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ARTICLE

Floristic analysis and biogeography of Tubiflorae in Egypt

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ABSTRACT The species distribution and biogeography of the Egyptian Tubiflorae were examined in detail. We found 284 species of vascular plants belonging to 96 genera and 12 families, making the Egyptian Tubiflorae richer in species than that of other arid region floras: Libya and Saudi Arabia. The most species rich families were Scrophulariaceae, Boraginaceae, Labiatae, Convolvulaceae and Solanaceae, constituting more than 85% of the total species in the order. The generic spectrum dominated by a suite of species-rich genera *(Convolvulus, Heliotropium, Veronica, Solanum, Salvia, Cuscuta, Echium, Ipomoea* and *Orobanche)*. Therophytes were the most dominant life forms among the families, followed by chamaephytes and hemicryptophytes. Boraginaceae and Scrophulariaceae had the highest share of annuals. Remarkable distribution patterns of the life forms in the seven studied biogeographic zones were noticed. Trees were dominant in the Mediterranean zone, while shrubs, perennial herbs and therophytes were dominant in the Sinai. Altogether 8 endemic species and 14 near-endemics were included in the Tubiflorae of Egypt; mostly from southern Sinai. We found that Labiatae and Scrophulariaceae were the families with higher concentration of endemics. Notably, *Teucrium* was among the genera of the Mediterranean Africa with highest endemism. Gamma diversity varied from 171 in the Sinai Peninsula to 43 and 39 in the Oases of the western Desert and along the Red Sea, respectively. Interestingly, highest significant values of similarity and species turnover (beta diversity) were observed between the Oases and the Nile lands. It is worthy noting the combined effect of both temperature and precipitation on gamma diversity of Tubiflorae in the 7 biogeographic zones. Our results indicated that almost one-half of the species showed a certain degree of consistency, *i.e.,* with narrow geographic expansion. On the basis of UPGMA clustering and PCoA analysis, 4 floristic groups were recognized, each include one or more biogeographic zone. The occurrence of the species of Tubiflorae in the adjacent regional arid floras and their phytochorological affinities, were discussed.
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KEY WORDS

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Tubiflorae is by far the largest order of the Egyptian vascular flora. Generally, Engler and Diels (1936) recognised the order Tubiflorae to be composed of 8 suborders and 23 families of the flowering plants. On the other hand, Hutchinson (1959) organized the families in 5 orders: Verbenales, Solanales, Personales, Boraginales and Lamiales. In Egypt, it is represented by 5 suborders (Convolvulineae, Boragineae, Verbenineae, Solanineae, and Acanthineae), 96 genera, 12 families (Convolvulaceae, Boraginaceae, Verbenaceae, Avicenniaceae, Labiatae, Solanaceae, Scrophulariaceae, Orobanchaceae, Globulariaceae, Acanthaceae, Pedaliaceae, and Lentibulariaceae) and 284 species comprising 13.7% of the total flora. It is a group of great importance, not only for its species diversity, but also for the capacity of their species to colonize a great variety of environments, wide range of life forms, habitats and distribution patterns (Tàckholm 1974; Boulos 2000, 2002). Interestingly, one third of its total number of species was considered endangered and vulnerable (El Hadidi 1979). However, Boulos (1989) enumerated 14 desert plant species belonging to Boraginaceae, Convolvulaceae, Labiatae, Orobanchaceae and Solanaceae of promising economic potentialities. It also includes shrubs that present clear adaptation syndromes to the arid and semi-arid environs (e.g. pubescence and spinescence), which have given them a great diversification not only in Egypt, but also in the entire Middle East and Mediterranean North Africa. Furthermore, the order constitutes a model system for the study of arid biogeographical patterns, and could generate useful information for the conservation of certain vegetation enclaves inside the country and the whole region as well. In fact, the Convention on International Trade in Endangered Species of wild Fauna and Flora (CITES 1990) includes most of the families of Tubiflorae in its Appendix 2 and a considerable number of its species are listed in Appendix 1.

Biological diversity, or biodiversity, refers to the variety of distinct ecosystems or habitats, the number and variety of species within them, and the range of genetic diversity within the populations of these species. Two attributes of biodiversity have attracted particular attention from the

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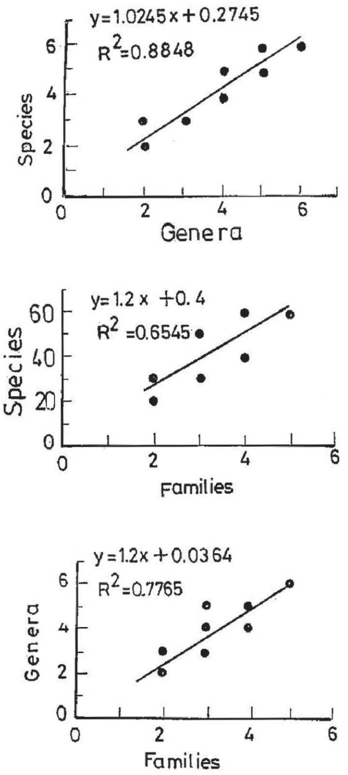

Figure 1. Relationships between taxic richness of Egyptian Tubiflorae at different levels.

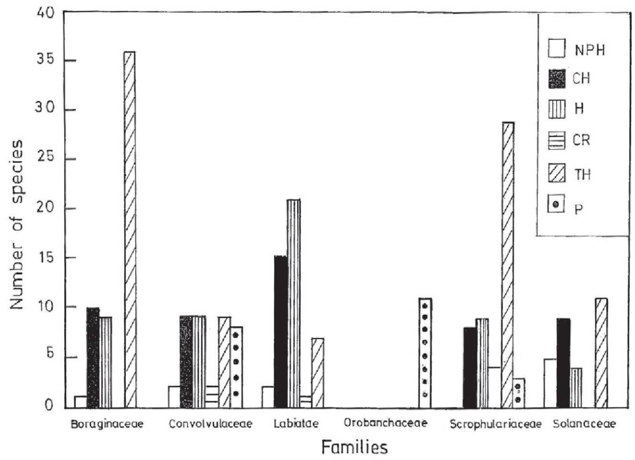

Figure 2. Life form spectrum within the species-rich families of Tubiflorae.

international conservation community: gamma diversity (the total number of species in an area), and endemism (the number of species in that area that occur nowhere else). Because these two attributes reflect the complexity, uniqueness and intactness of natural ecosystems, they are believed to indicate overall patterns of biodiversity in a useful manner. Phylogenetic diversity is in part a function of the size of a flora, and partly of the pattern of distribution of the species into higher taxa (Fenner et al. 1997). Recently the pattern of species distribution among higher taxa has been shown to be an effective indicator of phylogenetic diversity (Williams and Humphries 1994).

The biogeography of the flora of Egypt is still poorly documented, and with few notable exceptions (El Hadidi et al. 1996; Abd El-Ghani and El-Sawaf 2004), there has been little attempt to analyze the biogeographical implications of most species distribution patterns. Khedr et al. (2002) reported that the flora of Egypt contains many families and genera relative to the number of species (120 families, 742 genera, 2088 species) and a relatively large number of oligotypic families, each represented by only one or a few species. They suggested that a flora, in which the species are distributed among numerous genera or families, or other higher-order ranks, should contain greater phylogenetic diversity and genomic information than one in which the same number of species is concentrated into fewer higher-order taxa. The high fraction (97%) of native species in the Egyptian flora may reflect fewer opportunities to acquire more species per genus or per family, due to fewer successful biotic invasions as well as lower speciation rates.

Despite the fact that some families of Egyptian Tubiflorae have been taxonomically revised (Boulos 2000, 2002), our basic knowledge on the diversity and biogeography of this order is still fragmentary and far from complete. This paper attempts to analyse and interpret the diversity in relation to relative family and genus sizes, spatial distribution patterns and phytogeography of the members of Tubiflorae particularly in Egypt, compared to another North African arid country (Libya), and Saudi Arabia as well. It also stresses the need to combine taxonomic, floristic, life form differentiations and biogeographical parameters to understand the relationship between plant habit and the speciation propensity of the Tubiflorae.

Materials and Methods

The provisional account presented here was based on the authors' own data from field work carried out during several years (1999-2005) in all seasons from different parts of Egypt; especially those from the Oases of the western Desert, Sinai and Gebel Elba. In addition, an inventory of all available herbarium collections from Egypt was compiled, and taxonomic determinations were revisited. The plant materials assembled by MM Abd El-Ghani and S El-Naggar during their field work in western Saudi Arabia for the former and Gebel Akhdar of Libya for the latter were also used. Specimens were examined from the herbarium of Cairo University (CAI), the herbarium of the Agriculture Museum (CAIM) and the Herbarium of Assiut University (AST). Taxonomic revisions for some families and genera of Egyptian Tubiflorae were

Table **1.** A summary of systematic diversity of the families of Tubiflorae in Egypt. S/G= species per genera.

Family	Number of species (S)	% of species	Number of genera (G)	S/G
Scrophulariaceae	60	21.1	17	3.5
Boraginaceae	58	20.4	19	3.0
Labiatae	54	19	22	2.8
Convolvulaceae	46	16.2	10	4.6
Solanaceae	31	11	8	3.8
Orobanchaceae	11	3.9	2	5.5
Verbenaceae	8	2.8	6	1.3
Acanthaceae	8	2.8	6	1.3
Pedaliaceae	3	1.1	3	1
Lentibulariaceae	2	0.7	1	2
Avicenniaceae	1	0.3	1	1
Globulariaceae	2	0.7	1	2
Total	284	100	96	3.0

also consulted (El-Husseini 1986; El-Husseini and Zareh 1989; Hepper 1998; El Hadidi et al. 1999). Nomenclature and species distribution was based mainly on Tåckholm (1974), Boulos (2000, 2002) for Egypt, Collenette (1985), Chaudhary and Al-Jowaid (1999) for Saudi Arabia, and Jafri and El-Gadi (1977-1984) for Libya. The system of phyogeographical territories of Egypt that proposed by El Hadidi (2000) was adopted in this study. Each territory will be here referred to as "biogeographic zone". Thus seven major biogeographic zones were included in this study: the Mediterranean (M), the Nile region (N), the Eastern Desert (De), Sinai Peninsula (S), the Red Sea coastal land (R), Gebel Elba (Ge) and the Oases of the Western Desert (O).

The biogeographical analysis was done down to species level. A species list that formed the base of the analysis was prepared using the authors' plant collections and held notes, all relevant references and floras of Egypt and adjacent countries. Two levels of biogeographic analysis were considered: genera and species. For the analysis, the number of species each genus possesses weighted the importance of genera. For each species, the following attributes were also recorded: life span (annual or perennial), and life-form categories were identified according to Raunkiaer's system of classification (Raunkiaer 1937). When several life forms were given for a species, the most representative species was chosen. The phytogeographical affinity of each taxon was also included. The latter information was determined largely from sources such as Wickens (1976), Zohary (1972) and Feinbrun-Dothan (1978). When these resources for a single taxon gave more than one phytogeographical element, the most appropriate was chosen.

Based on the presence-absence matrix of the 284 species in the seven major bigeographic zones of Egypt, a cluster analysis was performed using the agglomerative algorithm UPGMA that included in the Multivariate Statistical Package MVSP for Windows, version 3.1 (Kovach 1999). The obtained groups were represented in a dendrogram. A Principal Coordinate Analysis (PCoA) was preferred using the product-moment correlation as a coefficient. We preferred PCoA than a PCA (Principal Components Analysis) because the former performs better on data sets with missing data (Rohlf 1972). Gamma diversity was calculated as the total number of species in each biogeographic zone. Species turnover (beta diversity) was calculated using I-Jaccard's index of similarity since it provides a way to measure species turnover between different areas (Whittaker I960; Magurran 1998). The calculation of the index has been designed to equal 1 in case of complete similarity. Fifty percent turnover of species composition, termed half change, has been used as the unit of beta diversity. All the statistical analyses were carried out using SPSS for Windows version 10.0.

Results and Discussion

Taxonomic composition

The Egyptian flora falls into the category of a widespread mid-continental flora having low mean genus size and a very low level of endemism (Fenner et al. 1997). It has a low level of speciation and a high level of monotypism, with very few genera having more than 30 species. The continuous nature of geographic distribution of habitats and relative lack of reproductive isolation are perhaps the most important factors influencing the rate of speciation in this country. However, Kedr et al. (2002) found that the number of species per family in Egypt was higher in cosmopolitan families and families whose dominant mode of dispersal is abiotic and which possess a herbaceous growth habit. Yet, the actual family speciation rate *(i.e.,* the number of varieties per species) did not differ among the traits. Our results proved that the species diversity was unevenly distributed among taxonomic groups (Table 1). The family size in the Egyptian Tubiflorae was relatively high: 5 dominant cosmopolitan families (Scrophulariaceae, Boraginaceae, Labiatae, Convolvulaceae and Solanaceae) had more than 30 species comprising 87.7% (249 species of the total species in the order) and 6 families had less than 10 species each (table 1). There were a suite of species-rich genera, but the majority (50) of the 96 genera was represented by a single species. The most species-rich genera were *Convolvulus* (23), *Heliotropium* (17), *Veronica* (13), *Solanum* (11), *Salvia* (9), *Cuscuta* and *Echium* (8 each) and *Ipomoea* and *Orobanche* (7 each). Altogether, they constitute 36.3% of the total number of the order (284), while monospecific genera (40) accounted for 14.1%.

The overall lower ratio of species/genus (3.0) for the whole order may explain its higher diversity. Interestingly, lower ratios of S/G (1-2) were estimated in Lentibulariaceae, Globulariaceae, Verbenaceae, Acanthaceae, Pedaliaceae and Avicenniaceae indicated higher diversity among families. The

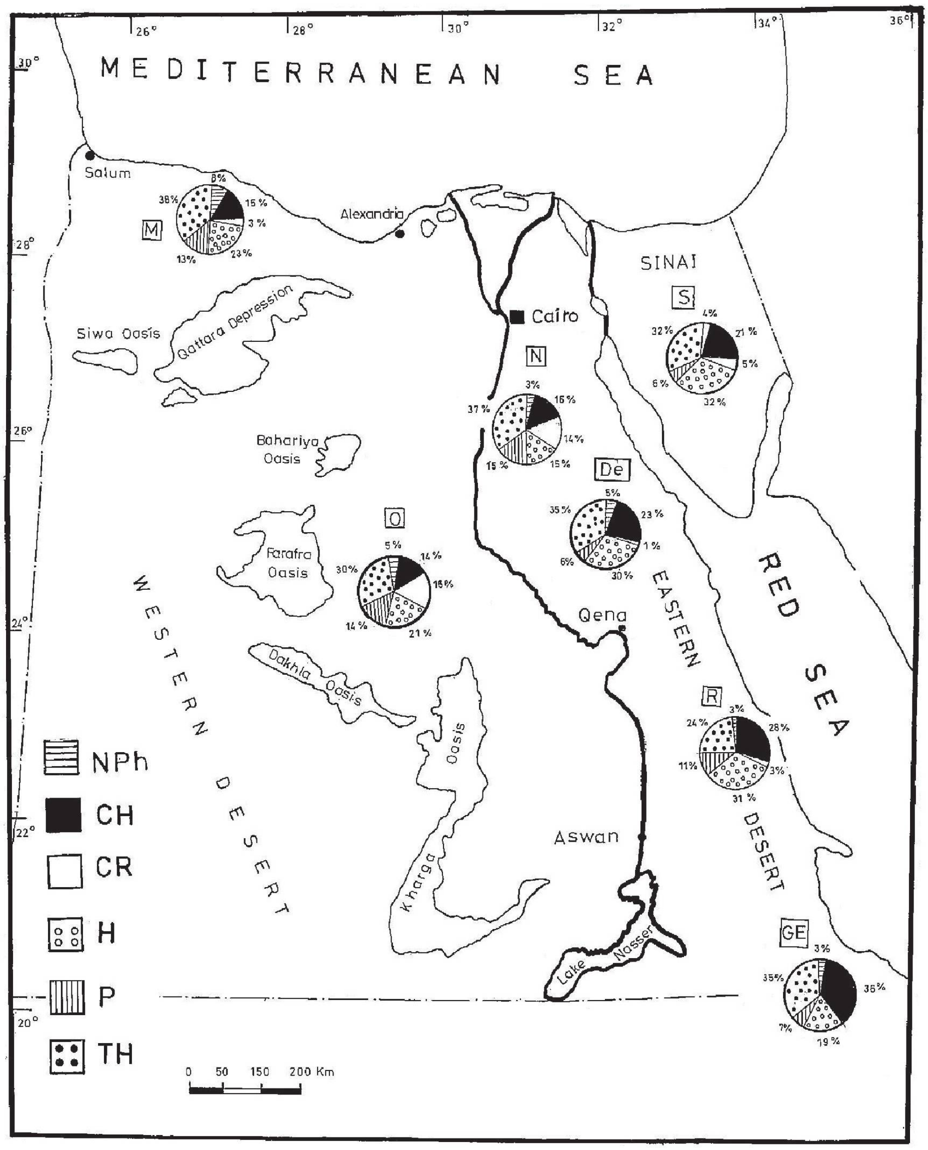

Figure 3. Distribution of life forms in different biogeographic zones of Egypt. For abbreviations, see text.

relationships among taxonomic ranks of species, largest genera and the species-rich families with respect to their gamma diversity along with htted regression equations (models) were shown in Figure 1. There was signihcantly positive correlation ($p<0.005$) between species, genera and family level. Thus, the higher taxonomic units such as genera or the families may be employed as surrogates for predicting species diversity of the Egyptian Tubiflorae.

Life-strategies of species

The life form spectrum within the families of the order showed the dominance of therophytes (annuals), followed by chamaephytes and hemicryptophytes (Fig. 2). Non-succulent trees, parasites and perennial herbs (terrestrial or aquatic) were all represented by few species, compared to other categories. The overall comparison of frequencies for the different categories of life forms showed signihcant variation among families ($p<0.001$). Boraginaceae and Scrophulariaceae had the highest share of annuals. The uncontested leader for shrubs and shrublets was Labiatae, whereas Orobachaceae was strictly for parasites. Notably, Convolvulaceae was the only family in which all life form categories were represented. It is to be mentioned here that, most genera of the Egyptian Tubiflorae had a single characteristic life form. However, some genera exhibited diversity. *Convolvulus* had several different growth forms, particularly annual erect herbs, dwarf shrubs and

Table 2. Endemic and near-endemic species in the species-rich families of Tubiflorae of Egypt, Libya and Saudi Arabia. += present.

Taxa	Endemics			Near-Endemics		
	Libya	Egypt	Saudi Arabia	Libya	Egypt	Saudi Arabia
Boraginaceae						
Heliotropium longiflorum (A.DC.) Höchst et St. ex Bunge						+
Nonea viviani A.DC.				+	+	
Onosma cyrenaica Durand & Barratte	+					
Convolvulaceae						
Convolvulus maireanus Pamp.	+					
C. shimperi Boiss.					+	+
C. spicatus Hallier.f.					+	
Labiatae						
Ballota andrenzziana Pamp.	+					
Marrubium deserti Noe ex Coss.				+		
Micromeria guichardii (Quézel & Zaffran) Brullo & Furnari	+					
M. serbaliana Danin & Hedge		+				
Nepeta cyrenaica Quézel & Zaffran						
N. septemcrenata Benth.					+	+
N. vivianii (Coss.) Bég. &Vacc.	+					
Origanum cyrenaicum Bég. & Vacc.	+					
O. isthmicum Danin		+				
O. syriacum L. subsp. *sinaicum* (Boiss.) Greuter & Bürdet		+				
Phiomis aurea Decan.		+				
Stachys tournefortii Poiret				+		
Teucrium apollinis Maire & Weiller	+					
T. barbeyanum Ascher. & Taubert	+					
T. davaeanum Cosson	+					
T. lini-vaccarii Pamp.	+					
T.zazonii Pamp.	+					
T. decussatus Benth.					+ +	
Orobanchaceae						
Orobanche cyrenaica Beck	+					
Scrophulariaceae						
Anarrhinum forsskalü (J.E. Gmel.) Cufod. subsp. *pubescens* (Fresen.) D.A. Sutton		+				
Kickxia floribunda (Boiss.) Täckh. & Boulos					+	+
K. macilenta (Decne.) Dänin					+	
K. pseudoscoparia V.W. Smith & D.A. Sutton					+	+
Linariajoppensis Bornm.					+	
Parentucellia floribunda Viv.	+					
Verbascum fruticulosum Post					+	+
V. letourneuxii Asch.				+ +		
V. schimperianum Boiss.					+	+
Verónica anagallis-aquatica L. var. *nilotica* R. Uechtr.					+	
V. kaiseriV. Täckh.		+				
V. musa V. Täckh. & Hadidi		+				
Solanaceae						
Hyoscyamus boveanus (Dunall) Asch. & Schweinf.		+				
Solanum sinaicum Boiss.					+	

shrublets, and twiners or climbers. *Heliotropium* had both annuals and shrubs, while *Nicotiana* was represented by two species, one a tree and the other an erect annual herb. The wide range of tolerance of the members of this order enabled the genera to occupy wide range of habitats. For example, *Limosella* and *Bacopa* (Scrophulariaceae) were subaquatic in water courses, *Stachys* and *'Thymus* (Labiatae) an indicator of stony ground (Girgis 1972), *Lamium, Convolvulus*, *Mentha, Veronica* and *Datura* were alien weeds of the agro-ecosystem, *Trichodesma, Salvia, Hyoscyamus, Scrophularia, Lavandula* and *Lycium* were dominants of the Egyptian desert ecosystem. Though few in number, parasitic genera were of special interest. Beside *Orobanche* and *Cistanche* (Orobanchaceae), *Cuscuta* (Convolvulaceae), *Striga* (Scrophulariaceae) were encountered in this study.

The distribution of the life-form categories within the seven biogeographic zones was demonstrated in Figure 3. The composition of life forms reflects the response of vegetation to variations in certain environmental factors. In this study, preponderance of therophytes, chamaephytes and hemicryptophytes over other life forms is a response to the hot dry climate, topographic variations and human and animal interference (Abd El-Ghani 1998; Abd El-Ghani and Amer 2003; Salama et al. 2003). The abundance of cryptophytes along the

Table 3. Gamma diversity of the families of Tubiflorae recorded in the studied biogeographic zones of Egypt, with their total numbers and percentages (see text for biogeographic zones abbreviations).

Family	Biogeographiczone						
	N	M	O	S	R	GE	De
Scrophulariaceae	18	13	9	36	10	12	13
Boraginaceae	27	28	7	39	9	13	19
Labiatae	3	15	3	42	4	8	17
Convolvulaceae	17	17	11	22	5	19	12
Solanaceae	15	10	7	21	4	8	13
Orobanchaceae	6	10	2	6	3	2	4
Verbenaceae	4	3	3	2	1	3	0
Acanthaceae	0	0	0	1	1	8	2
Pedaliaceae	0	0	0	0	0	2	1
Lentibulariaceae	1	0	1	0	0	0	0
Avicenniaceae	0	0	0	1	1	1	0
Globulariaceae	0	2	0	1	1	0	1
Total number of species	91	98	43	171	39	76	82
% of the total	32	34.5	15.1	60.2	13.7	26.7	28.9

Table4. Sorensen coefficients of floristic similarity (lower half), and the beta diversity (upper half) between the 7 studied biogeographic zones of Egypt. * = p<0.05, ** = p< 0.01.

Biogeograpnic zones	N	M	O	S	GE	De	R
N		0.5	0.6	0.4	0.2	0.4	0.1
M	0.3		0.3	0.5	0.1	0.3	0.2
O	0.4**	0.2		0.2	0.2	0.2	0.1
S	0.2	0.3	0.1		0.2	0.5	0.2
GE	0.1	0.07	0.1	0.2		0.3	0.4
De	0.2	0.2	0.1	[illegible]*	0.2		0.3
R	0.1	0.02	0.04	0.2*	[illegible]*	[illegible]*	
Gamma diversity	91	98	43	171	76	82	39

Table 5. Annual means of climatic data of representative meteorological stations in each ofthe studied biogeographic zone (after Zahran & Willis, 1992; Abd El-Ghani, 1998 &2000). Max= Maximum, Min= Minimum.

Biogeographiczone	Temperature (°C)		Rain- fall (mm year -')	Rela- tive Hu- midity (%)
	Max	Min		
The Mediterranean				
Sallum	24	14	90	65
Mersa Matruh	24	14	144	66
Alexandria	25	16	192	68
El-Arish	26	12	180	70
The Nile land				
Menofiya	28	14	3	65
Faiyum	29	14	11	51
Luxor	33	16	<1	35
Oases of the Western Desert				
Siwa	30	13	10	41
Bahariya	30	14	4	39
Kharga	32	16	<1	31
Sinai proper (south Sinai)				
Saint Catherine	25	5	45	38
Red Sea coastal lands				
Suez	31	17	16	53
Hurghada	28	19	4	46
Quseir	28	19	3	50

Nile banks may be related to their rhizomatous growth habit, which was believed to be more resistant to decomposition under water submergence. This detected distribution pattern conforms to previous studies at this zone, especially those of Shaltout and Sharaf El-Din (1988). It is of interest to note that the trees of Tubiflorae grow well in the Mediterranean zone, while shrubs, perennial herbs and therophytes occurred in Sinai. High percentages of therophytes and hemicryptophytes were coincides with the floristic characters of the arid zones in the Mediterranean Basin, and in general for the floras of arid and semi-arid zones (Bomkamm and Kehl 1985; Pignatti and Pignatti 1989).

Endemism

Studies have focused predominantly on determining patterns of endemism at global and regional scales (Major 1988; Cowling 1983). Endemics are usually rare and restricted to rather small geographical region, so they deserve special attention for their conservation. No endemic families are known from the Middle East and North Africa (Boulos 1997). Zohary (1973) suggested that the source of this poverty is doubtless in the huge stretches of open and almost plantless desert that provide no isolating barrier against connection with adjacent countries, themselves part of the extremely barren Sahara. The major families with highest endemic species in the tropical areas are Asclepiadaceae, Acanthaceae, Liliaceae *(sensu lato)* and Euphorbiaceae, whereas Labiatae, Compositae, Scrophulariaceae and Cruciferae in temperate areas. Endemic taxa to Egypt are very few: 61 species or 2.9% of the total flora. However, 60.7% of the endemics are known from Sinai (Boulos 1995; Ayyad et al. 2000). Highest endemics within families of the Egyptian vascular flora are in Labiatae, followed by Liliaceae and Scrophulariaceae constituting 10.9, 10.4 and 6.5% of the total flora, respectively.

It has been estimated that 8 endemic and 14 near endemic species were included in the taxa of the Egyptian Tubiflorae. This study showed also that the majority of the endemic species in Tubiflorae of Egypt was recorded from southern Sinai (Sinai proper *sensu* El Hadidi 2000) in the rugged mountainous areas that support the highest peaks in Egypt (Zohary 1973; Moustafa and Klopatek 1995). Labiatae (4 species) and Scrophulariaceae (3 species) were the families of higher concentration of endemics. *Teucrium* and *Veronica* were the

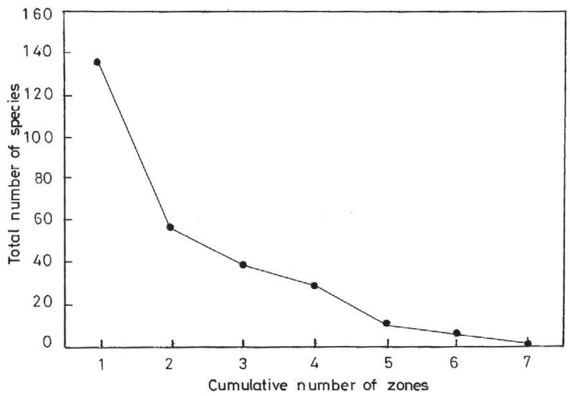

Figure 4. Species distribution in the biogeographic zones (cumulative numbers).

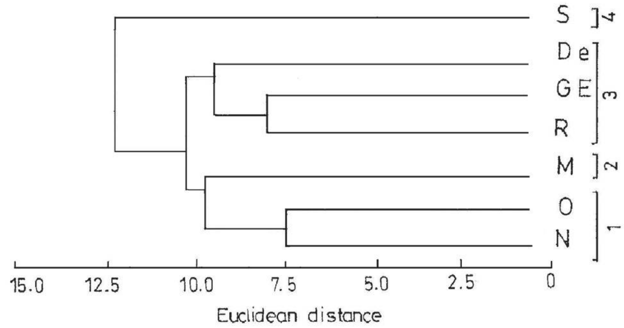

Figure 5. Dendrogram of similarity among the analysed biogeographic zones.

endemic-rich genera. Similarly, Libya and Saudi Arabia have most of their endemics in the mountainous regions: Gebel Akhdar in the former (Boulos 1975), and the highlands of southwestern Saudi Arabia of the latter (Chaudhary 1999-2001). Both are considered among the endemic-rich areas for vascular plants in the region of the Middle East (Boulos 1997).

Comparing the level of endemism among the species of Tubiflorae in the regional floras of Egypt, Libya and Saudi Arabia, we found that the endemic species *(sensu lato)* were not very numerous and can be currently estimated at 39 taxa (Table 2). The highest number of endemics was recorded in Libya (13 or 7.5% of the total flora), followed by Egypt (8 or 11.0% of the total flora), but none in the flora of Saudi Arabia. At the generic level, six genera were totally, or almost, restricted to Libya *(Onosma, Convolvulus, Ballota, Teucrium, Parentucellia* and *Orobanche),* three to Egypt *(Phlomis, Anarrhinum* and *Hyoscyamus).* It can here be noted that *Teucrium* is among genera of the Mediterranean Africa with highest endemism. It is represented by 67 species of which 44 or 65.7% are endemic (Greuter et al. 1986). Despite the importance of the endemic species in their regional floras, these species have been poorly studied. More research is required on the management requirements of the endemic taxa in the Middle East and Mediterranean North Africa.

Variations in beta and gamma diversities

Gamma diversity differed considerably among the studies biogeographic zones of Egypt (Table 3). Sinai Peninsula was the richest in species (171), while the lowest number of species was found in the Oases of the Western Desert and along the Red Sea coastal lands (43 and 39, respectively). Interestingly, highest significant values of Sprensen's coefficient of floristic similarities (0.4,p=0.01) and species turnover (0.6) were noticed between the Oases and the Nile land (Table 4). Clearly, the floristic composition of these two zones was closely related and characterised by the occurrence of many species in common. Fakhry (1973, 1974) reported the existence of an old relation between the two biogeographic zones. All travellers and government officials used an important ancient caravan route linking the Oases with the Nile Valley (near Minya on the Nile) until 1968 for the oases' commerce. The low gamma diversity and species turnover of the Gebel Elba may be related to the fact that most of its species were highly specific to the prevailing environmental conditions and geographic situation. This means that the species replacement or biotic change is low in this area (Wilson and Shmida 1984). Through the combined effect of climate (temperature and rainfall) and human activities (grazing, building new settlements and establishment of summer resorts) along the coasts of the Mediterranean and the Red Sea substantially altered the vegetation structure and the floristic composition of these biogeographic zones to include new habitats that were not found earlier (Ayyad and Fakhry 1996), with reduced gamma and beta-diversities.

Climatic zonation is probably the most important factor influencing plant distribution, particularly summer heat, winter cold and precipitation (Zahran and Willis 1990). On the other hand, as minimal precipitation and frequent droughts characterize arid zones, availability of water may be one of the primary factors controlling the distribution of species (Yair and Danin 1980; Abd El-Ghani 2000). Table 5 gives some climatic characteristics of selected meteorological stations to represent each of the studied biogeoraphic zones. The most striking climatic feature is the precipitation gradient. Temperatures below zero can be reached in the more continental parts of the Western Desert, and soil surface frost is a regular phenomenon in the mid-winter months. The gamma diversity gradient was decreased from Sinai Peninsula where a less arid climate prevails, to the Oases and the Red Sea coastal lands where more arid climate prevails. It is worthy noting the combined effect of temperature and precipitation on the gamma diversity of Tubiflorae in the seven studied

Table 6. Distribution patterns of species of the Egyptian Tubiflorae confined to a certain biogeographic zone. For zone abbreviations, see text. += recorded.

Species	Biogeographic zone						
	N	M	O	S	R	GE	De
Ipomoea carnea Jacq.	+						
I. eriocarpa R.Br.	+						
Dichondra micrantha Urb.	+						
Cuscuta monogyna Vahl	+						
C. epilinum Weihe	+						
Heliotropium curassavicum L.	+						
H. amplexicaule Vahl	+						
Clerodendrum acerbianum (Vis.) Benth. & Hook.f.	+						
Physalis angulata L.	+						
Salpichroa origanifolia (Lam.) Baill.	+						
Nicotiana plumbaginifolia Viv.	+						
Sutera glandulosa Roth	+						
Limosella aquatica L.	+						
Striga hermonthica (Delile) Benth.	+						
5. *asiatica* (L.) Kuntze	+						
Parentucellia viscosa (L.) Caruel	+						
Lindernia parvifiora (Roxb.) Haines	+						
Utricularia inflexa Forssk.	+						
Convolvulus lineatus L.		+					
C. stachydifolius Choisy		+					
C. humilis Jacq.		+					
Calystegia silvática (Kit.) Griseb.		+					
Heliotropium hirsutissimum Grauer		+					
Buglossoidesincrassata (Guss.) I.M. Johnst.		+					
Nonea melanocarpa Boiss.		+					
Echium plantagineum L.		+					
E. sabulicola Pomel		+					
E. glomeratum Poir.		+					
Thymus capitatus (L.) Link		+					
Prasium majus L.		+					
Teucrium brevifolium Schreb.		+					
Linaria micrantha (Cav.) Hoffmanns. & Link		+					
Scrophularia canina L.		+					
Verónica pérsica Poir.		+					
V. syriaca Roem. & Schult.		+					
V. anagalloides Guss.subsp. *taeckholmiorum* Chrtek & Osb.-Kos.		+					
Globularia alypum L.		+					
Orobanche lavandulacea Rchb.		+					
O. schschultzü Mutei		+					
Cistanche violácea (Desf.) Beck		+					
Striga gesnerioides (Willd.) Vatke			+				
Utricularia gibba L.			+				
Convolvulusspicatus Hallier f.				+			
C. schimperi Boiss.				+			
C. scammonia L.				+			
C. palaestinus Boiss.				+			
Heliotropium bovei Boiss.				+			
H. makallense 0. Schwartz				+			
Paracaryum rugulosum (DC.) Boiss.				+			
P. bungei (Boiss.) Brand				+			
P. calathicarpum (Stocks) Boiss.				+			
Lappula sinaica (DC.) Asch. & Schweinf.				+			
Asperugo procumbens L.				+			
Alkanna orientalis (L.) Boiss.				+			
A. strigosa Boiss. & Hohen.				+			
Nonea ventricosa (Sm.) Griseb.				+			
Mentha spicata L.				+			
Origanum syriacum L. subsp. *sinaicum* (Boiss.) Greuter & Bürdet				+			

Table 6. Continued

Species	N	M	0	S	R	GE	De
				Biogeographic zone			
O. isthmicum Dänin				+			
Thymus decussatus Benth.				+			
Satureja serbaliana (Dänin & Hedge) Greuter & Bürdet				+			
5. *myrtifolia* (Boiss. & Hohen.) Greuter & Bürdet				+			
Ziziphora capitata L.				+			
Z. tenuior L.				+			
Salvia multicaulis Vahl				+			
5. *dominica* L.				+			
S. sclarea L.				+			
Nepeta septemcrenata Benth.				+			
Stachysnivea Labill.				+			
Ballota saxatilis C. Presl				+			
B. kaiseri Täckh.				+			
Phiomis aurea Decne.				+			
Eremostachys laciniata (L.) Bunge				+			
Ajuga chamaepitys (L.) Schreb. subsp. tridactylites (Benth.) P.H. Davis				+			
Solanum sinaicum Boiss.				+			
5. *villosum* (L.) Mili.				+			
Nicotiana rustica L.				+			
Hyoscyamus reticulatus L.				+			
Verbascum fruticulosum Post				+			
V. schimperianum Boiss.				+			
V. sinaiticum Benth.				+			
V. eremobium Murb.				+			
V. decaisneanum Kuntze				+			
Anarrhinumpubescens Fresen.				+			
Linariajoppensis Bornm.				+			
*L. sinsimpiex*Desf.				+			
Kickxia macilenta (Decne.)Danin				+			
K. scariosepala Täckh. & Boulos				+			
Scrophularia libanotica Boiss.				+			
Verónica kaiseri Täckh.				+			
V macropoda Boiss.				+			
V. biloba Schreb.				+			
V. campylopoda Boiss.				+			
V. rubrifolia Boiss.subsp. *respectatissima* M.A. Fisch.				+			
Cistanche salsa (C.A. Mey.) Beck				+			
Kickxia nubica (Skan) Dandy					+		
Convolvulus rhyniospermus Choisy						+	
Jacquemontia tamnifolia (L.) Griseb.						+	
Merremia aegyptia (L.) Urb.						+	
M. semisagitata (Peter) Dandy						+	
Ipomoea obscura (L.) Ker Gawl.						+	
Evolvulus alsinoides (L.) L.						+	
E. nummularius (L.) L.						+	
Seddera arabica (Forssk.) Choisy						+	
Cuscuta chinensis Lam.						+	
Heliotropium zeylanicum (Burm. f.) Lam.						+	
H. strigosum Willd.						+	
Brandella erythraea (Brand) R.R. Mili						+	
Lantana viburnoides (Forssk.) Vahl						+	
L. rugosa Thunb.						+	
Priva cordifolia (L.) Greene						+	
Plectranthus hadiensis (Forssk.)Spreng.						+	
Orthosiphon pallidus Royle ex Benth.						+	
Satureja biflora (D. Don) Briq.						+	
Leucas neuflizeana Courbai						+	
L urticifolia (Vahl) R. Br.						+	
Solanum aethiopicum L.						+	

Table 6. Continued

Species	Biogeographic zone						
	N	M	O	S	R	GE	De
5. *carense* Dunal						+	
5. *forsskaolii* Kotschy exDunal						+	
Kickxia hastata (R. Br. ex Benth.) Dandy						+	
Scrophularia arguta Sol.						+	
Schweinfurthia pedicellata (T. Anderson) Balf. F.						+	
Barleria hochstetteri Nees						+	
Ruellia patula Jacq.						+	
Ecbolium viride (Forssk.) Alston						+	
Justicia heterocarpa T. Anderson						+	
J. schimperi (Höchst.) Dandy						+	
Peristrophepaniculata (Forssk.) Brummitt						+	
Pedalium murex L.						+	
Rogeria adenophylla J. Gay ex Delile						+	
Ipomoea pes-caprae (L.) R. Br.							+
Podonosma galalensis Schweinf. ex Boiss.							+
Lavandula atriplicifolia Benth.							+
L. multifida L.							+
Sesamum alatum Thonn.							+
Cressa crética L.	+	+	+	+	+	+	
Cuscuta planiflora Ten.	+	+	+	+	+	+	
Hyoscyamus muticus L.	+	+	+	+	+	+	
Orobanche ramosa L.	+	+	+	+	+	+	
Trichodesma africanum (L.) var. *africanum*	+	+	+	+	+	+	+
Solanum nigrum L.	+	+	+	+	+	+	+

biogeographic zones. When the correlation analyses were performed independently for each of temperature and rainfall at each zone with gamma diversity, the results showed weak correlations (Spearman rank correlation coefficient r= 0.175, p=0.43 for the former and r=0.23,p=0.27 for the latter). Yet, gamma diversity showed high signihcant positive correlations with both temperature and rainfall in Sinai (r=0.39,p=0.01), but neither in the Mediterranean zone (r=0.17,p= 0.50) nor in the Oases *(r*= 0.67, r=0.01). Therefore, colder temperature and relatively high precipitation rate may play a major role in decreasing gamma diversity. The relationship between the climate and species distribution has long been studied in other parts of the world; amongst others, Freitag (1986) in Iran and Afghanistan, Rahman and Wilcok (1991) in south-west Asia and the Indian subcontinent, Cowling et al. (1994) in arid and semi-arid southern Africa, and Gómez-Gonzáles et al. (2004) in the Iberian Peninsula and Balearic Islands.

Geographical expansion and distribution pattern

Our results demonstrated a very strong geographical pattern in the distribution of the Egyptian species of Tubiflorae. There were few highly-frequent species and very many that were infrequent. The majority of species were narrowly distributed. Almost one-half (48%) of the species showed a certain degree of consistency, where they exclusively recorded in or conhned to a single biogeographic zone and do not penetrate elsewhere (Table 6). These species were distributed as follows: 18 in the Nile land (e.g., *Ipomoea carnea, Heliotropium amplexicaule, Limosella aquatica, Striga hermonthica* and *Utricularia inflexa),* 22 in the Mediterranean (e.g., *Echium plantagineum, Thymus capitatus, Veronica persica, Globularia olypum* and *Cistanche violacea),* 2 in the Oases *(Striga gesnerioides* and *Utricularia gibba),* 54 in the Sinai Peninsula (e.g., *Paracaryum calathicarpum, Alkanna orientalis, Thymus decussatus, Nepeta septemcrenata, Solanum sinaicum, Verbascum schimperianum, Kickxia macilenta* and *Veronica kaiseri),* one in the Red Sea *(Kickxia nubica),* 34 in the Gebel Elba (e.g., *Seddera arabica, Heliotropium zeylanicum, Lantana rugosa, Leucas urticifolia, Barleria hochstetteri* and *Peristrophe paniculata)* and 5 in the Eastern Desert (e.g., *Ipomoeapes-carpae, Podonosma galalensis, and Lavandula multifida).* Only 2 species *(Trichodesma africanum* and *Solanum nigrum)* of the 284 species; that have wide ecological and sociological range of distribution; occur at all the 7 studied biogeographic zones, yet 29 species (about 10% of the total) had a frequency more than 50% *(i.e.,* recorded in *4* zones; see Fig. 4).

Figure 5 shows the dendrogram obtained with the UPGMA clustering species according to their geographical similarity. Four floristic groups (1-4) of Tubiflorae can be detected for Egypt. Results of the Principal Coordinate Analysis (PCoA) support this classification (Fig. 6). Floristic

Table 7. Occurrence of species (excluding endemics) within the major six families of the Tubiflorae in Egypt, Libya and Saudi Arabia. += recorded. Chorotype abbreviations: ES= Euro-Siberian, M= Mediterranean, IT=Irano-Turanian, SA=Saharo-Arabian, SZ= Sudano-Zambezian, COSM= Cosmopolita, Nat= Naturalized, PAL= Palaeotropical, PAN= Pantropical. Sources: 1 = S. El-Naggar; unpublished data, 2= M. Abd El-Ghani; unpublished data.

Taxa	Libya[1]	Egypt	Saudi Arabia[2]	Chorotype
Borago officinalis L.	+			M
Cynoglossum cheirifolium L.	+			M
Echium arenarium Guss.	+			M
E. humile Desf.	+			M
E. italicum L.	+			M
E. parviflorum Moench	+			M
E. tuberculatum Hoffmanns & Link	+			M
Elizaldia calycina (Roem. & Schultes) Maire	+			M
Nonea micrantha Boiss. & Reuter	+			M
N. vesicaria (L.) Reichenb.	+			M
‹C. supinus Cosson & Kralik	+			M
‹C. tricolor L.	+			M
Ballota hirsute Benth.	+			M
Micomeria Juliana (L.) Reichenb.	+			M
Nepeta scordotis L.	+			M
Phlomis floccosa D. Don	+			M
Teucrium campanulatum L.	+			M
Thymus algeriensis Boiss. & Reut.	+			M
Anarrhinum fruticosum Desf.	+			M
Antirrhinum siculum Mill.	+			M
Bellardla trlxago (L.) All.	+			M
L. laxiflora Desf.	+			M
Parentucellia latifolia (L.) Caruel	+			M
Verbascum balli (Batt.) Qaiser	+			M
W blatteria Boiss.	+			M
W tripolitanum Boiss.	+			M
W cymbalaria Bod.	+			M
Neatostema apulum (L.) I.M. Johns.	+			M + SA
Cuscuta epithymum (L.) Murray	+			M + SA
C. europaea L.	+			M + SA
Mentha aquatica L.	+			M + SA
Veronica hederifolia L.	+			M + SA
Convolvulus cantabaricus L.	+			M + IT
Sideritis curvidens Stapf	+			M + IT
Scrophularia peregrina L.	+			M + IT
Linaria arvensis (L.) Desf.	+			M + ES
Veronica agrestis L.	+			M + ES
Sideritis romana L.	+			IT + Libya
Veronica peregrine L.	+			ES (Nat.)
Ipomoea cairica (L.) Sweet		+		PAL
Ipomoea eriocarpa R. Br.		+		PAL
Ipomoea purpurea (L.) Roth.		+		PAL
Jacquemontia tamnifolia Choisy		+		PAL
Lindernia parviflora (Roxb.) Haines		+		PAL
Ipomoea carnea Jacq.		+		PAN
Ipomoea obscura (L.) Ker Gawl.		+		PAN
Marremeia aegyptiaca (L.) Urb.		+		PAN
Solanum elaeagnifolium Cav.		+		PAN
Ballota damascene Boiss.		+		M
Micromeria sinaica Benth.		+		M
Salvia dominica L.		+		M
Veronica scardica Griseb.		+		M
Podonosma galalensis Schweinf. & Boiss.		+		SA
Convolvulus hystrix Vahl		+		SA
Verbascum eremobium Murb.		+		SA
Veronica rubrifolia Boiss. subsp. *respectatissima* M.A. Fisch.		+		SA
Nogalia drepanophylla (Baker) Verde.		+		SZ

Table 7. Continued

Taxa	Libya[1]	Egypt	Saudi Arabia[2]	Chorotype
Evolvulus nummularis (L.) L.		+		**SZ**
Kickxia nubica (Skan) Dandy		+		**SZ**
Paracaryum calathicarpum (Stacks) Boiss.		+		IT
Convolvulus palaestinus Boiss.		+		IT
Kickxia gracilis (Benth.) D.A. Sutton		+		IT
Echium glomeratum Poiret		+		M + SA
Alkanna strigosa Boiss. & Hohen.		+		M + IT
A. orientalis (L.) Boiss.		+		M + IT
Heliotropium bovei Boiss.		+		M + IT
H. rotundifolium Lehm.		+		M + IT
Nonea melanocarpa Boiss.		+		M + IT
Convolvulus scammonia L.		+		M + IT
Convolvulus stachydifolius Choisy		+		M + IT
Cuscuta monogyna Vahl		+		M + IT
Cuscuta palaestina Boiss.		+		M + IT
Ballota saxatilis C. Presl		+		M + IT
Eremostachys laciniata (L.) Bunge		+		M + IT
Salvia multicaulis Vahl		+		M + IT
Salvia palaestina Benth.		+		M + IT
Salvia sclarea L.		+		M + IT
Hyoscyamus reticulatus L.		+		M + IT
Nonea ventricosa (Sm.) Griseb.		+		M + ES
Kickxia elatine (L.) Dumort.		+		M + ES
Veronica catenata Pennell		+		M + ES
Lappula sinaica (A.DC.) Asch. & Scweinf.		+		SA+ IT
Clstanche salsa (C.A. Mey.) C. Beck		+		SA+ IT
Anticharislinearis(Benth.) Höchst. &Asch.		+		SA+ IT
Veronica campylopoda Boiss.		+		SA+ IT
Striga asiatica (L.) Kuntze		+		SA + SZ
Paracaryum intermedium (Fresen.) Lipsky		+		M + SA+IT
Cuscuta approximate Bab.		+		M + SA+IT
Scrophularia sinaica Benth.		+		M + SA+IT
Calystegia silvática (Kit.) Griseb.		+		M + IT+ES
Cuscuta epilinum Weihe		+		M + IT+ES
Ziziphora capitata L.		+		M + IT+ES
Ziziphora tenuior L.		+		SA+IT+ ES
Dicandra micrantha Urb.		+		Nat.
Ipomoea hederacea Jacq.		+		Nat.
Ipomoea pes-caprea (L.) R. Br.		+		Nat.
Nicotiana plumbaginifolia Viv.		+		Nat.
Nicotiana rustica L.		+		Nat.
Physalis angulata L.		+		Nat.
Physalisixocarpa Hornem.		+		Nat.
Cordia abyssinica R.Br.			+	**SZ**
Ocimum hadinese Forssk.			+	**SZ**
Cressa crética L.	+	+	+	COSM
Convolvulus arvensis L.	+	+	+	COSM
Lamium amplexicaule L.	+	+	+	COSM
Mentha pulegium L.	+	+	+	COSM
Teucrium polium L.	+	+	+	COSM
Datura sramonium L.	+	+	+	COSM
Solanum schimperianum Höchst. & A. Rich	+	+	+	COSM
Ajuva iva (L.) Schreber	+	+	+	M
Salvia verbenaca L.	+	+	+	M
Arnebia tinctoria Forssk.	+	+	+	SA
Echium longifolium Delile	+	+	+	SA
Ogastema pusillum (Bonett & Barratte) Brummitt	+	+	+	SA
Convolvulus prostrates Forssk.	+	+	+	SA
Teucrium decaisne C. Presl	+	+	+	SA
Misopates orontium (L.) Rafin.	+	+	+	SA

Table 7. Continued

Taxa	Libya[1]	Egypt	Saudi Arabia[2]	Chorotype
Scrophularia canina L.	+	+	+	SA
Scrophularia hypericifolia Wydl.	+	+	+	SA
Scrophularia libanotica Boiss.	+	+	+	SA
Echiochilon fruticosum Desf.	+	+	+	M + SA
Echium horridum Batt.	+	+	+	M + SA
Echium rauwolfii Delile	+	+	+	M + SA
Trichodesma africanum (L.) R. Br.	+	+	+	M + SA
Heliotropium hirsutissimum Grauer	+	+	+	M + SA
Linaria albifrons (Sm.) Spreng.	+	+	+	M + SA
Linaria haelava (Forssk.) F. Dietr.	+	+	+	M + SA
Linaria simples Desf.	+	+	+	M + SA
Linaria tenuis (Viv.) Spreng.	+	+	+	M + SA
Kickxia aegyptiaca Nabělek	+	+	+	M + SA
Scrophularia arguta Sol.	+	+	+	M + SA
Cistanchephelypaea (L.) Cout.	+	+	+	M + SA
Orobanche cernua Loefl.	+	+	+	M + SA
Hyoscyamus albus L.	+	+	+	M + SA
Lycium europaeum L.	+	+	+	M + SA
Anarrhium forsskahlii (J.E. Gmel.) Cufod. subsp. *forsskahli*	+	+	+	M + SZ
Moltkiopsisciliata (Forssk.) I.M. Johns.	+	+	+	M + IT
Convolvulus siculus L.	+	+	+	M + IT
Mentha longifolia (L.) Huds. subsp *typhoides* (Briq) Harley	+	+	+	M + IT
Salvia lanígera Poiret	+	+	+	M + IT
Cistanche tubulosa (Schenk) Wight	+	+	+	M + IT
Orobanche mutelii F.W. Schultz	+	+	+	M + IT
Verónica polita Fr.	+	+	+	M + IT
Heliotropium ovalifolium Forssk.	+	+	+	SA + SZ
Salvia aegyptiaca L.	+	+	+	SA + SZ
Kickxia acerbiana (Boiss.) Täckh.& Boulos	+	+	+	SA + SZ
Lycium shawii Roem. & Shult.	+	+	+	SA + SZ
Heliotropium lasiocarpum Fisch. & C.A. Mey.	+	+	+	SA+ IT
Heliotropium ramosissimum (Lehm.) Sieb, ex A. DC.	+	+	+	SA+ IT
Convolvulus fatmensis Kunze	+	+	+	SA+ IT
Verbascum sinuatum L.	+	+	+	SA+ IT
Hyoscyamus muticus L.	+	+	+	SA+ IT
Heliotropium bacciferum Forssk. var. *bacciferum*	+	+	+	M + SA + SZ
Heliotropium supinum L.	+	+	+	M + SA + SZ
Anchusa aegyptiaca (L.) A. DC.	+	+	+	M + SA+IT
Anchusa hispida Forssk.	+	+	+	M + SA+IT
Arnebia linearifolia A. DC.	+	+	+	M + SA+IT
Cuscuta planiflora Ten.	+	+	+	M + SA+IT
Verónica pérsica Poir.	+	+	+	M + SA+IT
Withania somnífera (L.) Dunal	+	+	+	M + SA+IT
Orobanche ramosa L.	+	+	+	M + SA+ES
Asperugo procumbens L.	+	+	+	M + IT+ES
Marrubium vulgare L.	+	+	+	M + IT+ES
Datura innoxia Mili.	+	+	+	Nat.
Total number of species	152	260	141	

group (1) includes the species of Tubiflorae in both the Nile lands and the Oases, as these two regions were closely related either commercially or through the introduction of field crops. Consequently, several common alien weed species of arable lands may grow in both agro-ecosystems. This is consistent with the findings of Abd El-Ghani and El-Sawaf (2004) in their account on the diversity and distribution of plant species in the agro-ecosystems of Egypt, who reported a clear segregation of the species composition in both the Nile lands and the Oases biogeographic zones than the others.

Floristic group (2) characterizes the Mediterranean region, in which 34.5% of the species of Tubiflorae were recorded. Certain families showed higher presence in this zone, e.g., Orobanchaceae and Globulariaceae. Despite its long shores on the Mediterranean Sea, the gamma diversity of Tubiflorae ranked second. The primary cause of the decline of biodiver-

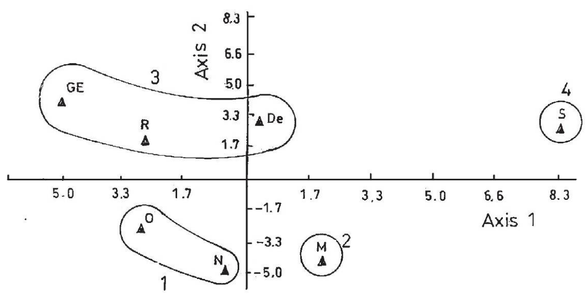

Figure 6. Scatterplot of the studied biogeographic zones against the first principal coordinate by the second principal coordinate.

sity is not direct human exploitation or malevolence, but the habitat destruction that inevitably results from the expansion of human populations and human activities (Wilson 1988). It is to be mentioned here that the western Mediterranean coastal strip has been subjected to ecosystem degradation and species impoverishment due to the way in which man has used and misused the natural resources of the zone. A variety of human-induced stresses have already taken their toll on ecosystems. With so much habitats being lost, the populations of many species were being dramatically reduced. The continued uncontrolled wood-cutting, overgrazing and rain-fed farming for cultivation of annual crops have dominated the Mediterranean zone for centuries. More recent land use activities have been even more devastating, e.g., intensive irrigated agriculture, obliteration of limestone ridges for bricks making which is endangering many chasmophytic species, and the occupation of large areas of the coastal sand dunes by summer resorts is endangering many psammophytic species. Ayyad and Fakhry (1996) overviewed the plant biodiversity in the western Mediterranean desert of Egypt in terms of habitat, community and species diversity. They concluded that the nature of human impact on biodiversity may be either sudden and/or radical (e.g., establishment of new settlements, and summer resorts) or may be gradual (e.g., grazing of wild vegetation). Generally, loss of species is the ultimate result.

The third floristic group (Group 3) includes three closely related biogeographic zones; the Eastern Desert, the Gebel Elba and the Red Sea coastal lands. It is noteworthy, but not surprising, that these three zone form one entity, and can be known as the "Eastern Desert complex" group. Forty-nine species of the order were distributed among this complex, and manifests either very narrowly or widely distributed species (Table 6). *Podonosma galalensis, Sesamum alatum, Satureja biflora* and *Leucas neufliziana* were recorded in the three zones. Geographical areas containing high gamma diversity, a high level of endemism, and/or harbouring a high number of rare or threatened species have been dehned as biodiversity hotspots, and have been considered to set priorities for conservation planning (Myers 1990; Reid 1998). In spite of the interesting biogeographical and botanical features of the Gebel Elba mountain range, it has been overlooked in most global biodiversity assessments (Heywood and Watson 1995). Of the 142 woody perennial threatened plant species that are included in the Plant Red Data Book of Egypt (El Hadidi et al. 1992), 56 or 39.4% were known from the Gebel Elba district. Endangered and rare species include *Seddera arabica* (Forssk.) Choisy (Convolvulaceae); *Cordia sinensis* Lam. (Boraginaceae); *Lantana viburnoides* (Forssk.) Vahl (Verbenaceae) and *Solanum albicaule* Ky. ex Dun (Solanaceae). Its ecological features, together with its particular geographic position, seem to have promoted plant diversity, singularity and endemism in this biogeographic zone. It comprises elements of the Sahelian regional transition zone (*sensu* White and Léonard 1991) and represents the northern limit of this geoelement in Africa. The phytogeographical analysis of some arboreal species in Egypt revealed that the Red Sea coast represents the main pathway for the penetration of the arboreal species to Egypt together with the southern border of both Western and Eastern Deserts (Hassan and Abd El-Ghani 1992).

The Sinai group (Group 4) represents the most diversihed and species-rich zone in the Egyptian Tubiflorae. The natural conditions and geographical position of the Sinai Peninsula make it a very distinctive region. The Sinai Desert is a desert of the 'Saharan type' (McGinnies et al. 1968) linking Asia with Africa, and constitutes a transition between the Egyptian Deserts and those of the Middle East. The great diversity of climate (mean annual precipitation decreases from about 100 mm in the north, near the Mediterranean, to 5-30 mm in the south; Danin 1978), rock and soil types make the existence of some 900 species and 200-300 associations possible (Danin 1986). Besides, it is an interesting phytogeographic area as it borders the Mediterranean, Irano-Turanian, Sahara-Arabian and Sudanian regions (Zohary 1973). Recent studies on plant diversity in southern Sinai (Moustafa and Klopatek 1995; Moustafa et al. 2001) reported that many species were now under threat due to the severe human impacts such as over-cutting for fuel, over-collection, overgrazing, tourism activities and urbanization. High contribution of these species was from Labiatae, Compositae and Gramineae. It is to be also noted that the threatened endemic species of St. Catherine area (southern Sinai) were either facing grazing stresses due to their high palatability for domestic animals (e.g.,*Anarrhinumpubescens, Veronica islensis* and *V. kaiseri)* or were used frequently in the folk medicine and gradually reduced its coverage and number (e.g., *Nepeta septemcrenata* and *Ballota kaiseri).*

Distribution of the Tubiflorae in adjacent countries

The highlands of western Saudi Arabia and Gebel Akhdar at the north-eastern part of Libya are among the major species-rich and endemic-rich areas in the Middle East region (Boulos 1997). Distribution of the species within the major six families (Boraginaceae, Convolvulaceae, Labiatae, Orobanchaceae, Scrophulariaceae and Solanaceae) of the Tubiflorae in Egypt, Gebel Akhdar (Libya) and western Saudi Arabia, together with their chorology was demonstrated in Table 7. The total number of species varied from 260 in Egypt to 152 in Libya and 141 in Saudi Arabia. Interestingly, Boraginaceae, Labiatae and Scrophulariaceae were the species-rich families, while Orobanchaceae was the poorest. Thirty-nine species were confined to Libya, 61 to Egypt and 2 to Saudi Arabia. Prevalence of the Mediterranean geoelement in the Libyan Tubiflorae was noticeable, where 73 species representing different Mediterranean chorotypes (mono, bi- and pluriregional) were recognised. The pure Mediterranean geoelement was best represented in Libya (29), and decreasing eastwards in Egypt (6) and Saudi Arabia (2). In general, a remarkable decrease in the number of Mediterranean taxa was recorded in the west-east direction: 65 in Egypt and 38 in Saudi Arabia. Although the fact that the presence of a Mediterranean territory in Egypt was well documented since Engler (1882), several authors (Zohary 1973; Boulos 1975; Ayyad and Ghabbour 1986) stressed the absence of such territory due to the lack of any arboreal Mediterranean species in Egypt. The annual rainfall *(c* 200 mm) can hardly support the growth of such species characteristic to the Mediterranean biome. Wickens (1977) reported that there was ample evidence to suggest that the apparent increase in the desert conditions since the Roman time is due to activities of Man. The Saharo-Arabian geoelement, in the contrary, attained its highest number of species in Egypt (28), decreased in Libya and Saudi Arabia (18 for both). Recently, Salama et al. (2003) reviewed the chorological analysis of the Sallum area (at the Egyptian-Libyan border) on the western Mediterranean coast of Egypt. They concluded that despite its occurrence within the Mediterranean phytogeographic territory of Egypt, yet the monoregional Saharo-Arabian chorotype overrode the pure Mediterranean. This may be attributed to the fact that plants of the Saharo-Arabian geoelement are good indicators for harsh desert environmental conditions, while Mediterranean species stand for more mesic conditions.

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