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A numerical taxonomic study of the family Zygophyllaceae from Egypt

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RESUMO

(Um estudo de taxonomia numérica da família Zygophyllaceae do Egito). Um estudo sistemático de 29 táxons pertencentes a sete gêneros das subfamílias Balanitoideae, Zygophylloideae, Peganoideae, Tribuloideae, Seetzenioideae eTetradiclidoideae das Zygophyllaceae do Egito foi realizado por meio de análise numérica, baseada em 61 caracteres morfológicos, incluindo partes vegetativas, grãos de pólen e sementes. Com base no agrupamento UPGMA e análise PCO, seis grupos principais são reconhecidos. Representantes destes grupos são agrupados com base em características com cargas fatoriais elevadas na análise PCO. Os resultados indicam que as Zygophyllaceae são um grupo heterogêneo, incluindo *Peganum harmala* que foi proposto para fazer parte de uma família separada. Zygophylloideae, Tribuloideae, Tetradiclidoideae e Seetzenioideae são os grupos mais homogêneos. Seções e grupos em ambos os gêneros *Tribulus* e *Fagonia* parecem ser artificiais.

Palavras-chave: Zygophyllaceae, Balanitoideae, Zygophylloideae, Peganoideae, Tribuloideae, Seetzenioideae, Tetradiclidoideae, Taxonomia numérica, UPGMA , PCO

ABSTRACT

(A numerical taxonomic study of the family Zygophyllaceae from Egypt). A systematic study of 29 taxa belonging to 7 genera of subfamilies Balanitoideae, Zygophylloideae, Peganoideae, Tribuloideae, Seetzenioideae and Tetradiclidoideae of Zygophyllaceae from Egypt was carried out by means of numerical analysis based on sixty-one morphological characters, including vegetative parts, pollen grains and seeds. On the basis of UPGMA clustering and PCO analysis, six main groups are recognized. Representatives of these groups are clustered together based on characters with high factor loadings in the PCO analysis. The results indicate that Zygophyllaceae are heterogeneous, including *Peganum harmala* which has been proposed to belong in a separate family. Zygophylloideae, Tribuloideae, Tetradiclidoideae and Seetzenioideae are the most homogeneous groups. Sections and groups in both *Tribulus* and *Fagonia* seem artificial.

Key words: Zygophyllaceae, Balanitoideae, Zygophylloideae, Peganoideae, Tribuloideae, Seetzenioideae, Tetradiclidoideae, Numerical taxonomy, UPGMA cluster, PCO

Introduction

Zygophyllaceae is a widespread family of some 27 genera and 285 species subdivided into five subfamilies (Sheahan & Chase 1996; 2000). It consists of herbs, shrubs and trees growing in arid and semi-arid areas in the tropics and subtropics. Earlier studies place the Zygophyllaceae in different orders, e.g. Sapindales, Rutales, Polygalales, Linales, and Geraniales (Cronquist 1968; Takhtajan 1969; 1980; 1983; 1986; Thorne 1992). Soltis *et al*. (2000) put the Zygophyllaceae and Krameriaceae together in their own order Zygophyllales within the eurosid I group, and this position is changed in APG III (2009). They put it within Fabids group. Delimitation of taxa within the family has repeatedly changed over time, because of their diversity in structural detail, particularly in *Balanites, Nitraria*, *Peganum* and *Tetradiclis*. For example, Engler (1896a; 1931) divided the family into seven subfamilies, 8 tribes and 4 subtribes: Peganoideae, Tetradiclidoideae, Chitonioideae, Augeoideae, Zygophylloideae, Nitrarioideae and Balanitoideae. He considered that Zygophylloideae (including the tribuloid genera) formed the central typical group, with Augeoideae based on the characters of the leaves and fruits.

Pollen morphology of the family has been also examined by Erdtman (1952), Shimakura (1973), Kuprianova & Alyoshina (1978), Yunus & Nair (1988) and Perveen & Qaiser (2006). Sheahan & Cutler (1993) investigated the vegetative anatomy of 37 species in 19 genera, and

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illustrated that there is anatomical evidence to exclude of *Balanites* into a separate family and they recommended that the tribuloid genera *Tribulus, Kallstroemia* and *Kelleronia* should be separated from the Zygophylloid genera at least at subfamily level. Sheahan & Chase (1996) examined the phylogenetic analysis of Zygophyllaceae based on morphology, anatomy and *rbc*L DNA sequence. Zygophyllaceae form a clade. They divided Zygophyllaceae into five subfamilies, whereas *Nitraria* and *Peganum* were separated from Zygophyllaceae. Eventually, Sheahan & Chase (2000) analysed both *rbc*L and *trn*L-F sequences from 36 members of Zygophyllaceae. The results confirmed the previous division of Zygophyllaceae into five subfamilies, and Zygophylloideae were strongly supported as monophyletic, whereas *Zygophyllum* turned to be a polyphyletic genus.

Beier *et al*. (2003), using non-coding *trn*L plastid data for 43 species of Zygophylloideae investigated the phylogeny of the family, retrieving a monophyletic subfamily Zygophylloideae, and the genus *Zygophyllum*, together with the genera *Augea, Tetraena* and *Fagonia*, turned to be a paraphyletic. In the flora of Egypt Zygophyllaceae is represented by six genera belonging to three subfamilies: Peganoideae Engl., Tetradiclidoideae Engl., and Zygophylloideae (Tackholm 1974; El Hadidi 1972), but recently Boulos (2000) recorded five genera. Systematics of Zygophyllaceae may be difficult because only leave or fruit morphological characters are traditionally in use by taxonomists. These characters are variable even within genera, or differ with one another in their distribution patterns among genera and may not reflect natural groups.

The aim of present study was to confirm the phenetic relationships between genera within the family in Egypt based on a large number of characters (61) with the use of numerical taxonomy and to check whether these results correspond to the systematics of the genera proposed by Engler (1896a; 1931), El Hadidi (1975) and Sheahan & Chase (1996; 2000)

Materials and methods

Plant material

The present study is largely based on herbarium material kept in the following herbaria: CAI, CAIM, and SHG. A fresh material of most of the taxa from several localities in Egypt and Saudi Arabia was also studied. In the analyses, species constituted the OTU (Operational Taxonomic Unit) see Appendix 1. In order to broadly sample the variation, the OTU's consist of a number of collections (either herbarium specimens or fresh material or both) from different localities in Egypt. For some species from Egypt few specimens were available, in that case specimens from Saudi Arabia were used (Table 1).

Morphological characters observations

Table 2 shows the characters and character states scored for plant, pollen, and seed morphology, averaged for each OTU. In total 61 characters were taken into consideration, comprising 13 quantitative and 48 qualitative characters. Twelve of the qualitative characters were scored as binary and the remaining were scored as multi-state characters. Eleven characters from the 61 characters were treated as invariable characters and the rest are variable characters.

Vegetative parts, flower and fruit characters

The measurements for all specimens of a taxon were averaged into one OTU score for each of the characters. OTU scores for quantitative characters were arithmetic means based on at least 3 specimens (whenever possible). Because herbarium specimens cannot be considered to be a random sample of the species, we followed Wieringa (1999: 62-65) by calculating the mean of the minimum and maximum measurement. For some of the OTU's observations for some of the characters were not available, and these omissions were coded as missing data (-999). The complete data matrix is available on request at the Botany Department, Faculty of Science, Sohag University, Egypt.

Pollen grain and seed characters

The data of pollen morphology were mainly obtained from Erdtman (1952); Agababyan (1964); El Hadidi (1966); Yunus & Nair (1988); and Perveen & Qaiser (2006). Dried mature seeds were first examined by light microscope (Olympus type BH-2), and 5-10 seeds for each taxon were selected to cover the range of variation when available. Seeds were mounted on stubs with double adhesive tape. The stubs were sputter-coated with gold/palladium for 3 min. in a EMITECH K550. After coating, the specimens were examined with a Jeol-6300 scanning electron microscope, using accelerating voltages at 15-20 KV.

Data analysis

Two types of analyses were performed with NTSYS-pc 2.02k software (Applied Biostatistics Inc., Setauket, New York, USA). Firstly, I performed a cluster analysis using average taxonomic distance and UPGMA clustering (procedures SIMINT, SAHN, and TREE). To reduce the effects of different scales of measurement for different characters, the values for each character were standardized with procedure STAND, according to the formula: yI,STD = (yi- AVGyi)/ STDyi), Where the default value in NTSYS-pc (STAND) for yi = the value to be standardized, AVGyi= the average of all values for the character, and STDyi = the standard deviation. The cophenetic correlation coefficient between the distance matrix and the tree matrix was calculated to examine the goodness of fit of the cluster analysis to the distance matrix (procedures COPH and MXCOMP). Secondly, a principal coordinates analysis (PCO) was performed, using the product-moment correlation as a coefficient. The procedure SIMINT was used to calculate the distance matrix based on

Table 1. List of taxa used in the study (Boulos 2000), a comparison of most traditional (Engler 1896a, 1931; El Hadidi 1975) and phylogenetic classifications (Sheahan & Chase 1996, 2000) are shown.

Nº	Taxon	Engler (1896a, 1931)	El Hadidi (1975)	Sheahan & Chase (1996, 2000)	Nº. of individuals
1	*Balanites aegyptiacus* Delile	Subfam. Balanitoideae	Family Balanitaceae	Subfam. Tribuloideae	8
2	*Fagonia arabica* L.	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	10
3	*F. boveana* (Hadidi) Hadidi & El-Garf	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	9
4	*F. bruguieri* DC. Burm. Boiss	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	10
5	*F. cretica* L.	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	8
6	*F. glutinosa* Delile	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	8
7	*F. indica* Burm	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	9
8	*F. isotricha* Murb.	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	7
9	*F. latifolia* Delile	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	7
10	*F. mollis* Delile	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	8
11	*F. scabra* Forssk.	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	10
12	*F. sinaica* Boiss	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	5
13	*F. tenuifolia* Steud. & Hochst.	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	2
14	*F. tristis* Sickenb	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	7
15	*Peganum harmala* L.	Subfam. Peganoideae	Family Peganaceae	Family Peganaceae	9
16	*Seetzenia lanata* (Willd.) Bullock	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Seetzenioideae	3
17	*Tetradiclis tenella* Litv.	Subfam. Tetradiclidoideae	Family Peganaceae	Family Peganaceae	2
18	*Tribulus bimucronatus* Viv.	Subfam. Zygophylloideae	Family Tribulaceae	Subfam. Tribuloideae	5
19	*T. kaiseri* Hosni	Subfam. Zygophylloideae	Family Tribulaceae	Subfam. Tribuloideae	4
20	*T. macropterus* Boiss.	Subfam. Zygophylloideae	Family Tribulaceae	Subfam. Tribuloideae	8
21	*T. mollis* Ehrenb. ex Schweinf.	Subfam. Zygophylloideae	Family Tribulaceae	Subfam. Tribuloideae	4
22	*T. pentandrus* Forssk.	Subfam. Zygophylloideae	Family Tribulaceae	Subfam. Tribuloideae	7
23	*T. terrestris* L.	Subfam. Zygophylloideae	Family Tribulaceae	Subfam. Tribuloideae	15
24	*Zygophyllum aegyptium* Hosny	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	7
25	*Z. album* L.	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	15
26	*Z. coccineum* L.	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	20
27	*Z. decumbens* Delile	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	7
28	*Z. dumosum* Boiss.	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	2
29	*Z. simplex* L.	Subfam. Zygophylloideae	Subfam. Zygophylloideae	Subfam. Zygophylloideae	20

STAND data, the procedures EIGEN, PROJ, and MXPLOT to perform the PCO. A PCO was preferred rather than a PCA (Principal Components Analysis), because a PCO performs better on data sets with missing data (Rohlf 1972).

Results

Cluster analysis

Figure 1 shows the UPGMA phenogram comprising all OTU's in the present study. The cophenetic correlation of distance matrix and tree matrix was 0.88, indicating a good fit of the phenogram to the distance matrix (see Rohlf 1993).

Six branches and clusters can be distinguished: (1) a branch with *Seetzenia lanata* (subfamily Seetzenioideae). This branch shows the largest distance from all other branches. (2) A cluster consisting of OUT's of the all species of *Tribulus* (subfamily Tribuloideae), (3) branch with *Tetradiclis tenella* (subfamily Tetradiclidoideae), (4) a branch with *Balanites aegyptiacus* (subfamily Balanitoideae), (5) a cluster which is divided into two subgroups: *Peganum harmala* (subfamily Peganoideae) and *Zygophyllum coccineum* (subfamily Zygophylloideae) subgroup, and a subgroup with all species of *Zygophyllum* (subfamily Zygophylloideae), and (6) a cluster comprising all species of *Fagonia* (subfamily Zygophylloideae).

Principal coordinates analysis (PCO)

The plot of 29 OTU's on the first three principal coordinates axes is shown in Figs. 2, 3, & 4. These axes explain

Table 2. Characters and character states used in morphometric analysis of the *Zygophyllace*

N	Character	Character state	Code
1	Life cycle	Annual annual or short lived perennial Perennial Perennial or sub shrub Sub shrub Shrub or tree	1 2 3 4 5 6
2	Plant length (mean length in cm)		
3	Plant nature	Prostrate Decumbent to ascending Ascending Procumbent Erect	1 2 3 4 5
4	Plant surface	Glabrous Glabrous to sparsely hairy Sparsely hairy Sparsely to densely hairy Hairy	1 2 3 4 5
5	Hair shapes	Simple Glandular Simple\ stellate	1 2 3
6	Trichome stalk	Present Absent	1 2
7	Stem nature	Herbaceous Woody at the base Woody	1 2 3
8	Stem outline shape	Terete Quadrangular	1 2
9	Nature of branches	Spinescent Not spinescent	1 2
10	Stipules	Present Absent	1 2
11	Stipules nature	Spinescent Membranous Scarious Bristle	1 2 3 4
12	Stipule length (mean length in mm)		
	Leaf character		
13	Leaves\leaflets arrangement	Opposite Alternate Opposite below and alternate above	1 2 3
14	Leaf-blade\leaflets	Flattened Terete	1 2
15	Leaf structure	Simple or 1-foliolate 2-foliolate 1, 3- foliolate 3-foliolate Multi-foliolate Pinnatisect	1 2 3 4 5 6
16	Leaf petiole measurements (mean length in mm)		
17	Leaf\leaflet shape	Linear Oblong to lanceolate Linear to elliptical Cylindrical Oblong to elliptical Ovate to elliptical Ovate Obovate	1 2 3 4 5 6 7 8

Continue

Table 2. Continuation

N	Character	Character state	Code
18	Leaf apex	Mucronate Acute Obtuse Retuse	1 2 3 4
19	Petiolule	Present Absent	1 2
		Flower characters	
20		Flower pedicle (mean length in mm)	
21		Sepal length (mean length in mm)	
22		Sepal width (mean width in mm)	
23	Sepal shape	Lanceolate Lanceolate to ovate Ovate to oblong Oblong Obovate Ovate	1 2 3 4 5 6
24	Sepal apex	Apiculate Acute Obtuse	1 2 3
25	Sepal surface	Glabrous Glabrous to sparsely hairy Hairy	1 2 3
26	Sepal persistence at fruit maturity	Persistent Deciduous	1 2
27	Petal Persistence	Present Absent	1 2
28		Petal length (mean length in mm)	
29		Petal width (mean width in mm)	
30	Petal shape	Obovate Obovate -oblong Spathulate Spathulate with long claws	1 2 3 4
31	Petal colour	White Cream Yellow to white Yellow Pink Pink to mauve Violet	1 2 3 4 5 6 7
32	Petal apex	Apiculate Obtuse	1 2
33	Stamens number	15 10 5-10 5 4	1 2 3 4 5
34		Filament length (mean length in mm)	
35	Filament appendages	Present Absent	1 2
36	Ovary surface	Glabrous Glabrous to sparsely hairs Hairy	1 2 3
37	Nectariferous disc below ovary	Present Absent	1 2

Continue

Table 2. Continuation

N	Character	Character state	Code
38	Style number	1 5	1 2
39		Style length (mean length in mm)	
		Pollen grain characters	
40	Pollen shape	Oblate spheroidal (P/E = 0.88-1) Spheroidal (P/E = 1) Subprolate (P/E = 1.14-1.33) Prolate (P/E = 1.33-2)	1 2 3 4
41	Pollen types	Tricolpate Tricolporate Pantoporate	1 2 3
42	Exine sculpture	Striate-perforate Rugulate-reticulate Micro-reticulate Reticulate Coarsely-reticulate	1 2 3 4 5
		Fruit characters	
43	Fruit type	Loculicidal capsule Schizocarpic Drupe	1 2 3
44		Fruit length (mean length in mm)	
45		Fruit width (mean width in mm)	
46	Fruit surface	Glabrous Glabrous to sparsely hairs Hairy	1 2 3
47	Fruit wings	Winged Not Winged	1 2
48	Fruit shape	Obovate Obconical Oblong-ellipsoid Spherical Sub spherical Pyramidal Disc-shaped	1 2 3 4 5 6 7
49	Mericarp edge	Spiny Winged Not winged	1 2 3
50	Number of fruit locules	3 4 5	1 2 3
51		Fruit pedicel (mean length in mm)	
		Seed characters	
52	Seed shape	Ellipsoid Oblong Obovoid Ovoid Flat to ovoid	1 2 3 4 5
53	Seed architecture	Smooth Tuberculate Crustaceous	1 2 3

Continue

Table 2. Continuation

N	Character	Character state	Code
54	Seed size (mm) (Length x width)	0.6-1.7 x 0.4-1.3	1
		1.8-4.2 x 1.3-3.7	2
		4.3-24 x 1.6-3	3
		25-35 x 10-15	4
55	Endosperm of seed	Present	1
		Absent	2
56	Epidermal cell patterns	Isodiametric or 4-5-6 polygonal	1
		Irregular or 4-5-6 polygonal	2
		Irregular or polygonal cells	3
		4-5 gonals	4
57	Anticlinal walls	Straight	1
		Straight to slightly sinuous	2
58	Relief of cell wall boundaries	Raised	1
		Raised-channeled	2
		Channeled	3
59	Sculpture of anticlinal boundaries	Smooth	1
		Smooth to fine folded	2
		Folded	3
60	Curvature of outer periclinal cell wall	Flat to concave	1
		Flat to convex	2
		Flat to concave with sunken central papilla	3
		Convex	4
		Domate with globular central papilla	5
61	Sculpture of periclinal cell wall	Smooth	1
		Smooth to fine folded	2
		Folded	3
		Radiate-striate	4
		Micro-reticulate	5
		Reticulate	6

68.83% of the total observed variation. Plots 1/2, 1/3, and 2/3 together show six groups. On the first axis (31.60% of the total variation, Figs 2 & 3), a separation is demonstrated between four groups:- 1) group of all species of *Tribulus* (subfamily Tribuloideae*)*; 2) group comprising all species of *Fagonia* (subfamily Zygophylloideae; 3) *Seetzenia lanata* (subfamily Seetzenioideae*)*; 4) group of *Peganum harmala* (subfamily Peganoideae) nested within the genus *Zygophyllum* (subfamily Zygophylloideae). The main characters explaining this separation (characters with high factor loading > 0.6) were fruit shape, seed architecture, mericarp edge, leaf petiole length, seed shape, filament length, seed size, epidermal cell patterns, curvature of outer periclinal cell wall, pollen shape, relief of cell wall boundaries, fruit width, leaf structure and hair shapes (Table 3).The second principal coordinates axis (19.96 % of the total variation, Figs. 2 & 4) reveals a split between two groups: 1) *Balanites aegyptiacus* (subfamily Balanitoideae) and 2) *Tetradiclis tenella* (subfamily Tetradiclidoideae). This split was based mainly on stipules nature, pollen types, pollen shape, seed architecture, stipules length, petal width, curvature of outer periclinal cell wall, sepal length, and petal colour (Table 3). Along the third axis (17.27% of the total variation, Figs. 3 & 4) a separation between group of *Peganum harmala* (subfamily Peganoideae) nested within the genus *Zygophyllum* (subfamily Zygophylloideae), based on flower pedicle length, fruit type, stamens number, plant nature, sepal shape, sculpture of anticlinal boundaries, style length, number of fruit locules, plant cycle, leaf structure, sculpture of periclinal cell wall, leaf/leaflet shape, leaf apex, pollen types, and petal length.

Discussion

Systematics must largely rely on morphological characters to define taxa. Problems in classification arise when the taxa display a large amount of variability, due to phenotypic plasticity (van den Berg & Groendijk-Wilders 1999). Groups within the Zygophyllaceae have become specialized for similar arid habitats, which has probably led to much parallel and convergent evolution. Some characters which turn out to be among the most homoplasious and distinguish taxa, such as the presence of staminal appendages, nectariferous disc and endosperm. These characters may be of value only among subgroups within the family and for distinguishing genera, and not for phylogenetic purposes in the whole family (Sheahan & Chase 1996). Several authors have tried to provide a natural system to divide the Zygophyllaceae into subfamilies, tribes and sections (Engler 1896a; 1931;

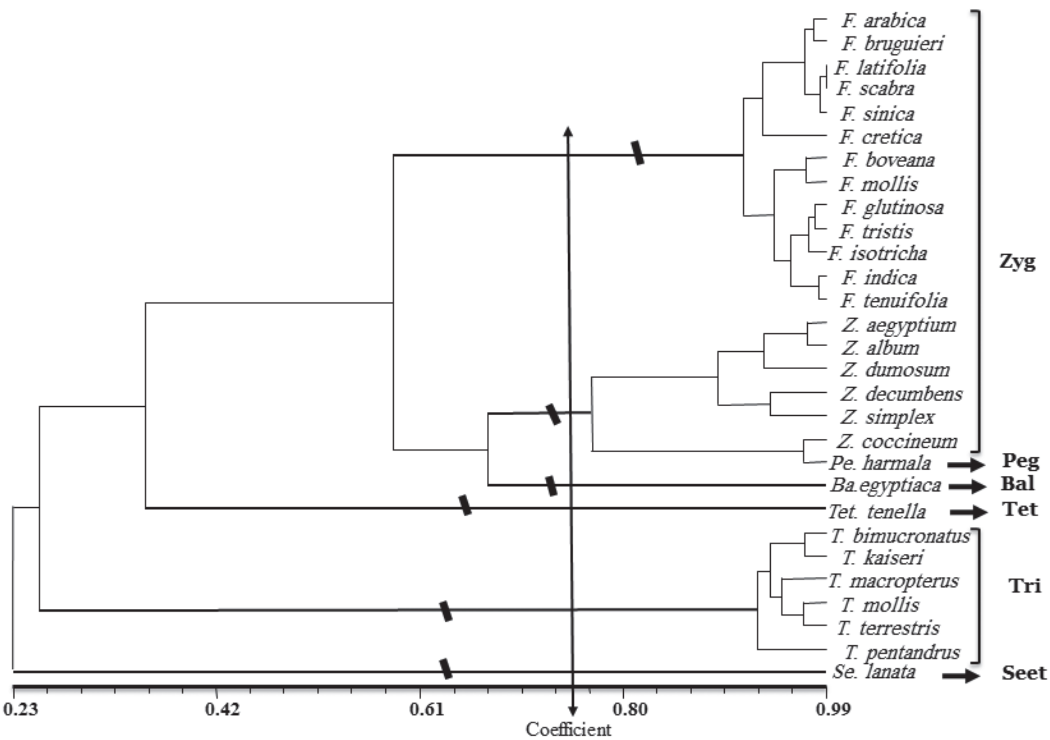

Figure 1. Phenogram of the 29 studied taxa, clustering with UPGMA method: **Bal,** *Balanitoideae;* **Peg,** *Peganoideae*; **Seet,** *Seetzenioideae;* **Tet**, *Tetradiclidoideae;* **Tri,** *Tribuloideae;* **Zyg,** *Zygophylloideae.*

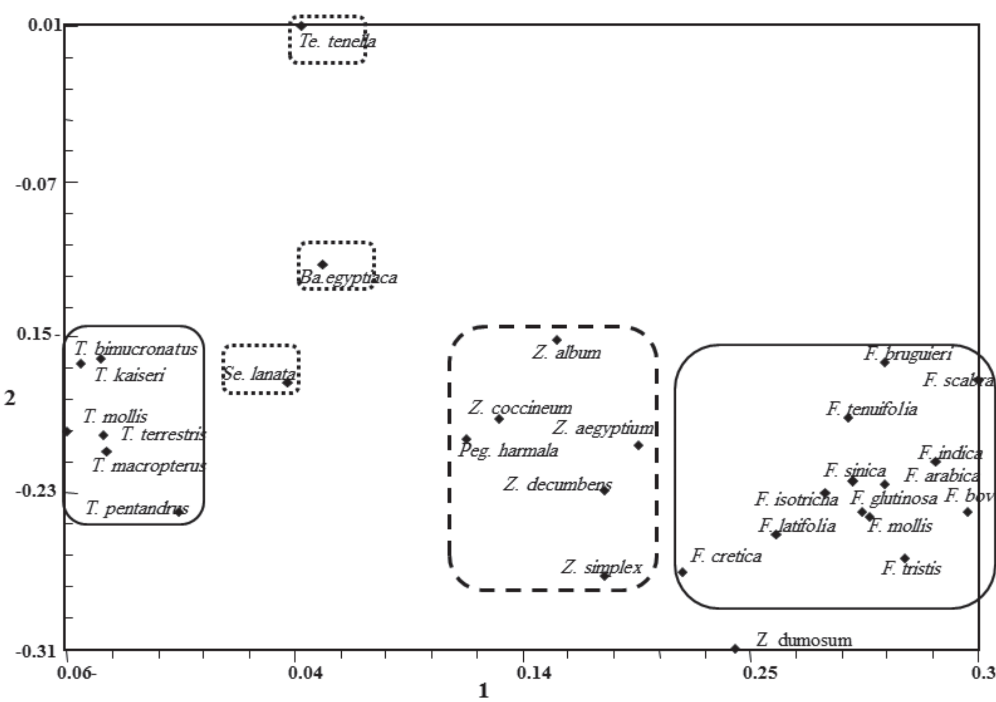

Figure 2. Scatterplot of the 29 OUTs plotted against the first principal coordinate by the second principal coordinate.

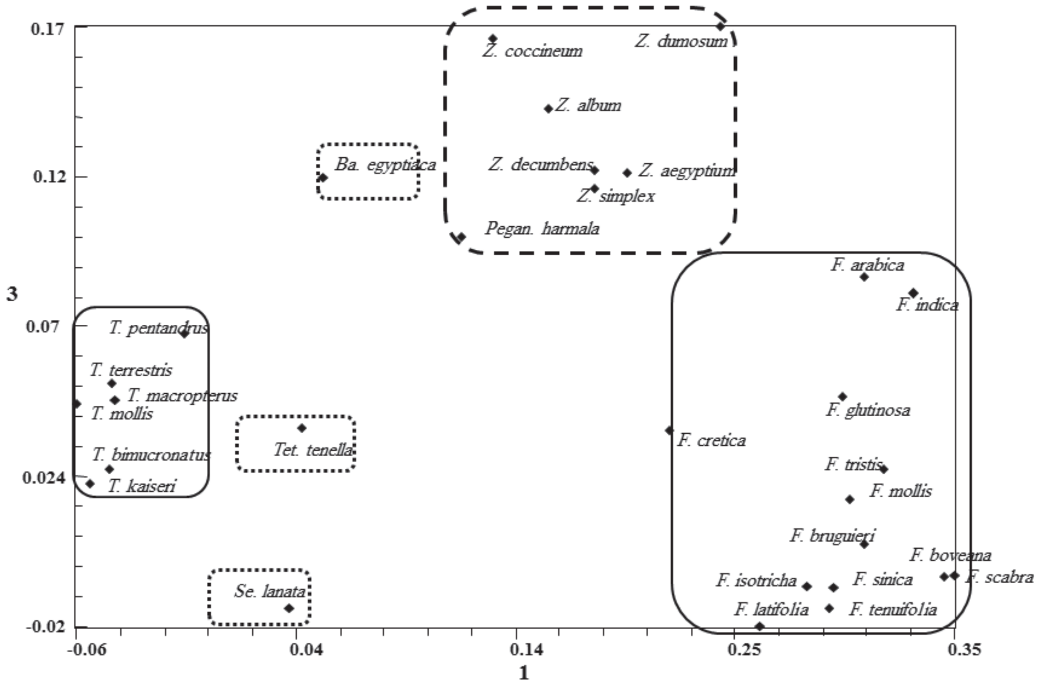

Figure 3. Scatterplot of the 29 OUTs plotted against the first principal coordinate by the third principal coordinate.

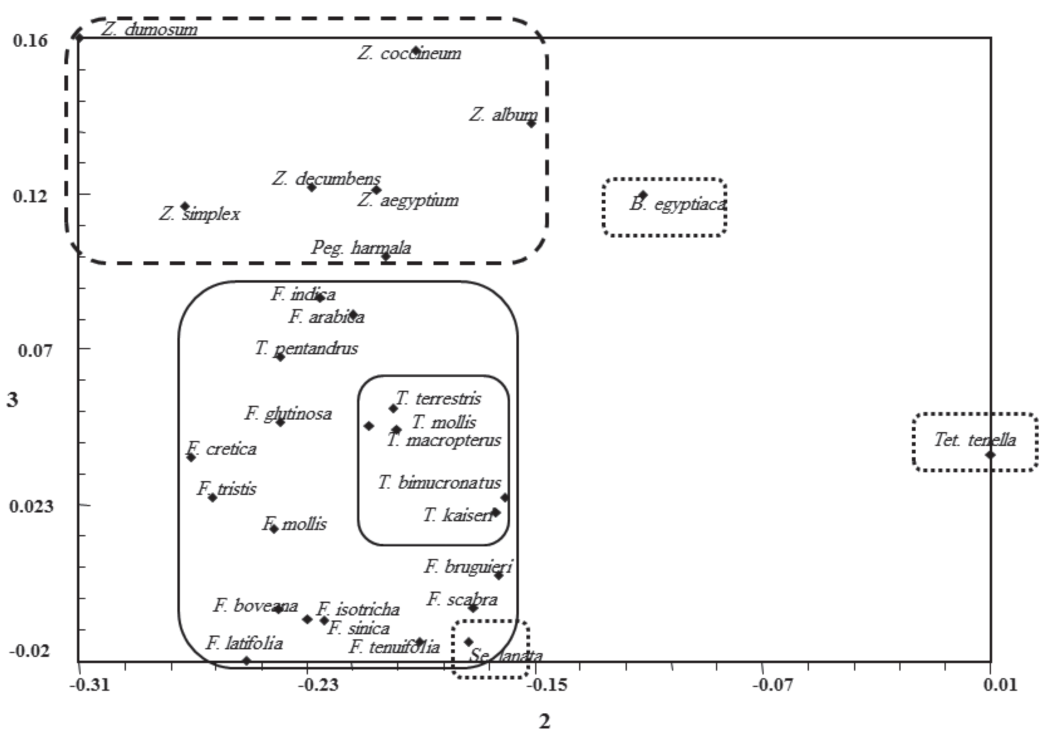

Figure 4. Scatterplot of the 29 OUTs plotted against the second principal coordinate by the third principal coordinate.

Table 3. Morphological characters showing highest factor loading on the first three Principal coordinate axes. The shaded numbers mean characters with high factor loading > 0.6.

N	Characters	Principal coordinates		
		1	2	3
		Factors loading		
1	Plant cycle	0.56	0.12	**0.76**
2	Plant length (mean length in cm)	-0.13	-0.51	0.55
3	Plant nature	0.31	-0.24	**-0.95**
4	Plant surface	0.24	0.12	-0.13
5	Hair shapes	**0.60**	-0.41	-0.42
6	Trichome stalk	-0.30	0.23	-0.28
7	Stem nature	0.21	0.27	0.20
8	Stipules nature	-0.18	**-0.99**	-0.27
9	Stipules length (mean length in mm)	0.26	**-0.71**	-0.29
10	Leaves\leaflets arrangements	0.23	0.50	0.40
11	Leaf structure	**-0.61**	-0.17	**-0.70**
12	Leaf petiole measurements (mean length in cm)	**0.86**	0.29	0.44
13	Leaf\leaflet shape	-0.38	-0.28	**-0.65**
14	Leaf apex	-0.24	-0.16	**-0.65**
15	Flower pedicle (mean length in mm)	-0.38	-0.18	**0.96**
16	Sepal length (mean length in mm)	-0.11	**-0.63**	0.42
17	Sepal width (mean width in mm)	0.19	-0.50	0.52
18	Sepal shape	-0.10	-0.18	**0.94**
19	Sepal apex	0.38	0.24	0.46
20	Sepal surface	-0.24	0.20	0.43
21	Petal length (mean length in mm)	0.26	-0.54	**-0.61**
22	Petal width (mean width in mm)	0.20	**-0.67**	0.41
23	Petal shape	0.27	-0.22	0.36
24	Petal colour	0.28	**0.63**	0.51
25	Petal apex	0.37	-0.25	0.38
26	Stamens number	0.35	0.12	**0.95**
27	Filament length (mean length in mm)	**-0.80**	-0.17	-0.40
28	Ovary surface	0.45	-0.41	0.38
29	Style length (mean length in mm)	-0.22	-0.19	**-0.93**
30	Pollen shape	**0.73**	**-0.81**	0.35
31	Pollen types	0.31	**-0.91**	**-0.63**
32	Exine sculpture	0.31	-0.10	-0.54
33	Fruit type	0.51	0.41	**0.95**
34	Fruit length (mean length in mm)	-0.33	-0.59	0.21
35	Fruit width (mean width in mm)	**-0.63**	-0.40	0.29
36	Fruit surface	-0.12	-0.26	-0.40
37	Fruit wings	-0.16	-0.17	-0.21
38	Fruit shape	**-0.95**	-0.45	0.33
39	Mericarp edge	**-0.88**	-0.32	-0.26
40	Number of fruit locules	0.49	0.13	**0.91**
41	Fruit pedicel (mean length in mm	-0.54	-0.50	0.22
42	Seed shape	**0.83**	0.21	-0.16
43	Seed architecture	**0.91**	**0.72**	0.23
44	Seed size in mm (Length x width)	**0.79**	0.26	0.30
45	Epidermal cell paterns	**0.78**	-0.13	-0.58
46	Anticlinal walls	0.15	0.56	0.18
47	Relief of cell wall boundaries	**0.66**	-0.13	-0.45
48	Sculpture of anticlinal boundaries	0.10	-0.12	**0.94**
49	Curvature of outer periclinal cell wall	**0.74**	**-0.66**	-0.46
50	Sculpture of periclinal cell wall	0.10	-0.13	**0.67**
Percentage per PCO		31.60	19.96	17.27
Percentage total variation for the first three principal coordinates amount 68.83%				

El Hadidi 1975; Sheahan & Chase 1996; 2000; Beier *et al*. 2003, see Table 1). Some of these studies were based on a small number of morphological characters or few numbers of the taxa. In the present study, a large number of characters were scored and numerical methods (UPGMA and PCO) were applied to study the relationships between taxa and to estimate the level of variation between them. UPGMA gives insight into the degree of similarity among the OTUs and whether they form groups/ clusters, and indicates the level of variation between species. On the other hand, PCO reflects which characters are important on the axes, and indicates the significant characters on the basis of the highest factor loading (Table 3). Thus it becomes clear which characters help differentiate between the groups and can be useful to distinguish taxa. Generally, our results demonstrated similarity between the UPGMA clustering and PCO ordination. In general, six taxonomic groups can be distinguished

Fagonia *group*

The taxonomy of *Fagonia* is very difficult mainly due to a high degree of plasticity and thereby adaptations to climatic conditions (Zohary 1972; Danin 1996). Ozenda & Quézel (1956) grouped the North African *Fagonia* species into four natural groups: (1) the *F. kahirina–cretica–flamandii* group, (2) the *F. arabica–bruguieri* group, (3) the *F. glutinosa–latifolia* group, and (4) the *F. microphylla*- group. However, El Hadidi (1966) classified *Fagonia* species into three natural groups based on pollen and trichome morphology. Also, El Hadidi (1972 & 1974) classified *Fagonia*-species into complexes. Beier *et al*. (2004) studied the phylogenetic relationships within genus *Fagonia* based on *trnL* & ITS DNA sequences and they did not support the natural groups of *Fagonia*, and showed that all species from the Old World, except *Fagonia cretica* form a weakly supported clade. Abdel Khalik & Hassan (2012) investigated seed and trichome morphology of *Fagonia* in Egypt and indicated that the seed and trichome morphology are useful in distinguishing the species and not supporting the natural groups. The results of both cluster and principal coordinated analysis presented here confirmed that all species of *Fagonia* form a well-distinguished group, characterized by several characteristics: obconical fruit shape, smooth seed architecture, non-winged mericarp edge, ovoid seed shape, filament length (3-7 mm), seed size (1.8-4.2 x 1.3-3.7 mm), subprolate to prolate pollen shape, 1-3-foliolate leaf and glandular hair shapes. Within this group, we can show that *Fagonia arabica, F. bruguieri, F. sinaica*, *F. latifolia,* and *F. scabra* form a subgroup; *F. cretica* forms a subgroup and another one includes the remaining species of *Fagonia*. These results are incongruent with those of Ozenda & Quézel (1956), El Hadidi (1966; 1972; 1974) and partially agree with both of Beier *et al*. (2004) and Abdel Khalik & Hassan (2012).

Zygophyllum *and* Peganum *group*

Van Zyl (2000) presented morphological analysis of the genus *Zygophyllum* in South Africa, and supported the division of *Zygophyllum* into the two subgenera *Agrophyllum* and *Zygophyllum*, which was contended by previous authors (Endlicher 1841; Van Huyssteen 1937). Van Huyssteen (1937) treated *Z. coccinum*, *Z. album* and *Z. aegyptium* as members of section Mediterranea Engl., and circumscribed *Z. simplex* and *Z. decumbens* in the section *Bipartia* Huysst. Moreover, she placed *Z. dumosum* in a separate section *Alata* Huysst. based on characters of fruit, stamens, and leaves characters. Sheahan & Chase (2000) analysed both *rbc*L and *trn*L-F sequences from 36 members of Zygophyllaceae and indicated that *Zygophyllum* is a polyphyletic genus, and show that, both *Z. simplex and Z. decumbens* were joined together in the same clade and the clade is a sister to the clade composed of *Zygophyllum album, Z. coccinum,* and *Tetraena*.

In some publications *Peganum* was placed in a separate family (Takhtajan 1969; El Hadidi 1975). Furthermore, Sheahan & Chase (1996) divided Zygophyllaceae into five subfamilies, whereas *Peganum, Malacocarpus* and *Nitraria* were separated from Zygophyllaceae and close to members of Sapindales, and also they recommended of Peganaceae and Nitrariaceae. However, Takhtajan (1980) and El Hadidi & Fayed (1995) returned it to Zygophyllaceae. The results of both cluster and principal coordinated analysis confirmed that the group of all species of *Zygophyllum* and *Peganum harmala* is a well-distinguished group, characterized by: short flower pedicle length (1-7 mm), schizocarpic fruits, 10 stamens, style length (1-2 mm), perennial to sub shrub plants, 2-foliolates, obtuse leaf apex, tricolpate pollen type, 5 locules per fruit. Within this group, we can show three subgroups: *Zygophyllum simplex* and *Z. decumbens* subgroup; *Z. album, Z. aegyptium* and *Z. dumosum* subgroup, and another subgroup includes *Z. coccineum and Peganum harmala*. Our results identify three branches that are congruent with the *Zygophyllum* sections proposed by Van Huyssteen (1937), and the results from previous studies of phylogenetic relationships by Sheahan & Chase (2000) and Beier *et al*. (2003). Moreover, the results indicate that *Peganum harmala* is not such an isolated species as has been thought (Takhtajan 1969; El Hadidi 1975; Sheahan & Chase 1996). Some characters that have been put advance as unique for it, such as tricolporate pollen grains, non-winged fruit, 5 styles, present of nectiferous disc, and endospermic seed, are also found in the other members of *Zygophyllum*, and these results are congruent with those of Takhtajan (1980) and El Hadidi & Fayed (1995).

Tetradiclis *group*

Engler (1896a; 1931) delimited *Tetradiclis* under subfamily Tetradiclidoideae with in Zygophyllaceae. However, El Hadidi (1975); Takhtajan (1980, 1983); Sheahan & Chase (1996; 2000), and Bolous (2000) removed it from the family Zygophyllaceae and put it under a family Peganaceae. Moreover, Takhtajan (1996) treats it under a separate monotypic family Tetradiclidaceae. Morphologically, *Tetradiclis tenella* is quite distinct and easily identifiable. It is distinguished from other Zygophyllaceae by the exstipulate pinnatisect leaves, , flower small (1 mm) and tetramerous, 4 loculed fruit. It shares with genera of Zygophyllaceae the absence of filament appendages, the annual habit, the loculicidal capsule, flattened leaf blade, and the obtuse leaf apex. The results of both cluster and principal coordinates analyses distinct the group from the other species by herbaceous stem, exstipulate leaves, leaves opposite below and alternate above, tetramerous flower, 4 loculed fruit.

Balanites *group*

Based on the morphological and anatomical studies within the *Balanites,* it was suggested that the genus can be assigned circumscribed within its own family Balanitaceae (Hutchinson 1973; El Hadidi 1975; Takhtajan 1983; Sands 1989). However, Engler (1896a;1931); Scholz (1964); Hegnauer (1973); Cronquist (1981), and Sheahan & Chase (1996; 2000) included it in Zygophyllaceae. In my results, both cluster and principal coordinates analysis, *Balanites aegyptiacus* is separated from other groups, and characterized by shrub to tree habit, spinescent branches, exstipulate leaves, striate-perforate pollen sculpture, drupaceous fruit, and crustaceous seed. It is close to members of Zygophylloideae and Peganoideae based mainly on stamen numbers (10), tricolporate pollen type, 5 loculed-fruit. From the results of this study it appears that *Balanites* (subfamily Balanitoideae) is closed to the members of Zygophyllaceae and embedded within it. Consequently, it should not be regarded as a separate family and this result agrees with those of Engler (1896a; 1931); Scholz (1964); Hegnauer (1973); Cronquist (1981), and Sheahan & Chase (1996; 2000).

Tribulus *group*

Engler (1931) put *Tribulus* in tribe Tribuleae within the subfamily Zygophylloideae. However, El-Hadidi (1975; 1977) proposed a new family Tribulaceae based on Engler's tribe Tribulae. El Hadidi (1978) recognized three sections in *Tribulus*, each with a specific diagnostic character: (1) section Terrestris L. (*T. terrestris*, *T. parvispinus* & *T. spurius*) with spiny mericarps, (2) section Alata Hadidi (*T. macropterus, T. megistopterus* & *T. pentandrus*) with winged mericarps and (3) section Inermis Hadidi (*T. mollis*, *T. kaiseri* & *T. bimucronatus*) with spineless or wingless mericarps. According to Hosni (1978), the most reliable and constant characters for *Tribulus* species, and hence of major systematic value, are those of the mature carpels and the size of the flower, while other characters such as the habit of the plant, hairiness, size of leaf, morphology of the style and stigma are of minor systematic value. Furthermore, Mohamed (2006) studied seed morphology, seed proteins and Iso-enzymes in *Tribulus*, and divided this genus into two main groups: (i) *T. macropterus* and *T. mollis,* and (ii) *T. terrestris*, *T. bimucronatus, T. pentandrus,* and *T. kaiseri.* The results of both cluster and principal coordinated analysis confirmed that the group of all species of *Tribulus* is a well-distinguished group, characterized by: multi- foliolate leaf, opposite leaflet, flat, 5-10 stamens, filament without appendages, oblate spheroidal pollen shape, pantoporate, coarsely-reticulate pollen schizocarpic fruit, 5 indehiscent mericarps. Within this group, we can show that *T. bimucronatus* and *T. kaiseri* form two subgroups: 1) *T. macropterus, T. mollis,* and *T. terrestris* and 2) another one includes *T. pentandrus.* These results disagree with El Hadidi (1978) and partially agree with Mohamed (2006).

Seetzenia *group*

Engler (1931) and El Hadidi (1975) placed *Seetzenia* with *Fagonia* and *Zygophyllum* in the subfamily Zygophylloideae within the family Zygophyllaceae. However, Sheahan & Chase (1996; 2000) proposed a new subfamily Seetzenioideae. According to the cluster and principal coordinates analysis, *Seetzenia lanata* (Seetzenioideae) shows the largest distance from all other groups, and is distinct from the others by trifoliate leaves, apetalous flowers, 5 stamens, 5 styles, tricolpate pollen type, oblong seed shape, crustaceous seed architecture. This result disagree with those of Engler (1931) and El Hadidi (1975) and agrees with Sheahan & Chase (1996; 2000) for separating it as a subfamily.

Conclusion

UPGMA and PCO analysis can be used to study the morphological variation within the family to determine the discontinuities among genera and subfamilies. My results indicate that Zygophyllaceae are heterogeneous, including *Peganum harmala* which has been proposed to form a separate family. There are many splits between subfamilies Zygophylloideae, Tribuloideae, Tetradiclidoideae and Seetzenioideae which seem to be distinct groups. However, there is also some degree of similarity among certain taxa of the subfamilies Balanitoideae, Peganoideae and Zygophylloideae. I consider *Zygophyllum* the most heterogeneous of the Zygophylloideae because I found that the taxa from this genus interspersed with taxa from Peganoideae (*Peganum harmala*), and this is congruent with the results of Sheahan & Chase (2000). Although this study has contributed new conclusions to literature, it is limited to the known genera in Egypt. A comprehensive study covering all *genera* would be necessary to make a more thorough classification and it would be very useful for the further studies to use molecular data.

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Appendix 1.

List of specimens used for the study; species arranged alphabetically within subfamilies according to Engler (1896a, 1931) and Sheahan & Chase (1996, 2000).

Subfamily Balanitoideae
***Balanites aegyptiacus* Delile**
Egypt: Red sea coast, Wadi El Gemal, Abdel Khalik s.n. (SHG); Gebel Elba, W. Yahameib, Abdel Ghani & Abdel Khalik s. n. (SHG); Red sea coast, Mersa Alam, gebel Hamata, Abdel Khalik et al. s. n. (SHG); Shalateen area, Wadi Baaneed, Abdel Khalik & al. s. n. (SHG).

Subfamily Peganoideae
***Peganum harmala* L.**
Egypt: Burg El Arab, Abdel Khalik s.n. (SHG); Ras El Hekma, Abdel Khalik, s.n. (SHG); Amria, Burg El Arab, Ibrahim El Sayed s.n. (CAI); Salloum town, Tackholm et al. s.n. (CAI); El Garawla, East Matrouh, Tackholm et al. s.n. (CAI); South Sinai, St. Catherine, H. Hosni s.n. (CAI); El Daba, A. Abdel Fadeel s.n. (CAI); Cairo- Suez road, Tackholm et al. s.n. (CAI); Wadi Gebal and Gebel Serbal region, Fayed et al. s.n. (SHG).

Subfamily Seetzenioideae
***Seetzenia lanata* (Willd.) Bullock**
Egypt: South Sinai, St. Catherine, wadi El Arbaeen, Abdel Khalik s.n. (SHG).
Saudi Arabia: Mecca-Taif, El Hada road, Abdel Khalik & Kotob Faghaly s.n. (SHG); Qassim, Near Nabhaniyah. 100 km SWof Buraydah. in hard gravelly sand. 2300 ft., Collenette1787

Subfamily Tetradiclidoideae
***Tetradiclis tenella* Litv.**
Egypt: Alexandria, El Dekhala, Abdel Khalik & El Kordy s.n. (SHG); Burg El Arab, Abdel Khalik & El Kordy s.n. (SHG).

Subfamily Tribuloideae
***Tribulus bimucronatus* Viv.**
Egypt: Gebel Elba, W. Yahameib, Abdel Ghani & Abdel Khalik s.n. (SHG); Wadi abu Hammadah, Kom Ombo, tackholm et al. s.n. (CAI).
Saudi Arabia: Mecca, El Abdia, Umm Al Qura University campus, Abdel Khalik s.n. (SHG); Mecca – Jedda road, near Jedda, Abdel Khalik, s.n. (SHG); North Jedda, Abdel Khalik, s.n. (SHG).
***T. kaiseri* Hosni**
Egypt: South Sinai, Farsh El Hamam, Kaiser 175 (CAIM); Sinai, Wadi El Siq, Kaiser 501 (CAI).
Saudi Arabia: Jedda, Abdel Khalik s.n. (SHG); Mecca-El Madina road, 70 km south El Madina, Abdel Khalik, s.n. (SHG).
***T. macropterus* Boiss.**
Egypt: Cairo-Suez desert road, Abdel Khalik, s.n. (SHG); Cairo-Suez desert road, Tackholm et al. s.n. (CAI); Gebel Ahmar, Tackholm et al. s.n. (CAI); El Qossir, Drar 44 (CAIM).
Saudi Arabia: Mecca- Jedda road, 14 km from Jedda, Abdel Khalik, s.n. (SHG); Wadi Hanifa, Kadry & Khodir, s.n. (CAI).
***T. mollis* Ehrenb. ex Schweinf.**
Egypt: Wadi El Hamura, Shabetai 4207 (CAIM); Affluent of Wadi Adendan, Tackholm 259 (CAI); Abu Zaabal, Shabetai 6792 (CAIM); Cairo- Suez desert road, Oliver s.n. (CAI).
***T. pentandrus* Forssk.**
Egypt: Cairo- suez road, Abdel Khalik, s.n. (SHG); Sohag University campus, near faculty of Science, Abdel Khalik, s.n. (SHG); Gift- El Qossir desert road, Abdel Khalik & Osman s. n. (SHG); 18 km South of Mersa Alam, Tackholm et al. s.n. (CAI).
Saudi Arabia: Mecca, wadi Fatma, Abdel Khalik, s.n. (SHG); Jedda, Abdel Khalik, s.n. (SHG); Badr, Batanouni 132 (CAI).
***T. terrestris* L.**
Egypt: Gebel Elba, W. Yahameib, Abdel Ghani & Abdel Khalik s.n. (SHG); Sohag, near the Nile, Abdel Khalik, s. n. (SHG); Wadi El Gemal, Abdel Khalik & el kordy, s.n. (SHG); Burg El arab, Abdel Khalik, s.n. (SHG); South Sinai, Wadi Gebal, Abdel Khalik & Osman s. n. (SHG); Gebel Serbal, Fayed et al. s.n. (SHG).

Subfamily Zygophylloideae
***Fagonia arabica* L.**
Egypt: Cairo-Alexandria desert road, Abdel Khalik s.n. (SHG); Cairo-Alexandria desert road, Tackholm et al. s.n. (CAI); Abu Rawash desert, El hadidi s.n. (CAI); Siwa Oasis, A. Zahran, s.n. (CAI); Cairo-Suez road, Kassas et al. s.n. (CAI); Wadi Natroun, Mustafa Imam s.n. (CAI); Faiyum, Chrtek s.n. (CAI); Helwan, Wadi Gerawi, Tackholm et al. s.n. (CAI); Gebel Serbal, Ain Alloza, Fayed et al. s.n. (SHG); Farsh Al Rommana, Fayed et al. s.n. (SHG).
***F. boveana* (Hadidi) Hadidi & El-Garf**
Egypt: Sinai, Wadi Ferieh, Tackholm et al. s.n. (CAI); Wadi Aber near Suez, Hadidi s.n. (CAI); Wadi Segal, N. Galala, M. Imam, s.n. (CAI); Wadi Abar, G. Ataqa, Suez, Imam & Fadeel s.n. (CAI); Suez Gulf, Aboud,s Factory, Hadidi s.n. (CAI); Near Ain Soukhna, Suez Gulf, Wadi Segal, Hadidi s.n. (CAI); Wadi Sermatai, Abdel Khalik & El Kordy s.n. (SHG); Sinai, Wadi Ferieh, Tackholm et al. s.n. (CAI); S. Sinai, Wadi El-Kid, Fayed et al. s.n. (SHG).
***F. bruguieri* DC.**
Egypt: Wadi Hof, I. El Garf s.n. (CAI); cairo- Suez desert road, 102 from Cairo, Tackholm et s.n. (CAI); Suez, Wadi Batar, Tackholm et s.n. (CAI); north of suez, wadi fool, Tackholm et s.n. (CAI); Wadi Aber, Gebel Ataqa, Hadidi et al. s.n. (CAI); Wadi El Deir, S. Galala,

Boulos s.n. (CAI); gebel Ahmar, Tackholm et s.n. (CAI); Helwan, Ibrahim El sayed s.n. (CAI); S. Sinai, Wadi Mander, Fayed et al. s.n. (SHG); Wadi Baida, Fayed et al. s.n. (SHG).

***F. cretica* L.**

Egypt: Alexandria-Matrouh coastal road, Sidi Abdel Rahman, Abdel Khalik s.n. (SHG); Sallum near shore, Tackholm et al. s.n. (CAI); Maruit, Mandara, Hefnawy s.n. (CAI); Maruit, Amal Amine s.n. (CAI); Ikingi Maruit, G. tackholm s.n. (CAI); 75 km from Alexandria, Cairo--Alexandria dearest road, Hadidi s.n. (CAI); Sidi Abdel-Rahman, Mexmuller et al. s.n. (CAI); ras El Hekma, Maruit, Boulos s.n. (CAI).

***F. glutinosa* Delile**

Egypt: N. Sinai, Gebel El Maghara, Hadidi & El Garf s.n. (CAI); N. Sinai, Rafah, El Garf s.n. (CAI); Sinai, St. Khaterina Mts. Gebel Serbal, Fayed et al. s.n. (SHG); Cairo--Suez road, K. 35, Imam s.n. (CAI); Cairo-Suez road, K. 22, Samir Ghabbour s.n. (CAI); Cairo-Suez road, K. 30, Imam s.n. (CAI); Cairo-Suez road, Kassas s.n. (CAI); Wadi Batar, Suez road, Tackholm et al. s.n. (CAI);Burg El Arab, Tackholm et al. s.n. (CAI).

***F. indica* Burm.**

Egypt: Wadi Allaqi, S. the village, Abdallah s.n. (CAIM); Wadi Nugdeib, Tackholm et al s.n. (CAI); Kom Ombo desert, Wadi Khareit, Tackholm et al. s.n. (CAI); 60 km from Idfu, Idfu-Mersa Alam road, Hadidi & El Garf s.n. (CAI); 90 km from Idfu, Idfu-Mersa Alam road, Tackholm et al. s.n. (CAI); Qena forest, Abbas & Khattab s.n. (CAIM); Wadi Bir El Ain, Sohag, Abdel Khalik s.n.n (SHG); Kharga oasis, Boulaq, Imam s.n. (CAI); Kharga, Paris, at Omda's new spring, Tackholm & Kassas 73 (CAI).

***F. isotricha* Murb.**

Egypt: Gebel Elba, Wadi Mawaw, Abdel Khalik s.n. (SHG); Wadi Aak, Tackholm et al. 780 (CAI); Gebel Astriba, Tackholm et al. 956 (CAI); Wadi Halos, Red sea coast, Tackholm et al. 266 (CAI); Gebel Hamata, Tackholm et al. 329 (CAI).

***F. latifolia* Delile**

Egypt: Cairo-Suez desert road, kmo 34, Samir Ghabbour s.n. (CAI); Wadi Anqabiya, El Hadidi s.n. (CAI); near the desert laboratory on the Suez road, Mustafa Imam s.n. (CAI); Suez road, K. 25 Tackholm s.n. (CAI); Suez road K. 35 Luckman Lawand s.n. (CAI); Cairo- Suez road, 50 km from Cairo, Abdel Khalik & Abdel Ghani (SHG); Mountain near Wadi Er-Rokhama between Madi and Suez, G. Tackholm s.n. (CAI).

***F. mollis* Delile**

Egypt: Galala desert, Wadi Hagaul, Hadidi & Garf s.n. (CAI); Wadi Hof, G. Tackholm, s.n. (CAI); Wadi Rashid, Simpson 1069 (CAIM); Wadi Araba, Bir El Arayda, Shabetai 6589 (CAIM); Cairo - Suez road, Kassas s. N. (CAI); Wadi Aber, Gebel Ataqa, Tackholm et al. s.n. (CAI); N. Abu Zenima, S. Sinai, Abdallah 519 (CAIM); Wadi Gharandal, El Hadidi et al. s.n. (CAI).

***F. scabra* Forssk.**

Egypt: Sallum Plateau, near the Town, Boulos s.n. (CAI); Burg El Arab, Hamada s.n. (CAI); Cairo- Alexandria desert road, Shabetai 7362 (CAIM); Abu Rawash, El Garf s.n. (CAI); Cairo-Suez road, 34 km from Cairo, El Hadidi s.n. (CAI); Wadi Liblab, near Cairo, Ayyad & Amin s.n. (CAI); Gebel Ataqa, S. Suez, Hadidi s.n. (CAI); Gebel Ahmar, El Hadidi s.n. (CAI); Wadi Hamata, an affluent of Wadi Hoff, Galala desert, Garf s.n. (CAI); Wadi Hof, M. Hassib s.n. (CAI).

***F. sinaica* Boiss.**

Egypt: North Sinai, Gebel Halal, Hadidi & Garf s.n. (CAI); Wadi El Maghara, Boulos s.n. (CAI); Wadi El Arish, Drar s.n. (CAIM).

***F. tenuifolia* Steud. & Hochst.**

Egypt: Red Sea coast, Gebel Hamata, at the foot of the mountain, Tackholm et al. 444 (CAI).

***F. tristis* Sickenb.**

Egypt: Between Mokattam and Gebel Ahmar, Hartmann s.n. (CAI); Gebel Tourrah, between Cairo and Helwan, Hartmann s.n. (CAI); Wadi Hof, Tackholm & Hadidi, s.n. (CAI); Wadi Digla, Boulos s.n. (CAI); Wadi Aber, gebel Ataqa, S. Suez, Boulos s.n. (CAI); Wadi Rishrash, Kassas s.n. (CAI); Wadi sheikh Salma, near Wadi Gerawi, Tackholm et al. s.n. (CAI).

***Zygophyllum aegyptium* Hosny**

Egypt: Alexandria- Matruh road, Burg El Arab, Abdel Khalik, s.n. (SHG); Mersa Matruh, Ghabbour s.n. (CAI); Alexandria, El Maks, Bornmüller 10504 (CAI); Burg El Brollus, Kassas s.n. (CAI); Baltim, Hadidi s.n. (CAI); Ras El Bar, Gazzar s.n. (CAI).

***Z. album* L.**

Egypt: Mariut, Burg El Arab, Abdel Khalik & Abdel Ghani s.n. (SHG); Red sea coast, mouth of wadi Gemal, Abdel Khalik & El kordy s.n. (SHG); 80 km north of Mersa Alam, Tackholm et al. 574 (CAI); 73 Km South of Mersa Alam, Tackholm et al. 28 (CAI); Mersa Samedai, Tackholm et al. 144 (CAI); Wadi Natroun, Chrtek (CAI); East Qantara, Gazzar s.n. (CAI).

Saudi Arabia: Red Sea coast, Jedda, Obher, Abdel Khalik s.n. (SHG); North of Jedda, on the coast, Abdel Khalik, s.n. (SHG).

***Z. coccineum* L.**

Egypt: Cairo-Alexandria desert road, 100 km from Cairo, Abdel Khalik s.n. (SHG); Wadi natroun, Abdel Khalik & El Kordy s.n. (SHG); Sohag, wadi Bir El Ain, Abdel Khalik s.n. (SHG); Cairo - Suez desert road, 30 km from Suez, Abdel Khalik & Abdel Ghani s.n. (SHG); Wadi El Arbaeen, South Sinai, Abdel Khalik & Osman s.n. (SHG); Siwa Oasis, Boulos s.n. (CAI); Wadi Betar, Suez - Cairo road, Tackholm et al. s.n. (CAI); Wadi Hof, Tackholm et al. s.n. (CAI).

Saudi Arabia: Red Sea coast, Jedda, Obher, Abdel Khalik s.n. (SHG); North of Jedda, on the coast, Abdel Khalik, s.n. (SHG).

Z. decumbens **Delile**

Egypt: Cairo- Suez desert road, 15 km from Cairo, Hilali et al. s.n. (CAIM); Cairo-Suez road, 93 km from Cairo, Darar s.n. (CAIM); Cairo-Suez road, Hadidi & Hosny (CAI); Gebel Ataqa, Hadidi s.n. (CAI); Wadi Aber, Gebal Ataqa, Tackholm et al. s.n. (CAI); Wadi Qusseib, Kassas s.n. (CAI).

Z. dumosum **Boiss.**

Egypt: Wadi Heridin, south of El Arish, Darar s.n. (CAI); Darb El Hagg at Sudur el Heitam Darar 677 (CAIM).

Z. simplex **L.**

Egypt: Gebel Elba, W. Yahameib, Abdel Ghani & Abdel Khalik s.n. (SHG); Siwa Oasis, Boulos s.n. (CAI); Wadi Natroun, Abdel Khalik s.n. (SHG); Cairo-Suez road, Tackholm et al. s.n. (CAI); Mersa Alam, Zahran et al. s.n. (CAI); Sohag, Wadi Bir El Ain, Abdel Khalik et al. s.n. (SHG).

Saudi Arabia: Jedda - El Madina road, Abdel Khalik s.n. (SHG); Wadi Noman, Mecca, Abdel Khalik s.n. (SHG); Mecca, El Abdia, Um-Alqura University campus, Abdel Khalik s.n. (SHG).