbing plants in the flora of Egypt as compared to other arid and hyperarid regions of the world, to characterise the vegetation composition of the 5 selected climbing desert plants in relation to the prevailing soil factors, and to analyse the floristic diversity, vegetation composition, and chorological affinities of those species associated with the 5 studied species.

Materials and methods

Vegetation sampling

Between 2005 and 2007, an extensive detailed survey was carried out at 41 different sites representing a variety of phytogeographic regions in Egypt (Wickens, 1977). Specimens of the selected climbing plants were collected in varying degrees of abundance from the western Mediterranean coastal strip, the Eastern Desert, the Red Sea coast, and the Sinai Peninsula in order to compile a list of the plant species associated with them. The studied species were common climbing plants and included *Citrullus colocynthis* (L.) Schrad., *Cocculus pendulus* (J.R.Forst. & G.Forst.) Delile, *Cucumis prophetarum* L., *Pergularia tomentosa* L., and *Periploca angustifolia* Labill. A stratified random sampling method was employed (Greig-Smith, 1983; Ludwig & Reynold, 1988) within each of the 41 georeferenced study sites using a GPS model Trimble SCOUT M (Figure 1). A floristic-count list was taken from the 41 sites to represent the 5 climbing plants in different phytogeographic regions of Egypt, and distribution was determined to be as follows: 14 from the Red Sea, 13 from the Mediterranean, 10 from Sinai, and 4 from the Eastern Desert. *Citrullus colocynthis* was found at 18 sites in the Red Sea, Mediterranean, and Sinai regions; *Cocculus pendulus* was seen at 8 sites in the Eastern Desert, Red Sea, and Sinai Peninsula; 6 sites in the Red Sea region and Sinai Peninsula contained *Cucumis prophetarum*; 9 sites in the Eastern Desert, Red Sea region, and Sinai

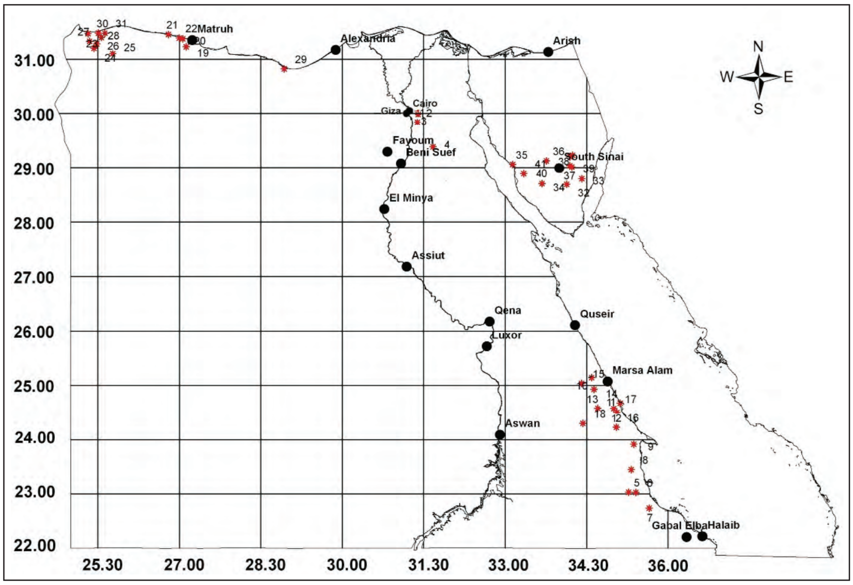

Figure 1. Map showing the distribution of the 41 studied sites.

Peninsula offered specimens of *Pergularia tomentosa*; and *Periploca angustifolia* was noted at 9 sites from the western Mediterranean coastal strip. From each site (20 × 20 m), ecological notes and the presence or absence of plant species other than climbers were collected and recorded. Species richness is referred to here as the total number of species per site. Specimens of each species were collected and plant identification was carried out both in the field and in the herbarium of Cairo University (CAI), where specimens were deposited. Taxonomic nomenclature was used according to the works of Täckholm (1974), Cope & Hosni (1991), and Boulos (1995, 1999, 2000, 2002). The analysis of phytogeographic ranges was carried out using the methods of Zohary (1949 & 1962) and Bornkamm and Kehl (1990).

Soil sampling and analysis

At each of the 41 georeferenced study sites, 3 soil samples were collected (depths of 0-20, 20-35, and 35-50 cm). The samples were pooled together to form a single composite sample, which was then spread over sheets of paper and left to dry in the air. Dried soils were passed through a 2-mm sieve and packed into paper bags for physical and chemical analysis. The soil texture was determined using the sieve method and calculated as a percentage of the original weight (Allen et al., 1974). Soil extracts were prepared and then used in order to determine pH, electric conductivity, soluble anions, and soluble cations. A pH meter (Jenway 3020) was used to determine the pH values, electric conductivity (EC) was determined using an electrical conductivity meter, sodium and potassium were determined using a flame photometer (Jackson, 1962), and soluble nitrogen forms (NH_4^+ and NO^-_3) were measured using an AutoAnalyzer II in accordance with the methods of Markus et al. (1982). The estimation of chlorides in the soil extract was carried out by titration methods against silver nitrate ($AgNO_3$) using potassium chromate ($K_2Cr_2O_7$) as an indicator (Hazen, 1989). Soluble carbonates and bicarbonates were estimated according to the methods of Allen et al. (1974) and Maff (1986), and calcium and magnesium ions were determined by titration with EDTA. Sulphates were determined turbidimetrically as barium sulphate at 470 nm (Verma et al., 1977).

Data analysis

Classification and ordination of the associated vegetation of the studied climbing plants were performed using presence/absence data. For this purpose, a floristic data matrix of 41 sites and 98 species was used before being subjected to classification by cluster analysis by the Community Analysis Package (CAP) computer program, version 1.2 (Henderson & Seaby, 1999), using the minimum variance as an algorithm; results were presented in the form of a dendrogram. Unicates of the total flora were eliminated from the data set to avoid noise and summarise redundancy (Gauch, 1982). For ordination, the indirect gradient analysis was undertaken using detrended correspondence analysis (DCA; Whittaker, 1967).

Preliminary analyses were made by applying the default options of DCA (Hill & Gauch, 1980) in the CANOCO program to check the magnitude of change in species composition along the first ordination axis (i.e. gradient length in standard deviation units). DCA estimated the compositional gradient in the vegetation data of the present study to be larger than 4.0 SD units for all subset analysis. Canonical correspondence analysis (CCA) was thus the most appropriate ordination method for performing direct gradient analysis (Ter Braak, 2003). Direct gradient analysis is that in which species composition is directly and immediately related to measured environmental variables (Ter Braak, 1986). In CANOCO, the relationships between vegetation gradients and the studied environmental variables can be indicated on the ordination diagram produced by the CCA biplot. Prior to the CCA analysis, all data variables were assessed for normality using SPSS 10 for Windows, and appropriate transformations were performed. An arc-sin transformation was used on the soil sand fraction because this transformation has been shown to work better on wide-ranging percentages (Zar, 1984).

Using the computer program CANOCO, version 4.5 (Ter Braak, 2003), CCA was used in conjunction with the recorded soil variables to analyse patterns of variation in the distribution of the vegetation associated with the 5 studied climbing plants. The variables in the CCA biplots are represented by arrows pointing in the direction of maximum variation, with their length proportional to the rate of change (Ter Braak, 1986). Each arrow determines an axis upon which the species points can be projected. The exploratory CCA was evaluated using interset correlations and CCA axes were evaluated statistically by means of a Monte Carlo permutation test (Ter Braak & Prentice, 1988). Ter Braak (1986) suggested using DCA and CCA together to see how much of the variation in species data is accounted for by the environmental data. Automatic forward selection of soil variables was carried out by CANOCO in order to identify the most important variables. This study included 15 soil variables: pH, electric conductivity, gravel, coarse sand, clay, silt, chlorides, nitrates, sodium, potassium, calcium, magnesium, ammonium, bicarbonates, and sulphates.

The vegetation groups produced from cluster analysis were then subjected to one-way analysis of variance (ANOVA) testing, based on soil variables, to find out whether there were any significant variations among groups. Analysis of variance provides insight into the nature of variation of natural events, which is possibly of even greater value than the knowledge of the method as such (Sokal & Rohlfs, 1981).

Results and discussion

Diversity of climbing plants

Reviewing the studied flora, a total of 93 climbing species (76 vines and 17 lianas) belonging to 15 families and 41 genera were listed (Appendix), representing 4.4% of the total vascular flora of Egypt. This figure was slightly higher than the normal range of 1%-3% found for Mediterranean climate and arid zone floras that was proposed by Rundel & Franklin (1991), although clearly much lower than that recorded in tropical or temperate forests (19% and 6%, respectively) (Molina-Freaner et al., 2004). Represented by 76 species (81.7%), herbaceous species (vines) markedly dominated the recorded climbers and were most abundant in Leguminosae (29 species; 31.2%), Convolvulaceae (17 species; 18.3%), Cucurbitaceae (13 species; 14.0%), and Asclepiadaceae (8 species; 8.6%). The remaining families together constituted 26 species (27.9%) and included Cuscutaceae, Rubiaceae, Capparaceae, Ephedraceae, Loranthaceae, Oleaceae, Vitaceae, Labiatae, Menispermaceae, and Polygonaceae. This result is consistent with the conclusion of Rundel & Franklin (1991), who, in their study on vines of arid and semiarid environments, reported that the great majority of arid zone climbers are herbaceous (vines), while woody climbers (lianas) are rare.

Contrary to findings from tropical forests (Balfour & Bond, 1993; Sridhar Reddy & Parthasarathy, 2003; Dewalt et al., 2006; Yan et al., 2006), trees were not represented among the 93 climbing plants of Egypt. Herbs were the dominant growth form (76 species; 81.7%), 46 of which were annuals such as *Convolvulus* *siculus*, *Lathyrus annuus*, and *Cucumis dipsaceus*; the remaining 30 were perennials, including *Citrullus colocynthis*, *Cynanchum acutum*, and *Rhynchosia minima*. Shrubs were represented by 15 species (16.1%), among them *Cissus quadrangularis*, *Pergularia tomentosa*, and *Cocculus pendulus*, and 2 semiparasites (2.1%), *Plicosepalus acaciae* and *P. curviflorus*, were reported. Of the known climbing species in the flora of Egypt, 20 (e.g. *Podostelma schimperi*, *Maerua oblongifolia*, and *Kedrostis gijef*) were confined to the Gebel Elba region (in the southeastern corner of Egypt, on the Egyptian-Sudanese border) and do not penetrate into other regions. On the other hand, 9 species (e.g. *Ipomoea eriocarpa* and *Vigna luteola*) were consistent in their geographical distribution throughout the Nile region, a further 9 (e.g. *Bryonia cretica* and *Lathyrus setifolius*) were distributed in the Mediterranean region, 7 species (e.g., *Convolvulus palaestinus* and *Ephedra foemina*) were consistent in the Sinai Peninsula, and *Vicia hirsuta* was noted in the Eastern Desert (see Appendix). According to El Hadidi et al. (1992), 6 climbing plants were considered endangered, including *Cadaba farinosa*, *Maerua oblongifolia*, *Ephedra foemina*, and *Plicosepalus curviflorus*. Täckholm (1974) considered another 17 climbing plants species to be very rare (e.g. *Podostelma schimperi*, *Merremia semisagittata*, *Corallocarpus schimperi*, *Kedrostis foetidissima*, *Cissus quadrangularis*, *Pentatropis nivalis*, and *Pergularia daemia*).

Considering the total number of species, the total number of vines in Australian deserts is significantly lower when compared with those in North America and Egypt (Table 1), a fact that may partly reflect rainfall differences, as parts of the Sonoran and Chihuahuan deserts receive up to 470 and 500 mm of mean annual rainfall, respectively (Shreve & Wiggins, 1964). In contrast, the Western Australian Desert's mean annual rainfall reaches 300 mm in a small area in the northwestern region, but is more usually 180-200 mm (Beard, 1969). In the Egyptian deserts, this figure differs substantially between the western areas (where mean annual rainfall decreases from 150 mm at the coast to practically 0 mm in the south) and eastern areas (where mean annual rainfall decreases from 30 mm in the north to almost 0 mm in the south).The gradient in the annual rainfall is therefore obvious and is associated with an inverse evaporation gradient indicating the increase of aridity from west to east and from north to south (Ayyad & Ghabbour, 1986; Abd El-Ghani, 1998, 2000; Abd El-Ghani & El-Sawaf, 2004, 2005). The highest desert value, 198 species or 7.5% in the Sonoran Desert (Krings, 2000), is related to the migration of taxa from the wetter, more tropical areas nearby (Rundel & Franklin, 1991; Krings, 2000). There is no sign of a similar effect in the Australian data, although, unlike the other deserts in that country, the Great Sandy Desert directly adjoins wetter, more tropical land to the north (Parsons, 2005).

The comparison between the members of desert climbing plants in Egypt and those of deserts in other continents (namely the Australian, Sonoran, and Chihuahuan deserts) revealed that Convolvulaceae, Leguminosae, Cucurbitaceae, and Asclepiadaceae were the dominant plant families (Parsons, 2005). These 4 families accounted for 74.4%, 72.7%, 72.1%, and 62.1% of species in the Chihuahuan, Sonoran, Egyptian, and Australian deserts, respectively. This may reflect the large proportion of pantropical and cosmopolitan families shared between all of these data sets (Table 1). Although Rundel & Franklin (1991) thought that Convolvulaceae was especially important in Australian deserts, that view was not supported by our findings with regard to the vines of Egyptian deserts. In fact, in terms of the total number of vine species, the percentage for that family is 18% and 26%-27% in the Australian, Sonoran, and Chihuahuan deserts (Parsons, 2005). Speciation in the family Convolvulaceae has been more prolific in the Thar Desert of India, where it is the fourth largest family of vascular flora (Shmida, 1985). Values for Cucurbitaceae in Egypt (Table 1) were more similar to those of the North American areas (14%-15%) when compared with figures from Australia (5% of all vines). Again, the values in the Thar Desert are likely to be higher still (Shmida, 1985). Vitaceae, the fifth largest vine family in the 2 North American deserts, were poorly represented in the Egyptian deserts (2 species) but not known at all in Australian deserts. Australia has only about 34 species of the approximately 700 species of Vitaceae found worldwide (Morley & Toelken, 1983), the family being considered Laurasian (Krings, 2000). When comparing the climbing plant species of

Table 1. The most species-rich families of climbing plants in Egypt compared with data from the Australian and 2 North American deserts. [1] = Present study, [2] = Parsons (2005), [3] = Krings (2000).

Egypt [1]		Australian desert [2]		Sonoran Desert [3]		Chihuahuan Desert [3]	
Family	Number of species	Family	Number of species	Family	Number of species	Family	Number of species
Leguminosae	29	Convolvulaceae	10	Convolvulaceae	53	Convolvulaceae	35
Convolvulaceae	17	Leguminosae	6	Leguminosae	34	Leguminosae	31
Cucurbitaceae	13	Asclepiadaceae	5	Cucurbitaceae	30	Cucurbitaceae	19
Asclepiadaceae	8	Lauraceae	3	Asclepiadaceae	27	Asclepiadaceae	14
Cuscutaceae	8	Cucurbitaceae	2	Vitaceae	7	Vitaceae	6
Others	18	Others	11	Others	47	Others	28
Total	**93**		**37**		**198**		**133**

Egypt and those of the surrounding countries with arid environments, the Egyptian flora was found to be more rich (93 species) than that of Palestine (85 species), Libya (42 species), Saudi Arabia (34 species), or Qatar (9 species). In addition, there were 29 species recorded only in Egypt, which have not been found in the floras of these other countries.

General distribution patterns of the 5 climbing plants

In recent decades, most of the phytogeographic regions of Egypt have been affected by human activities, including the intensive collection of plant species for commercial use; this has greatly influenced the natural vegetation and distribution of plants in these areas. In their study of the diversity and distribution of medicinal plants in the North Sinai region of Egypt, Abd El-Wahab et al. (2008) stated that "about 60% of medicinal plants are threatened due to intensive collection and human activities." Due to the country's increased population, the Red Sea coast has also experienced a great increase in human interference as many new settlements were established in the vicinity of older cities such as Hurgada, Safaga, and Quseir (Zohary, 1983; Abd El-Ghani, 1998). The construction of roads is one of human society's largest impacts on desert vegetation.

The distribution patterns of the 5 selected plant species of this study are shown in Figure 2. *Citrullus colocynthis* was indicated to have a wide geographical range of distribution in Egypt. During recent years, *Citrullus colocynthis* has been collected from nearly all of the phytogeographic regions of Egypt. Kassas and Imam (1954) reported that the fruits of *Citrullus colocynthis* are often harvested for their medicinal value; this extensive collection reduces the reproductive capacity of the plant and, consequently, its number. In 2008, Abd El-Wahab et al. declared it to be a very rare species in the North Sinai. In the present study, the plant was collected from 3 phytogeographic regions (the Sinai Peninsula, Mediterranean, and Red Sea regions).We were not able to collect any specimens from the wadis of the Eastern Desert. *Citrullus colocynthis* was considered by Kassas and Imam (1954) to be a rare species in the Hof Wadi area (located in the Eastern Desert). Significantly, the plant has not been collected from that location since that time.

Cucumis prophetarum and *Cocculus pendulus* were confined to the eastern part of Egypt (the Eastern Desert, Red Sea region, and Sinai Peninsula) between latitudes 22° and 30.5° and longitudes 31° and 36.2°. The Nile River may act as a natural barrier for the spreading of the 2 species westward, preventing the plants from penetrating into the western parts of the

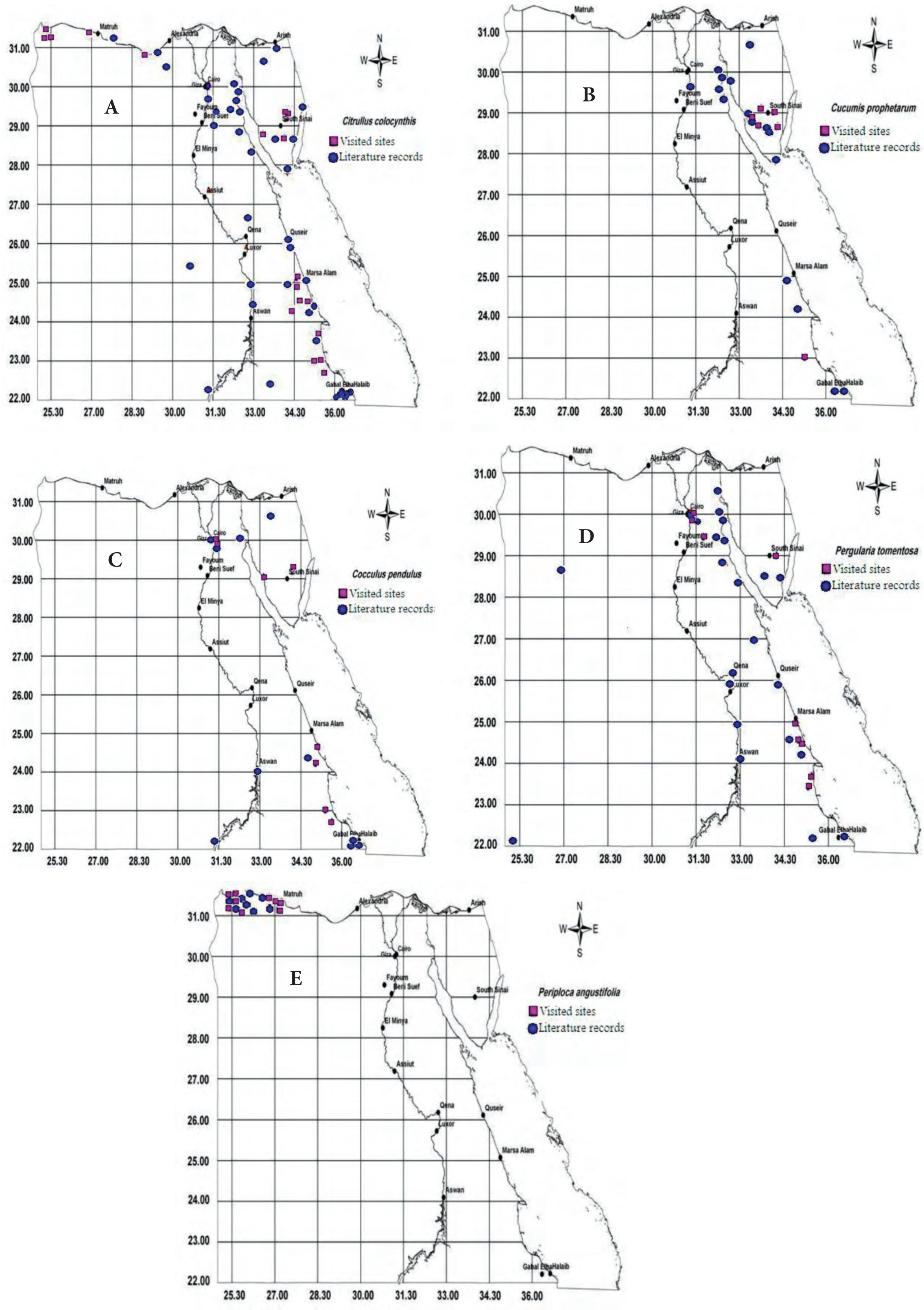

Figure 2. Distributional patterns of A) *Citrullus colocynthis*, B) *Cucumis prophetarum*, C) *Cocculus pendulus*, D) *Pergularia tomentosa*, and E) *Periploca angustifolia* showing visited sites and literature records.

country. Herbarium records of *Cocculus pendulus* show that it was recorded in 1910 from Mokattam and in 1926 from the Dwaiqa area, near Cairo. In this investigation, the general physiographic features of these 2 areas are substantially changed, resulting in the disappearance of many species that are recorded earlier.

The distribution of *Pergularia tomentosa* is mainly restricted to the eastern part of Egypt (Zahran & Willis, 1992). According to the literature and the current records, *Pergularia tomentosa* has been collected from nearly all parts of the Eastern Desert of Egypt and the Sinai Peninsula. It is recorded once from a few sites in the western part of the country.

Periploca angustifolia is restricted to the northwestern part of Egypt and is not recorded from any other part. Täckholm (1974) considered it a rare species in the Egyptian flora, but recently it has been recorded in many regions of the Western Desert (Salama et al., 2005). In its habitat, *Periploca angustifolia* is usually exposed to heavy grazing by goats and camels. In the Sallum area at the Libyan frontier, its occurrence represents the westernmost geographical distribution in Egypt. Further investigations on the biological and ecological correlates determining its distribution limits should be conducted in the future.

Biological spectrum and chorological affinities of the associated vegetation

This study recorded 97 species belonging to 85 genera from 33 families of flowering plants and 1 gymnosperm family associated with the selected 5 climbing plants (Table 2). The most species-rich families are Chenopodiaceae (12.4% of the total flora), followed by Leguminosae (11.3%), Zygophyllaceae (9.2%), Compositae (8.3%), Cruciferae (6.2%), and Asclepiadaceae (5.1%). This included 23 annuals and 74 perennials. Shrubs (50 species) and perennial herbs (17 species) are the dominant growth form, accounting for 69% of the total flora. In addition, 5 trees (*Calotropis procera*, *Acacia tortilis* subsp. *raddiana*, *A. tortilis* subsp. *tortilis*, *Tamarix aphylla*, and *T. nilotica*) are also counted.

When water is limited, as is the case in the study area, the relative advantage of shrubs over grasses can be explained by the extensive root systems of the former, which are capable of utilising water stored in different soil depths, whereas grasses must use the transient water stored in the upper soil synchronic with precipitation pulses. A preponderance of annuals and shrubs reflects a typical desert flora closely related to topography (Zohary, 1973; Orshan, 1986). Alternatively, they may be a response to the hot, dry climate and human and animal interference. As presented in this study, the dominance of shrubby plant species over grasses is evident.

Phytogeographically, Egypt is the meeting point of floristic elements belonging to at least 4 different regions: the African Sudano-Zambezian, the Asiatic Irano-Turanian, the Afro-Asiatic Saharo-Arabian, and the Euro-Afro-Asiatic Mediterranean (El Hadidi, 1993). As the whole country lies within the Saharo-Arabian belt of the Holarctic floristic realm, the chorological analysis of the floristic data indicated the abundance of the Saharo-Arabian chorotype (mono-, bi- and pluriregional) within the major growth forms (shrubs, perennial herbs, and annuals; Figure 3). Altogether, they comprised 69 species, or 71% of the total recorded flora. The various elements of the Mediterranean chorotype contributed 15 species (15.5%) to the total flora. This may be attributed to the fact that plants of the Saharo-Arabian species are good indicators for harsh desert environmental conditions, while Mediterranean species signal a more mesic environment (El-Demerdash et al., 1994; Sheded, 2002; Abd El-Ghani & Abdel-Khalik, 2006; El-Husseini et al., 2008).

Vegetation characteristics of the 5 climbing plants

A problem in dealing with species-poor desert vegetation is that few characteristic species can be identified to indicate the vegetation types (Danin et al., 1975). This is the case with the vegetation classification reported in our results. The application of cluster analysis and DCA ordination techniques produced 4 major vegetation groups that are similar in terms of their species composition (Figure 4 and Table 2). Each is linked to one or more of the studied climbing plants and they are named after the dominant species, as follows: Group A: *Thymelaea hirsuta-Anabasis articulata*, Group B: *Zilla spinosa-Acacia tortilis* subsp. *tortilis-Pulicaria crispa*, Group C: *Cleome droserifolia-Launaea nudicaulis*, and Group D: *Zilla spinosa-Ochradenus baccatus*.

Table 2. The distribution of the species recorded in the 4 vegetation groups resulting from cluster analysis, together with their presence values, families, growth forms (GF), and chorotypes (CT). Growth forms: T = tree, S = shrub, Ph = perennial herb, Pg = perennial grass, A = annual; chorotypes: COSM = Cosmopolitan, PAL = Palaeotropical, SA = Saharo-Arabian, SZ = Sudano-Zambezian, ME = Mediterranean, IT = Irano-Turanian. Species in **bold** are the climbing plants; figures in **bold** are the indicator and preferential species of the 4 vegetation groups. Boxes indicate that the species is recorded in only 1 group.

Species	GF	CT	Family	Vegetation Groups			
				A	B	C	D
Total number of sites				13	15	9	4
Total number of species				34	61	40	32
Species present in all groups							
Echinops spinosus L.	S	SA+IT	Compositae	23	7	11	75
Retama raetam (Forssk.) Webb. & Berthel.	S	SA+IT	Leguminosae	38	27	33	75
Zilla spinosa (L.) Prantl	S	SA	Cruciferae	31	**80**	55	**100**
Species present in 3 groups							
Anabasis articulata (Forssk.) Moq.	S	SA+IT	Chenopodiaceae	**85**	7	55	0
Citrullus colocynthis (L.) Schrad.	Ph	SA	Cucurbitaceae	38	60	44	0
Euphorbia retusa Forssk.	Ph	SA	Euphorbiaceae	15	7	33	0
Deverra tortuosa (Desf.) DC.	S	SA+SZ	Umbelliferae	77	2	0	75
Farsetia aegyptia Turra	S	SA+SZ	Cruciferae	8	27	0	5
Gymnocarpos decandrus Forssk.	S	ME+SA	Caryophyllaceae	31	13	0	75
Lycium shawii Roem. & Schult.	S	SA+SZ	Solanaceae	61	27	0	75
Rumex vesicarius L.	A	SA+IT	Polygonaceae	8	4	0	25
Achillea fragrantissima (Forssk.) Sch.Bip.	Ph	SA+IT	Compositae	0	4	33	5
Artemisia judaica L.	Ph	SA	Compositae	0	13	22	75
Cocculus pendulus (J.R.Forst. & G.Forst.) Diels	S	PAL	Menispermaceae	0	27	22	5
Ochradenus baccatus Delile	S	SA+SZ	Resedaceae	0	4	33	**100**
Trichodesma africanum (L.) R.Br.	S	SA+SZ	Boraginaceae	0	33	11	5
Zygophyllum simplex L.	A	SA+SZ	Zygophyllaceae	0	13	11	25
Species present in 2 groups							
Asphodelus ramosus L.	A	ME+SA	Liliaceae	61	7	0	0
Convolvulus arvensis L.	Ph	PAL	Convolvulaceae	23	7	0	0
Leptadenia pyrotechnica (Forssk.) Decne.	S	SA+SZ	Asclepiadaceae	8	53	0	0
Nitraria retusa (Forssk.) Asch.	S	SA+IT	Zygophyllaceae	8	33	0	0
Haloxylon salicornicum (Moq.) Bunge ex Boiss.	S	SZ	Chenopodiaceae	77	0	22	0
Peganum harmala L.	Ph	ME+IT	Zygophyllaceae	23	0	11	0
Solenostemma arghel (Delile) Hayne	S	SA+SZ	Asclepiadaceae	8	0	55	0
Aerva javanica (Burm.f.) Juss. ex Schult.	S	SA+SZ	Amaranthaceae	0	53	55	0
Aristida adscensionis L.	A	PAL	Gramineae	0	2	44	0

Table 2. (Continued).

Bassia muricata (L.) Asch.	A	SA+IT	Chenopodiaceae	0	2	33	0
Calotropis procera (Aiton) W.T.Aiton	T	SA+SZ	Asclepiadaceae	0	7	55	0
Caylusea hexagyna (Forssk.) M.L.Green	A	SA+IT	Resedaceae	0	7	44	0
Chrozophora plicata (Vahl) Spreng.	A	SA+SZ	Euphorbiaceae	0	2	55	0
Cleome droserifolia (Forssk.) Delile	S	SA+IT	Capparaceae	0	53	**67**	0
Cucumis prophetarum L.	Ph	SA+SZ	Cucurbitaceae	0	7	55	0
Erodium laciniatum (Cav.) Willd.	Ph	ME+IT	Geraniaceae	0	7	11	0
Fagonia arabica L.	S	SA	Zygophyllaceae	0	4	22	0
Forsskaolea tenacissima L.	Ph	SA+SZ	Urticaceae	0	33	44	0
Oligomeris linifolia (Hornem.) J.F.Macbr.	A	ME+SA+SZ	Resedaceae	0	2	33	0
Tephrosia purpurea (L.) Pers.	Ph	SZ+SA	Leguminosae	0	33	11	0
Tribulus terrestris L.	A	SA+SZ	Zygophyllaceae	0	7	11	0
Trigonella stellata Forssk.	A	SA+SZ	Leguminosae	0	7	44	0
Atriplex halimus L.	S	ME+SA	Chenopodiaceae	0	7	0	75
Capparis sinaica Veill.	S	SA	Capparaceae	0	7	0	75
Iphiona mucronata (Forssk.) Asch. & Schweinf.	S	SA+SZ	Compositae	0	4	0	5
Pergularia tomentosa L.	S	SZ+SA	Asclepiadaceae	0	4	0	75
Pulicaria undulata (L.) Kostel.	S	S-Z+SA-SI	Compositae	0	**73**	55	0
Zygophyllum coccineum L.	S	SA+SZ	Zygophyllaceae	0	53	0	75
Z. decumbens Delile	S	SA+SZ	Zygophyllaceae	0	13	0	25
Fagonia mollis Delile	S	SA+IT	Zygophyllaceae	0	0	55	75
Heliotropium digynum (Forssk.) C.Chr.	S	SA+IT	Boraginaceae	0	0	44	5
Launaea nudicaulis (L.) Hook.f.	Ph	SA+IT	Compositae	0	0	**67**	75
Species present in 1 group							
Anagallis arvensis L.	A	ME+IT	Primulaceae	8	0	0	0
Astragalus sieberi DC.	S	SA+IT	Leguminosae	31	0	0	0
Atriplex portulacoides L.	S	SA	Chenopodiaceae	23	0	0	0
Convolvulus lanatus Vahl	S	ME+SA	Convolvulaceae	8	0	0	0
Eremobium aegyptiacum (Spring.) Asch. & Schweinf. ex Boiss.	Ph	SA+SZ	Cruciferae	8	0	0	0
Globularia arabica Jaub. & Spach.	S	ME+IT	Globulariaceae	15	0	0	0
Halocnemum strobilaceum (Pall.) M.Bieb.	S	SA+IT	Chenopodiaceae	15	0	0	0
Limoniastrum monopetalum (L.) Boiss.	S	ME+SA+IT	Plumbaginaceae	31	0	0	0
Lygeum spartum Loefl. ex L.	Pg	SA	Gramineae	8	0	0	0
Noaea mucronata (Forssk.) Asch. & Schweinf.	S	ME+IT	Chenopodiaceae	23	0	0	0
Periploca angustifolia Labill.	S	ME	Asclepiadaceae	69	0	0	0
Salsola tetrandra Forssk.	S	SA+IT	Chenopodiaceae	15	0	0	0

Table 2. (Continued).

Suaeda pruinosa Lange	S	SA+IT	Chenopodiaceae	46	0	0	0
Thymelaea hirsuta (L.) Endl.	S	ME+SA	Thymelaeaceae	**100**	0	0	0
Zygophyllum album L.f.	S	ME+SA	Zygophyllaceae	8	0	0	0
Acacia tortilis (Forssk.) Hayne subsp. *raddiana* Savi	T	SA+SZ	Leguminosae	0	33	0	0
A. tortilis (Forssk.) Hayne subsp. *tortilis*	T	SA+SZ	Leguminosae	0	**73**	0	0
Aizoon canariense L.	A	SA+SZ	Mesembryanthemaceae	0	33	0	0
Arnebia hispidissima (Lehm.) DC.	A	SA+IT	Boraginaceae	0	33	0	0
Atriplex farinosa Forssk.	S	SA	Chenopodiaceae	0	53	0	0
Cotula cinerea Delile	A	SA	Compositae	0	6	0	0
Crotalaria aegyptiaca Benth.	S	SA+SZ	Leguminosae	0	6	0	0
Euphorbia granulata Forssk.	A	SA	Euphorbiaceae	0	47	0	0
Launaea spinosa (Forssk.) Sch.Bip. ex Kuntze	S	SA+SZ	Compositae	0	47	0	0
Morettia philaeana (Delile) DC.	Ph	SA+IT	Cruciferae	0	33	0	0
Neurada procumbens L.	A	ME+SA	Neuradaceae	0	33	0	0
Panicum turgidum Forssk.	Pg	SA+IT	Gramineae	0	6	0	0
Salvia aegyptiaca L.	S	SZ+IT	Labiatae	0	53	0	0
Schouwia purpurea (Forssk.) Schweinf.	A	SA+IT	Cruciferae	0	4	0	0
Solanum nigrum L.	A	COSM	Solanaceae	0	7	0	0
Tamarix aphylla (L.) H.Karst.	T	SA+IT	Tamaricaceae	0	7	0	0
T. nilotica (Ehrenb.) Bunge	T	SA+IT	Tamaricaceae	0	7	0	0
Taverniera aegyptiaca Boiss.	S	SA+IT	Leguminosae	0	4	0	0
Alkanna orientalis (L.) Boiss.	Ph	SA+SZ	Boraginaceae	0	0	11	0
Astragalus eremophilus Boiss.	A	SA+IT	Leguminosae	0	0	33	0
Hyoscyamus muticus L.	Ph	SA+IT	Solanaceae	0	0	55	0
Lotus arabicus L.	A	SA+SZ	Leguminosae	0	0	11	0
Reseda alba L.	A	SA	Resedaceae	0	0	11	0
Senna italica Mill.	S	SA+SZ	Leguminosae	0	0	11	0
Agathophora alopecuroides (Del.) Fenzl ex Bunge	S	SA	Chenopodiaceae	0	0	0	5
Anabasis setifera Moq.	S	SA+IT	Chenopodiaceae	0	0	0	75
Cistanche phelypaea (L.) Cout.	Ph	SA+IT	Orobanchaceae	0	0	0	25
Deverra triradiata Hochst. ex Boiss.	S	SA+SZ	Umbelliferae	0	0	0	5
Diplotaxis harra (Forssk.) Boiss.	A	SA+IT	Cruciferae	0	0	0	25
Ephedra alata Decne.	S	SA	Ephedraceae	0	0	0	5
Gypsophila capillaris (Forssk.) C.Chr.	A	SA	Caryophyllaceae	0	0	0	5
Limonium pruinosum (L.) Chaz.	S	SA	Plumbaginaceae	0	0	0	5
Scrophularia deserti Delile	Ph	SA	Scrophulariaceae	0	0	0	25

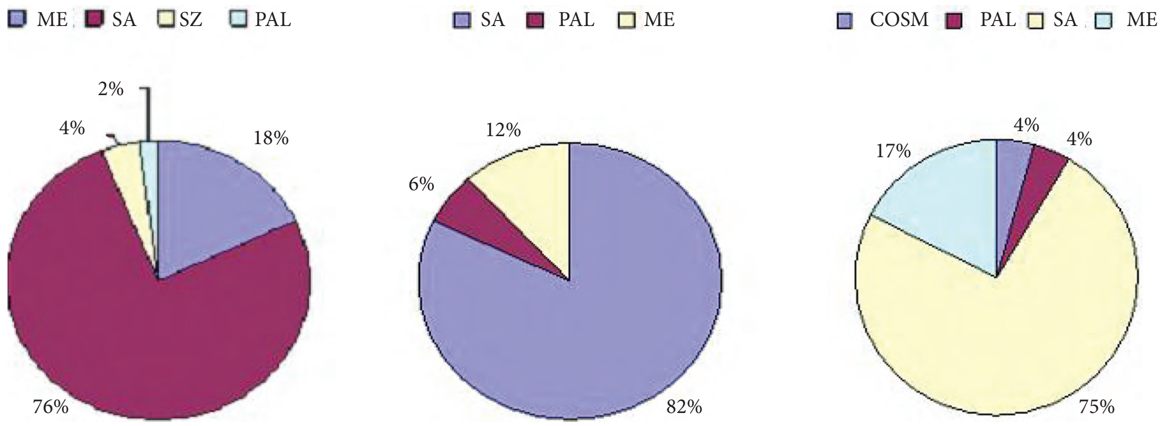

Figure 3. Distribution of the chorotypes in the major growth form categories. For chorotype abbreviations, see Table 2.

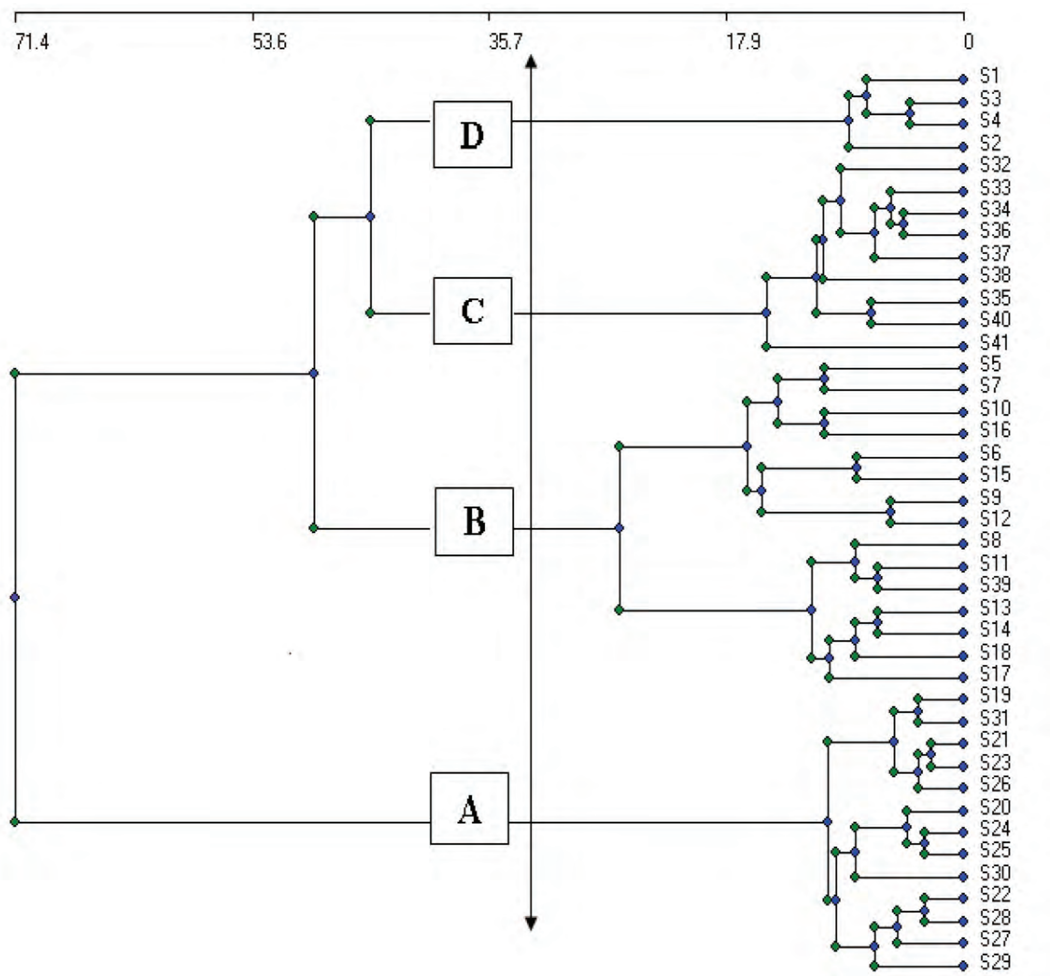

Figure 4. Dendrogram indicating the 4 vegetation groups (A-D) resulting from the cluster analysis of the 41 sampled sites.

Additionally, 3 species were determined to have a wide ecological range of distribution and occurred in the 4 identified vegetation groups: *Echinops spinosus*, *Retama raetam*, and *Zilla spinosa.*

Group A is dominated by *Thymelaea hirsuta* and *Anabasis articulata* from 13 sites in the inland western Mediterranean desert with the highest soil pH (7.9; see Table 3). This group is linked to *Periploca angustifolia.* The vegetation of this group can be further divided into 3 subgroups, each of which included *P. angustifolia*: *Periploca angustifolia-Thymelaea hirsuta*, *Periploca angustifolia-Deverra tortuosa*, and *Periploca angustifolia-Haloxylon salicornicum*. Among the common associates, *Asphodelus ramosus*, *Haloxylon salicornicum*, and *Suaeda pruinosa* occurred. In the Sallum area, Salama et al. (2005) reported a similar floristic composition to the 3 vegetation subgroups of *Periploca angustifolia*, with 12 species of common occurrence, such as *Asphodelus ramosus*, *Citrullus colocynthis*, *Haloxylon salicornicum*, and *Zilla spinosa. Periploca angustifolia* is highly grazed and conservation measures should be taken for the preservation of these populations in their natural habitat. Group A has the lowest share of annuals, with only *Asphodelus ramosus*, *Anagallis arvensis*, and *Rumex vesicarius* recorded.

Group B is characterised by *Zilla spinosa*, *Acacia tortilis* subsp. *tortilis*, and *Pulicaria undulata*, inhabiting 15 sandy gravel sites from the Mediterranean, Red Sea, and Sinai regions. The sites were found to have the highest levels of bicarbonates and the lowest salinity (Table 3), and they yielded the most diversified among the identified vegetation groups, with the highest total number of recorded species (61; 18.7 ± 6.6 species per site). *Citrullus colocynthis* is linked to this group, with a presence value of 60%. Apart from the dominant tree species, 4 other trees are found: *Calotropis procera*, *Acacia tortilis* subsp. *raddiana*, *Tamarix aphylla*, and *T. nilotica*. Common desert perennials are *Crotalaria aegyptiaca*, *Panicum turgidum*, *Aerva javanica*, *Launaea spinosa*, and *Leptadenia pyrotechnica.* Several associated species for this group have been repeatedly recorded in the wadis of the Eastern Desert (Kassas & El-Abyad, 1962; Kassas & Girgis, 1972; Abd El-Ghani, 1998; Sheded, 1998), along the Red Sea coast (Salama & Fayed, 1989), and along the western Mediterranean

Table 3. Mean values, standard errors (±SE), and ANOVA F-values of the soil variables and species richness of the 41 sites representing the 4 vegetation groups (A-D) obtained by cluster analysis. *P < 0.05, **P < 0.01.

Soil variables		**Mean**	**Vegetation groups**				**F-ratio**
			A	**B**	**C**	**D**	
pH		7.8 ± 0.3	7.9 ± 0.3	7.6 ± 0.4	7.8 ± 0.03	7.8 ± 0.3	1.16
EC	(mS cm^{-1})	1.7 ± 1.1	1.6 ± 0.6	1.4 ± 0.9	1.8 ± 1.3	5.2 ± 0.9	0.56
Gravel	(%)	4.9 ± 3.3	1.9 ± 0.7	7.6 ± 3.8	4.4 ± 1.3	5.2 ± 0.9	11.96**
Coarse sand	(%)	13.6 ± 3.4	15.3 ± 1.8	12.2 ± 3.9	15.6 ± 1.9	9.3 ± 0.6	7.64**
Silt	(%)	8.2 2.1	8.7 ± 2.1	7.8 ± 1.9	7.2 ± 2.0	10.6 ± 1.7	3.15*
Clay	(%)	6.7 ± 3.7	5.4 ± 1.2	9.2 ± 4.9	4.6 ± 2.5	6.4 ± 1.1	4.8**
Ca^{+2}	(mg 100 g^{-1})	6.5 ± 5.2	4.8 ± 3.0	9.2 ± 5.8	1.9 ± 1.2	12.1 ± 4.4	8.70**
Mg^{+2}	(mg 100 g^{-1})	2.2 ± 1.6	2.7 ± 1.7	2.2 ± 1.7	1.3 ± 0.7	3.0 ± 2.0	1.72
Na^{+}	(mg 100 g^{-1})	3.7 ± 2.2	3.2 ± 1.6	4.8 ± 2.2	1.7 ± 0.7	5.6 ± 2.5	7.26**
K^{+}	(mg 100 g^{-1})	0.9 ± 0.4	0.9 ± 0.3	1.1 ± 0.4	0.5 ± 0.3	1.3 ± 0.5	7.41**
HCO_3^{-}	(mg 100 g^{-1})	0.2 ± 1.2	2.1 ± 0.8	3.2 ± 1.3	1.3 ± 0.5	2.1 ± 0.8	7.26**
SO_4^{-2}	(mg 100 g^{-1})	3.5 ± 3.3	2.7 ± 2.5	5.0 ± 3.8	0.9 ± 0.5	6.7 ± 1.5	6.11**
Cl^{-}	(mg 100 g^{-1})	6.5 ± 4.6	4.9 ± 1.6	8.7 ± 4.0	2.0 ± 0.7	14.1 ± 5.0	18.82**
NH_4^{+}	(mg 100 g^{-1})	34.2 ± 12.6	30.5 ± 11.0	32.9 ± 10.9	35.5 ± 10.9	47.8 ± 20.4	2.21
NO_3^{-}	(mg 100 g^{-1})	27.5 ± 16.2	31.1 ± 13.4	28.4 ± 12.8	12.9 ± 6.6	45.9 ± 28.0	5.98**
Species richness		15.5 ± 5.9	10.5 ± 2.0	18.7 ± 6.6	14.0 ± 3.4	9.0 ± 2.2	9.79**

coast (Salama et al., 2005). This group had the highest share of annuals (17), of which *Euphorbia granulata*, *Arnebia hispidissima*, *Aizoon canariense*, *Neurada procumbens*, and *Zygophyllum simplex* had the highest presence values. Many land reclamation projects are continuing in the Mediterranean, Red Sea, and Sinai regions; combined with agricultural processes, farming practices, and other excessive human disturbances in the studied sites, these factors may contribute to the high share of annuals recorded. The relationship between salinity and species diversity has been documented by several authors (Danin, 1976; Ayyad & El-Ghareeb, 1982; Shaltout & El-Ghareeb, 1992; Abd El-Ghani & Amer, 2003).

Group C is dominated by *Cleome droserifolia* and *Launaea nudicaulis*, inhabiting 9 sites that are revealed to have the lowest values of many of the measured soil variables, excluding electric conductivity, gravel, coarse sand, and NH_4^+ (Table 3). This group is linked to *Cucumis prophetarum* with a presence value of 55%. A further 3 vegetation subgroups could be identified including *C. prophetarum*: *Cucumis prophetarum-Launaea nudicaulis* and *Cucumis prophetarum-Cleome droserifolia* from sites in South Sinai and *Cucumis prophetarum-Achillea fragrantissima* from the Red Sea region. As described by Zahran & Willis (1992), the community dominated by *Cleome droserifolia* in association with *Cucumis prophetarum* occupied the limestone country of the Red Sea coastal land and is indicated by the presence of *Fagonia mollis* and *Zilla spinosa.* Despite their pedological and phytogeographical differences, the floristic composition of the *Cucumis prophetarum-Cleome droserifolia* group that we recorded from Sinai seems to be similar to that described above.

Group D is dominated by *Zilla spinosa* and *Ochradenus baccatus*, inhabiting 4 sites studied in the wadis of Digla, Hoff, and Araba in the Eastern Desert; it is linked to *Pergularia tomentosa* and *Cocculus pendulus*. Apart from pH, coarse sand, clay, and bicarbonates, the soil of these studied sites is characterised by the highest values of other examined variables (Table 3) and the lowest mean species richness (9.0 ± 2.2). *Cocculus pendulus* associates can be further classified into 3 subgroups: *Cocculus pendulus-Aerva javanica*, *Cocculus pendulus-Euphorbia granulata*, and *Cocculus pendulus-Achillea fragrantissima*. *Achillea fragrantissima* and *Retama raetam* shared these groups. Springuel et al. (1997) recorded 50 species in association with *Cocculus pendulus*, 21 of which are recorded in common such as *Acacia tortilis* subsp. *tortilis*, *Aerva javanica*, *Citrullus colocynthis*, *Euphorbia granulata*, *Forsskaolea tenacissima*, *Ochradenus baccatus*, *Zilla spinosa*, and *Zygophyllum coccineum*. A similar floristic composition is also reported by Abd El-Ghani and Abd El-Khalik (2006) in Gebel Elba National Park; among these species, *Acacia tortilis* subsp. *tortilis*, *Aerva javanica*, *Citrullus colocynthis*, *Lycium shawii*, and *Salvia aegyptiaca* are reported.

Factors influencing the distribution of the 5 climbing plants

The 4 vegetation groups and their sites are differentiated along the first (eigenvalue = 0.680) and the second (eigenvalue = 0.311) axes of the detrended correspondence analysis (DCA; Figure 5). The 4 DCA axes explained 12.7%, 5.8%, 3.4%, and 2.5% of the total variation in the species data, respectively. The low percentage of variance explained by the axes is attributed to the many zero values in the vegetation data set. Group A occupied the extreme positive end of DCA axis 1, while group B occupied the negative end.

The successive decrease of the eigenvalues of the first 3 CCA axes (Table 4) suggests a well-structured data set. These eigenvalues are somewhat lower than those of the DCA axes, indicating that important explanatory site

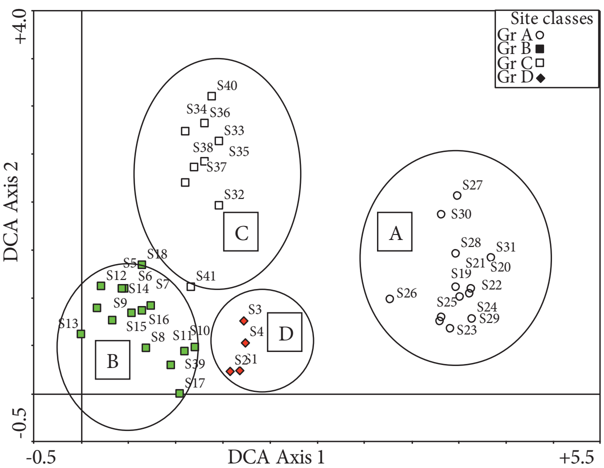

Figure 5. DCA ordination diagram of the 41 sites on axes 1 and 2 as classified by cluster analysis; A-D are the 4 vegetation groups.

variables are not measured and included in the analysis or that some of the variation could not be explained by environmental variables (Franklin & Merlin, 1992; McDonald et al., 1996).The species-environment correlations are higher for the first 3 canonical axes, however, explaining 52% of the cumulative variance. These results suggest an association between vegetation and the measured soil parameters presented in the biplot (Jongman et al., 1987).

In terms of the variation in species data, the contributions of chlorides, gravel, bicarbonates, clay, coarse sand, and NH_4^+, selected by the automatic forward selection option of environmental variables in CANOCO, are 15.0%, 12.8%, 7.5%, 6.6%, 7.5%, and 6.2%, respectively. They exhibited the most important factors that affected the distribution of the 5 studied climbing plants. A test for significance with an unrestricted Monte Carlo permutation test (99 permutations) found the F-ratio for the eigenvalue of axis 1 and the trace statistic to be significant ($P < 0.005$), indicating that the observed patterns did not arise by chance.

From the interset correlations of the soil factors with the first 3 axes of CCA (Table 4), it can be noted that CCA axis 1 is positively correlated with gravel, Na^+, SO_4^{-2}, and Cl^- and negatively correlated with coarse sand. This can be seen more clearly in the ordination triplot (Figure 6). This axis can be defined as a gravel-coarse sand gradient. It is worthwhile to note that the results of DCA demonstrated patterns very similar to those of CCA, suggesting that there might be no other important environmental variables missed in the sampling. CCA axis 2 is clearly positively correlated with SO_4^{-2}, Cl^-, and NO_3^- and negatively correlated with coarse sand. This axis can be defined as a coarse sand-Cl^- gradient. The pattern of ordination is similar to that of the floristic DCA (Figure 5), with most of the sites remaining in their respective vegetation groups.

The information shown in Figure 6 also indicates that the distribution of *Cocculus pendulus* (Cpn) can be affected by gravel, clay, bicarbonates, and Mg^{+2}, while *Pergularia tomentosa* (Pto) is affected by SO_4^{-2}, K^+, Na^+, and Cl^-. These 2 species are assigned to Group D. The distribution of *Periploca angustifolia* (Pa) in Group A is affected by soil reaction (pH), as it reached its highest value in its group. This can be attributed to its limestone substrate and proximity to the Mediterranean Sea coast. A similar conclusion was reached by Abd El-Ghani & El-Sawaf (2005) on the

Table 4. A comparison of the results of ordination for the first 3 axes of DCA and CCA. Interset correlations of the soil variables, together with eigenvalues and species-environment correlation coefficients. For units, see Table 3.

	DCA axis			CCA axis		
	1	2	3	1	2	3
Eigenvalues	0.68	0.31	0.19	0.56	0.27	0.15
Species-environment correlation coefficients	0.89	0.79	0.69	0.93	0.94	0.81
pH	0.16	0.16	-0.12	-0.16	0.08	0.17
EC	-0.37	-0.30	-0.22	0.006	0.01	0.23
Gravel	-0.62	-0.20	0.20	0.51	-0.03	0.02
Coarse sand	0.26	0.48	0.18	-0.43	-0.20	0.04
Silt	0.17	-0.30	0.15	0.07	0.11	0.08
Clay	-0.28	-0.35	-0.14	0.20	0.002	-0.09
Ca^{+2}	-0.26	-0.48	-0.25	0.27	0.24	-0.03
Mg^{+2}	0.16	-0.25	-0.12	0.14	0.06	-0.25
Na^+	-0.20	-0.56	-0.39	0.40	0.29	-0.11
K^+	-0.11	-0.44	-0.14	0.19	0.25	-0.09
HCO_3^-	-0.30	-0.38	-0.34	0.23	0.01	-0.002
SO_4^{-2}	-0.15	-0.51	-0.18	0.32	0.35	-0.07
Cl^-	-0.21	-0.630	-0.23	0.40	0.37	-0.06
NH_4^+	-0.02	-0.20	0.17	0.07	0.22	0.31
NO_3^-	0.11	-0.47	-0.20	-0.09	0.34	-0.04

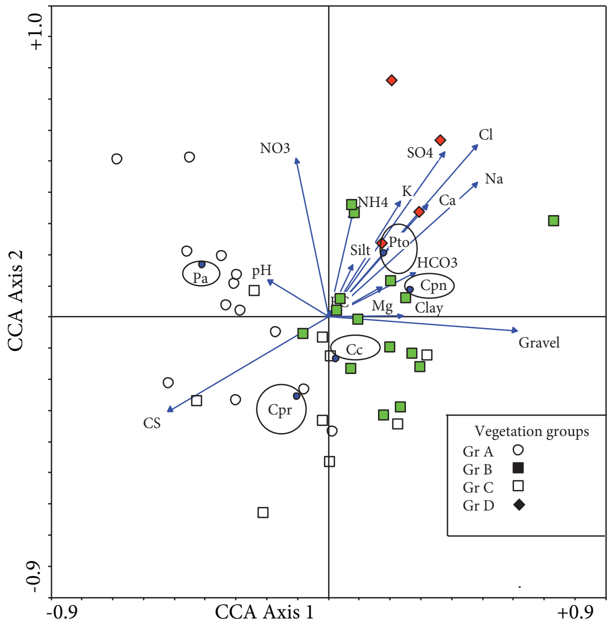

Figure 6. Canonical correspondence analysis (CCA) ordination triplot of the 5 studied climbing plants (encircled), sites, and soil variables, reflecting distributions of the 5 climbing plants along gradients of soil variables. *Cc = Citrullus colocynthis*, *Cpn = Cocculus pendulus*, *Cpr = Cucumis prophetarum*, *Pa = Periploca angustifolia*, and *Pto = Pergularia tomentosa*.

coastal vegetation along the eastern Mediterranean coast of Egypt, between El-Arish and Rafah, for the vegetation type dominated by *Panicum turgidum* and *Thymelaea hirsuta*. *Cucumis prophetarum* (Cpr) is shown to be affected by coarse sand, while *Citrullus colocynthis* (Cc), which is assigned to Group B in our study, showed a weak relation to gravel, clay, and bicarbonates. These results are also in line with those obtained from DCA and soil analysis. The role of the percentage of surface sediments of different size classes in the distribution of vegetation in the arid regions has been documented in the determination of the spatial distribution of soil moisture (Yair et al., 1980; El-Ghareeb & Shabana, 1990; Abd El-Ghani, 1998).

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Appendix. Enumerated list of climbing plants in Egypt, together with their families, growth forms, chorotypes, and habitats in the different phytogeographic regions of Egypt. Phytogeographical regions: N = Nile, M = Mediterranean, O = oases, S = Sinai, R = Red Sea, GE = Gebel Elba, De = Eastern Desert, Dw = Western Desert; growth forms: a = Annual; Ph = perennial herb, S = shrub; chorotypes: ME = Mediterranean, SA = Saharo-Arabian, SZ = Zambezian, SU = Sudanian, IT = Irano-Turanian, COSM = Cosmopolitan, PAL = Palaeotropical, PAN = Pantropical. Habitat: D = desert, AL(w) = weed of arable land. Figures are the total number of species found in each region.

Family	Species	Phytogeographical regions								Growth form	Chorotype	Habitat
		N	M	O	S	R	GE	De	Dw			
		39	36	15	34	8	37	20	4			
Asclepiadaceae	*Cynanchum acutum* L.	+	+	+	-	-	-	-	-	Ph	ME+IT	D
	Leptadenia arborea (Forssk.) Schweinf.	+	-	-	-	-	-	-	-	S	SA	D
	Oxystelma alpini Decne.	+	-	-	+	-	-	+	-	Ph	SA+SU	D
	Pentatropis nivalis (J.F.Gmel.) D.V.Field & J.R.I.Wood	-	-	-	+	+	+	+	-	S	SA+SU	D
	Pergularia daemia (Forssk.) Chiov.	-	-	-	+	+	+	-	-	Ph	SA+SZ	D
	P. tomentosa L.	-	-	-	+	-	+	+	-	S	SA+SZ	D
	Periploca angustifolia Labill.	-	+	-	-	-	-	-	-	S	ME	D
	Podostelma schimperi (Vatke) K.Schum.	-	-	-	-	-	+	-	-	S	SZ+SU	D
Capparaceae	*Cadaba farinosa* Forssk.	-	-	-	-	+	+	+	-	S	PAL	D
	Maerua oblongifolia (Forssk.) A.Rich.	-	-	-	-	-	+	-	-	S	SU	D
Convolvulaceae	*Calystegia silvatica* (Kit.) Griseb.	-	+	-	-	-	-	-	-	Ph	ME+IT	AL(w)
	Convolvulus althaeoides L.	-	+	-	+	-	-	+	-	Ph	ME	AL(w)
	C. arvensis L.	+	+	+	+	-	-	+	-	Ph	PAL	AL(w)
	C. glomeratus Choisy	-	-	-	+	-	+	+	-	Ph	SZ	AL(w)

	C. palaestinus Boiss.	-	-	-	+	-	-	-	-	Ph	ME	AL(w)
	C. scamonia L.	-	-	-	+	-	-	-	-	Ph	ME	AL(w)
	C. siculus L.	-	+	+	-	+	+	-	-	A	ME+IT	AL(w)
	C. stachydifolius Choisy	-	+	-	-	-	-	-	-	Ph	ME+IT	AL(w)
	Ipomoea cairica (L.) Sweet	+	+	-	-	-	-	-	+	Ph	PAL	AL(w)
	I. eriocarpa R.Br.	+	-	-	-	-	-	-	-	A	PAL	AL(w)
	I. hederacea Jacq.	+	-	-	-	-	-	-	-	Ph	PAL	AL(w)
	I. obscura (L.) Ker Gawl.	-	-	-	-	-	+	-	-	Ph	PAL	AL(w)
	I. purpurea (L.) Roth	+	-	-	-	-	-	-	-	A	PAL	AL(w)
	I. sinensis (Desr.) Choisy	-	-	-	-	-	+	+	-	A	SZ	AL(w)
	Jacquemontia tamnifolia (L.) Griseb.	-	-	-	-	-	+	-	-	A	PAN	AL(w)
	Merremia aegyptia (L.) Urb.	-	-	-	-	-	+	-	-	A	PAN	AL(w)
	M. semisagittata (Peter) Dandy	-	-	-	-	-	+	-	-	Ph	PAN	D
Cucurbitaceae	*Bryonia cretica* L.	-	+	-	-	-	-	-	-	Ph	ME	AL(w)
	B. syriaca Boiss.	-	-	-	+	-	-	-	-	Ph	ME	AL(w)
	Citrullus colocynthis (L.) Schrad.	+	+	+	+	+	+	+	+	Ph	ME+SA	D
	Coccinia abyssinica (Lam.) Cogn.	-	-	-	-	-	+	-	-	Ph	PAL	D
	C. grandis (L.) Voigt	-	-	-	-	-	+	-	-	Ph	PAL	D
	Corallocarpus schimperi (Naudin) Hook.f.	-	-	-	-	-	+	-	-	Ph	IT+SZ	D
	Cucumis dipsaceus Ehrenb.	-	-	-	-	-	+	-	-	A	IT	AL(w)
	C. prophetarum L.	-	-	-	+	+	+	+	-	Ph	SA+SZ	D
	C. pustulatus Hook.f.	-	-	-	-	-	+	-	-	Ph	SA	D
	Diplocyclos palmatus (L.) C.Jeffrey	-	-	-	-	-	+	-	-	Ph	PAL	D
	Kedrostis foetidissima (Jacq.) Cogn.	-	-	-	-	-	+	-	-	Ph	PAL	D
	K. gijef (J.F.Gmel.) C.Jeffrey	-	-	-	-	-	+	-	-	Ph	PAL	D
	Zehneria anomala C.Jeffrey	-	-	-	-	-	+	-	-	Ph	SU	D
Cuscutaceae	*Cuscuta approximata* Bab.	+	-	-	+	-	-	-	-	A	ME+IT	AL(w)
	C. campestris Yunck.	+	-	+	-	-	-	-	-	A	COSM	AL(w)
	C. chinensis Lam.	-	-	-	-	-	+	-	-	A	SA+SZ	AL(w)
	C. epilinum Weihe	+	-	-	-	-	-	-	-	A	ME+IT	AL(w)
	C. monogyna Vahl	+	-	-	-	-	-	-	-	A	ME+IT	AL(w)
	C. palaestina Boiss.	-	+	-	+	-	-	+	-	A	ME	AL(w)
	C. pedicellata Ledeb.	+	+	+	+	-	+	+	+	A	ME	AL(w)
	C. planiflora Ten.	+	+	-	+	+	+	+	-	A	ME	AL(w)
Ephedraceae	*Ephedra ciliata* Fischer & C.A.Mey.	-	-	-	+	-	+	+	-	S	PAL	D
	E. foemina Forssk.	-	-	-	+	-	-	-	-	S	PAL	D
Labiatae	*Prasium majus* L.	-	+	-	-	-	-	-	-	S	ME	D
Leguminosae	*Clitoria ternatea* L.	+	-	-	-	-	-	-	-	Ph	PAL	AL(w)
	Lathyrus annuus L.	+	-	-	+	-	-	-	-	A	ME	AL(w)
	L. aphaca L.	+	+	+	+	-	-	-	-	A	ME+IT	AL(w)
	L. gorgoni Parl.	+	+	-	+	-	-	-	-	A	ME	AL(w)

	L. hirsutus L.	+	+	+	-	-	-	-	-	A	ME	AL(w)
	L. marmoratus Boiss. & Blanche	+	+	-	+	-	-	-	-	A	ME	AL(w)
	L. sativus L.	+	+	+	-	-	-	-	-	A	ME	AL(w)
	L. setifolius L.	-	+	-	-	-	-	-	-	A	ME	AL(w)
	L. sphaericus Retz.	+	-	-	-	-	-	-	+	A	ME+IT	AL(w)
	Pisum fulvum Sm.	-	-	-	+	-	-	-	-	A	ME	AL(w)
	P. sativum L.	+	+	+	-	-	-	-	-	A	ME+IT	AL(w)
	Rhynchosia malacophylla (Spreng.) Bojer	-	-	-	-	-	+	-	-	Ph	SZ	AL(w)
	R. minima (L.) DC.	-	-	-	+	-	+	-	-	Ph	SA	AL(w)
	Vicia articulata Hornem	+	+	-	-	-	-	-	-	A	ME	AL(w)
	V. ervilia (L.) Willd.	-	+	-	-	-	-	-	-	A	ME	AL(w)
	V. hirsuta (L.) Gray	-	-	-	-	-	-	+	-	A	ME	AL(w)
	V. hybrida L.	+	+	-	-	-	-	-	-	A	IT	AL(w)
	V. lutea L.	+	+	+	-	-	-	-	-	A	ME+IT	AL(w)
	V. monantha Retz.	+	+	+	+	-	-	-	-	A	ME+IT	AL(w)
	V. narbonensis L.	+	+	+	+	-	-	+	-	A	IT	AL(w)
	V. palaestina Boiss.	-	+	-	+	-	-	-	-	A	ME	AL(w)
	V. parviflora Cav.	+	+	-	-	-	-	-	-	A	ME	AL(w)
	V. peregrina L.	-	+	-	+	-	-	-	-	A	ME+IT	AL(w)
	V. sativa L.	+	+	-	-	-	-	-	-	A	ME+IT	AL(w)
	V. tetrasperma (L.) Schreb.	+	+	-	-	-	-	-	-	A	ME+IT	AL(w)
	V. villosa Roth	-	+	-	-	-	-	-	-	A	ME	AL(w)
	Vigna luteola (Jacq.) Benth.	+	-	-	-	-	-	-	-	A	SZ	AL(w)
	V. membranacea A.Rich.	-	-	-	-	-	+	-	-	A	SU	AL(w)
	V. unguiculata (L.) Walp.	+	-	-	-	-	-	-	-	A	SZ	AL(w)
Loranthaceae	*Plicosepalus acaciae* (Zucc.) Wiens & Polhill	-	-	-	+	-	+	-	-	S	SA	D
	P. curviflorus (Benth. ex Oliv.) Tiegh.	-	-	-	-	+	+	+	-	S	SA	D
Menispermaceae	*Cocculus pendulus* (J.R.Forst & G.Forst.) Diels	+	-	-	+	-	+	+	-	S	PAL	D
Oleaceae	*Jasminum fluminense* Vell.	-	-	-	-	-	+	-	-	S	ME+IT	D
	J. grandiflorum L.	-	+	-	-	-	-	-	-	S	ME+IT	D
Polygonaceae	*Fallopia convolvulus* (L.) A.Love	+	+	-	-	-	-	-	-	A	ME	AL(w)
Rubiaceae	*Galium aparine* L.	-	-	-	+	-	-	+	-	A	SA	AL(w)
	G. ceratopodum Boiss.	-	-	-	+	-	-	-	-	A	SA	AL(w)
	G. tricornutum Dandy	+	+	+	+	-	-	+	-	A	SA	AL(w)
	Rubia tenuifolia d'Urv.	-	-	-	+	-	-	-	-	Ph	ME	AL(w)
Spindaceae	*Cardiospermum halicacabum* L.	+	-	+	-	-	-	-	-	A	PAL	AL(w)
Vitidaceae	*Cayratia ibuensis* (Hook.f.) Suess.	+	-	-	-	-	+	-	-	S	SU	D
	Cissus quadrangularis L.	-	-	-	-	-	+	-	-	S	IT+SU	D