

NUMERICAL TAXONOMY OF GENUS *FICUS* L. 1753 (MORACEAE), WITH ADDITION NEW RECORD SPECIES TO EGYPT

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ABSTRACT

The taxonomy of *Ficus* L., 1753 species is confusing because of the intense morphological variability and the ambiguity of the taxa. This study handled 36 macro-morphological characteristics to clarify the taxonomic identity of the taxa. The study revealed that *Ficus* is represented in the Egyptian gardens with forty-one taxa; 33 species, 4 subspecies and 4 varieties, and classified into five subgenera: *Ficus* Corner, 1960; *Terega* Raf., 1838; *Sycomorus* Raf., 1838; *Synoecia* (Miq.) Miq., 1867, and *Spherosuke* Raf., 1838; out of them seven were misidentified. Amongst, four new *Ficus* taxa were recently introduced to Egypt namely: *F. lingua* subsp. *lingua* Warb. ex De Wild. & T. Durand, 1901; *F. pumila* L., 1753; *F. rumphii* Blume, 1825, and *F. sur* Forssk., 1775. The application of the multivariate analyses in plant systematics namely the two-way clustering analysis and the principal component analysis revealed that the qualitative characters as the presence or absence of lateral peduncular or ostiolar bracts and the leaf margin delimit the differentiation of subgenera within genus *Ficus*. Whereas the qualitative characters of the leaf as leaf arrangement, lamina shape, length, ratio of length to width, base, apex, number of lateral veins, stipules and figs either pedunculate or sessile, shape, and width are significantly separating the species within the different sections. Seven different identification keys of the studied taxa based on the examined characters are provided. In addition, a diagrammatic key for all the studied taxa is given.

Keywords: Cluster analysis, *Ficus*, Identification, New record, Principal component analysis.

INTRODUCTION

Ficus L., 1753 (Moraceae), is ranked as one of the largest twentieth genera of angiosperms (Frodin, 2004); it is comprised of over 1000 species of trees, shrubs, climbers, stranglers, or woody epiphytes distributed throughout tropical and subtropical regions of the world (Weiblen, 2000), half of them are recorded in Asia and Australia. On the contrary, Africa and the Neotropics are hosting 110 and 130 species; it respectively shows the most diversified taxa concerning growth habits (Harrison, 2005). This genus is characterized by the milky juice and the presence of minute unisexual flowers inserted internally on the wall of an urceolate receptacle emerging externally through an apical pore (orifice) usually protected by scale-like bracts (Hutchinson and Dalziel, 1958; Sharma, 1993). The fig (syconium) is sessile or pedunculate, 2-3 involucre bracts its base; lateral bracts sometimes present on the side of fig, scale-like, caducous, or persistent. Economically, *Ficus* species are very important since their edible fruits are eaten by 1200 species of vertebrates (Shanahan *et al.*, 2001). Several *Ficus* species are reported to have medicinal properties as an antimalarial, antitrypanosoma (Caliskan *et al.*, 2017), antidiabetic and antioxidant (Arunachalam and Parimelazhagan, 2014).

In Egypt, *Ficus* presents in the wild flora by four species, namely *F. cordata* Thunb. subsp. *salicifolia* (Vahl) C.C. Berg, 1988; *F. palmata* Forssk., 1775; *F. carica* L., 1753 and *F. sycomorus* L., 1753 (Boulos, 2009). The two latter species are recorded in ancient Egypt (Zohary *et al.*, 2012). On the other hand, many species of the genus *Ficus* are introduced and cultivated in many of the historic gardens and avenues since the 19th century.

The genus of *Ficus* is subjected to earlier systematic studies, such as systematics of subgenus *Urostigma* sect. *Malvanthera* (Dixon 1999), in addition, he conducted a systematic revision of *Ficus* species (subgenus *Urostigma*, section *Malvanthera*) in Australia (Dixon, 2003). Mubo *et al.* (2004) made a morphometric analysis of this genus; Furthermore, van Noort *et al.* (2007) recorded two species of *Ficus* in Mozambique, while Ogunkunle and Oladele (2008) studied the leaf epidermis of the 20 Nigerian *Ficus* species; however; Chaudhary *et al.* (2012) provided a synopsis of the 115 taxa of genus *Ficus* in India, while, Fatihah *et al.* (2012) studied the correlation between the morphology and the genetic analysis of seven varieties of *Ficus deltoidea* from Malaysia, whereas, Jangam *et al.* (2017) studied the leaf morphometrics in some *Ficus* species in Kolhapur District in India; also Sudhakar and Murthy (2017) studied the taxonomy and distribution of *Ficus talbotii* in India. On the other hand, Machado *et al.* (2018) studied the relationship between biology, geographical history, and divergence times in Neotropical *Ficus*.

Few taxonomic studies were performed in Egypt, among them: leaf architecture of 24 species from the three subgenera *Ficus*, *Sycomorus*, and *Urostigma* (Loutfy *et al.*, 2005); Moreover, the Sequence Tag (EST) markers and morphological traits for some ornamental *Ficus* were expressed species (Esmail *et al.*, 2014). Furthermore; the pollen morphology of 17 *Ficus* species were investigated (Teleb and Salah-El-din, 2014).

The application of multivariate analyses in plant systematics was currently used in the classification of many taxa and presenting results in the systematic studies (Sneath and Sokal, 1973; Chiapella, 2000; Gomez-Campo *et al.*, 2001; López-Palacios *et al.*, 2019; Hssaini *et al.*, 2020; Kamran *et al.*, 2020; Muhammad *et al.*, 2021). Numerical taxonomic studies were significant for documenting the morphological characters, and several attempts have been made in this regard to the comprehension of phenetic connections in various classes of plants (Mubo *et al.*, 2004; Pinheiro and De Barros, 2007; Mulumba and Kakudidi, 2010; Deshmukh, 2011; Rahman and Rahman, 2012).

Taxonomy of Genus *Ficus* is still confusing because of the intense morphological variability and the ambiguity of the taxa (Mubo *et al.*, 2004). In Egypt, few studies (e.g. Loutfy *et al.*, 2005) deal with the taxonomic or statistical analysis of the genus *Ficus*. Therefore, the present study aims to identify, and trace the close relationships among the taxa belonging to this genus, and construct a manual systematic key to facilitate the identification and the differentiation among the various studied taxa.

MATERIALS AND METHODS

Plant material

The morphological data were based on fresh representative samples of the studied taxa collected between January 2019- December 2020 by the authors from the historic, public or private gardens, generic places and avenues in Egypt (Map 1); the coordinates of the localities where fresh specimens were collected are given in Appendix (1). In addition to the examinations of over 300 herbarium specimens deposited in Cairo University Herbarium (CAI), the Agricultural Research Centre, Flora and Phytotaxonomy Herbarium (CAIM), Orman garden Herbarium, and Mazhar botanic garden Herbarium (MAZHAR). Digital photographs of the authentic specimens from different online herbaria were also examined.

Voucher specimens of the studied taxa are given in Appendix (2) and deposited in Cairo University Herbarium (CAI). Identification and updated nomenclature were revised and confirmed using the available literature among them; Täckholm (1974), Bailey and Bailey (1976), Corner (1977), Ghafoor (1985), Berg and Hijman (1989), Berg (1991), Boulos (2009), and Pederneiras *et al.* (2015). The online sites such as: The Plant list (2013), IPNI (2021), van Noort and Rasplus (2021), and Missouri Botanical Garden (2021) were also consulted.



Map (1): Represents the locations of the 13 localities (public, private gardens and generic places) where fresh specimens were collected, for the coordinates (see appendix 1). (<https://earth.google.com>).

Morphological characters

Abbreviations of the morphological characters and character states scored for habit, vegetative parts, and fruit characters of the studied taxa, used in the statistical analyses, are outlined in Table (1). For each population, 30 specimens have been taken to study the different morphological traits of each taxon. In total, 36 characters were observed, comprising 12 quantitative and 24 qualitative characters, the Kew Plant Glossary (Beentje, 2016) was used for the trait terminology. Thirteen of these characters are scored as bistate and the remaining were scored as multistate characters such as; leaf arrangement is alternate, spiral or opposite is a multi (tri) state character. The collected specimens were investigated and measured using a stereomicroscope (Wild Heerbrugg, M1B) at Cairo University Herbarium.

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Table (1): The characters, character states, and abbreviations used in morphometric analysis of *Ficus* taxa, arranged alphabetically.

Characters and character states	Abbrev.	Characters and character states	Abbrev.
Basal bracts length (mm)		Leaf blade shape	
<4	bbrl:<4	oblanceolate to obovate	lsh:obla
4-9	bbrl:4-9	cordiform (broadly ovate)	lsh: cor
>9	bbrl:>9	obtriangular to sub-obovate	lsh:obt
Basal bracts number		elliptic (ovate-elliptic)	lsh: ell
2	bbrn:2	ovate to ovate-elliptic,	lsh: ova
3	bbrn:3	ovate-lanceolate	
Fig drywall Surface		oblong, oblong-lanceolate,	lsh:oblo
Glabrous	fdsu:gl	elliptic-oblong, ovate-oblong	
Sparsely hairy	fdsu: ha	Leaf lamina length (cm)	
Pubescent	fdsu:pu	< 6	ll:< 6
Fig Fresh Wall surface		6-12	ll:6-12
Glabrous	ffrsu:gl	12.1-20	ll:12.1-20
Sparsely hairy	ffrsu: ha	>20	ll:>20
Pubescent	ffrsu:pu	Leaf lamina length/width	
Fig inter floral bracts		L < 1 x W	ll/w:<1
Absent	finfbr: a	L = 1.5-3 x W	ll/w:1-3
Present	finfbr:b	L > 3 x W	ll/w:>3
Fig length (cm)		Leaf lower surface	
<1	fl:<1	glabrous	llo:gl
1-2	fl:1-2	sparsely hairy	llo: ha
2.1-3	fl:2.1-3	pubescent	llo:pu
3-5	fl:>3	Leaf margin	
Fig length/width		entire to undulate	lma: ent
L= 1 x W	fl/w:1	dentate/serrate	lma: dent
L= 1.5-2 x W	fl/w:2	Leaf symmetry	
Fig peduncular bracts		symmetrical	lsy:sym
Absent	fpdbr:a	asymmetrical	lsy:asym
Present	fpdbr:p	Leaf texture	
Fig peduncle length (mm)		chartaceous	lte:cha
0	fpl:0	coriaceous	lte:cor
1-3	fpl:1-3	Leaf upper surface	
4-10	fpl:4-10	glabrous	lup:gl
>10	fpl:>10	sparsely hairy	lup:ha
Fig peduncle		pubescent	lup:pu
Sessile	fp: sess	Leaf width (cm)	
Subsessile (1-3 Mm)	fp: subs	< 5	lw:<5
Pedunculate	fp: ped	5-10	lw:5-10
Fig shape		11-18	lw:10.1-20
Globose	fsh:glo	20-27	lw:>20
Obovoid to ± pyriform	fsh:obo	Number of lateral vein pairs	
Oblong	fsh:obl	4-8	lv:4-8
Fig width (cm)		9-14	lv:9-14
< 1	fw:< 1	15-20	lv:15-20
1-2	fw:1-2	21-30	lv:21-30
2.1-3	fw:2.1-3	Ostiole bracts number	
>3	fw:>3	2-3	obrn:2-3
Fig wrinkled (when dry)		several	obrn:se
Wrinkled	fd:wr	numerous	obrn:nu
Not wrinkled	fd:nwr	Ostiole shape	

Habit		circular	osh:cir
Climber	hab:clim	bi-labiate	osh:bi
Tree	hab: tree	Petiole length (cm)	
Lateral bract	labr:p	up to 2 (-3)	pel:<3
Present	labr:a	3-10	pel:3-10
Absent		>10	pel:>10
Leaf apex		Petiole surface	
Caudate	lap: caud	glabrous	pesu:gl
acuminate–obtuse acuminate	lap: acum	sparsely hairy	pesu: ha
acute to obtuse or round	lap: acut	pubescent	pesu:pu
truncate to emarginate	lap: trun	Monoecy-Dioecy	
Leaf arrangement		Monoecious	mo
Alternate	ar:alt	(gyno) dioecious	di
Spiral	ar:spi	(gyno) monoecious to dioecious	mo-di
Opposite	ar:opp	Relation of midrib to the apex	
Leaf base		midrib reach the apex	mr: re
Auriculate	lba:auri	midrib does not reach the apex	mr: nre
Cordate	lba:cord	Stipule connate or free	
truncate to sub-cordate	lba:trun	connate	s: con
acute, obtuse to round, cuneate	lba:acut	free	s: free
Leaf-blade composition		Stipule length (cm)	
Simple	lbl: sim	<1	sle:<1
Lobed	lbl: lob	1-3	sle: 1-3
		3.1-5	sle: 3.1-5
		>5	sle: >5

Data analysis

The Multivariate Analysis of Ecological Data, PC-ORD for window, version 5.0, the two-way cluster analysis was applied. Cluster analysis aims to arrange a collection of objects (taxa) in such a way that items (taxa) in the same category (called a cluster) are, in some sense, more similar to one another than objects in other groups (clusters). More specifically, it tries to identify homogenous groups of cases if the grouping is not previously known. Two-way cluster analysis recognizes groupings by applying pre-clustering followed by hierarchical techniques. Since it utilizes a quick cluster algorithm upfront, it may handle large data sets that could take a long period to compute with hierarchical grouping methods. Two-way clustering can deal the same model in scale and ordinal data, and it automatically selects the number of clusters. The matrices of the 5 subgenera, 11 sections and 33 species, 4 subspecies, and 4 varieties of *Ficus* species are subjected to the Euclidean Distance Measure with Ward's Method. The qualitative morphological characters are transformed into binary characters (0, 1) to allow the use of cluster analysis techniques. Then, the same data are subjected to the principal component analysis (PCA) for confirmation. This is followed by the generalization of artificial keys depending on the morphological characters investigated. An overall diagrammatic key is provided for all the studied species.

RESULTS

The clustering of the five subgenera

Seven morphological characters, namely the plant habit, the sexuality (monoecy and/or dioecy), leaf margin, ostiole bracts number, internal floral bracts, peduncular bracts, and lateral bracts are used to differentiate between the investigated *Ficus* taxa into five subgenera. The abbreviations of these characters are presented in Table (1) and at the top of the columns in Diagram (1). The results of the studied taxa revealed that these taxa were belonging to five subgenera namely: *Ficus* Corner, 1960; *Terega* Raf., 1838; *Sycomorus* Raf., 1838, *Synoecia* (Miq.) Miq., 1867, and *Spherosuke* Raf., 1838. At the first level of differentiation (Diag. 1), the five subgenera are divided into two branches at distance level 14.800, the first branch includes three subgenera (*Ficus*, *Sycomorus*, and *Terega*) characterized by dentate leaf margins and several or numerous ostiole bracts, while the other branch

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includes 2 subgenera (*Spherosuke* and *Synoecia*) which are characterized by entire leaf margins and 2-3 ostiole bracts, these characters are surrounded by pink-colored borders (Diag.1). The former branch is subdivided into *Terega* in one sub-branch, characterized by the presence of lateral and fig peduncular bracts while these are absent in *Ficus* and *Sycomoru* in the other branch, these characters are surrounded by yellow borders (Diag.1). *Spherosuke* is easily differentiated from *Synoecia*, that the former is a monoecious tree with fig inter floral bracts are present while *Synoecia* is a climber, (gyno) dioecious and its fig inter floral bracts are absent. Furthermore, subgenus *Ficus* is differentiated by being (gyno) dioecious, several ostiole bracts compared to subgenus *Sycomorus* that is monoecious - (gyno) dioecious and numerous ostiole bracts (surrounded by green borders).

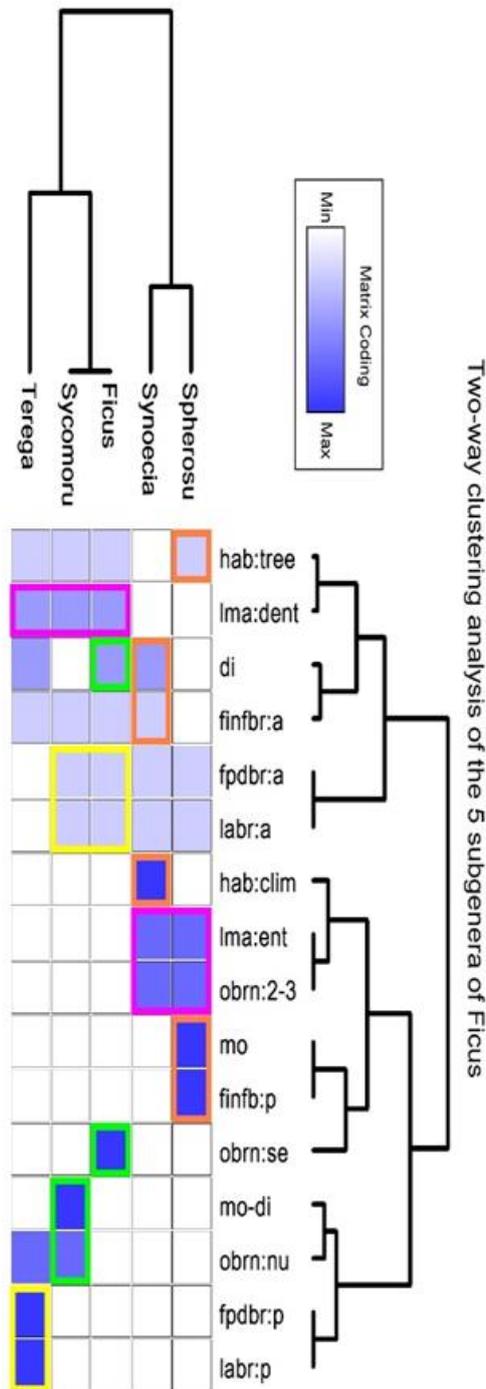


Diagram (1): The two-way clustering analysis using the Euclidean Distance Measure with Ward's Method of the 5 subgenera of *Ficus* in Egypt, (for abbreviations, see Table 1). The changes in borders' colors (pink, yellow, brown and green) indicate the levels of differentiation respectively.

Diagram (2) shows the principal component analysis of the morphological matrix of the five subgenera of *Ficus*. It is noticed that some of these characters are confined to a definite subgenus. For instance, the presence of peduncular and lateral bracts are confined to subgenus *Terega*, monoecious to (gyno) dioecious is confined to subgenus *Sycomorus*, several ostiolar bracts are confined to subgenus *Ficus*, climber habit is confined to *Synoecia*, monoecious and presence of figs inter floral bracts are confined to subgenus *Spherosuke*.

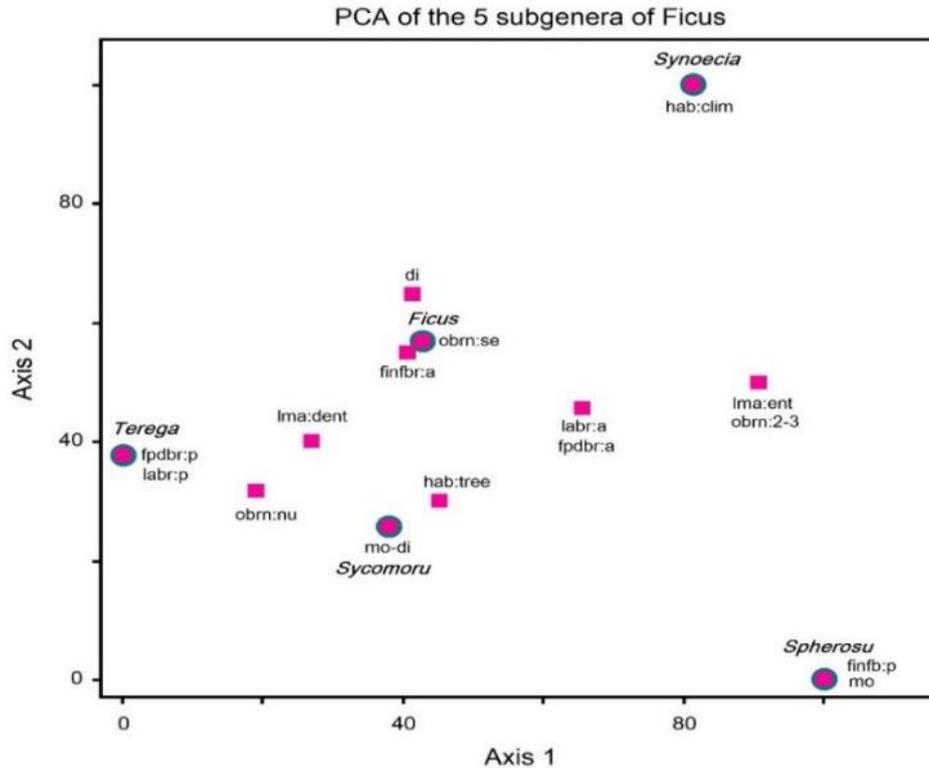


Diagram (2): The principal component analysis of the morphological matrix of the five subgenera of *Ficus*. (For abbreviation, see Table 1).

The application of the two-way clustering analysis (CA) and the principal component analysis (PCA) facilitated the construction of identification key for the five subgenera of the genus *Ficus* in Egypt as follows:

1. Leaf margin dentate, with several-numerous ostiolar bracts 2
 - Leaf margin entire, with 2-3 ostiolar bracts 4
2. Figs with lateral and peduncular bracts subgen. *Terega*
 - Figs without lateral and peduncular bracts 3
3. Plants (gyno) dioecious, figs with several (4-10) ostiolar bracts..... subgen. *Ficus*
 - Plants monoecious or (gyno) dioecious, figs with numerous (>10), ostiolar bracts subgen. *Sycomorus*
4. Plants (gyno) dioecious, climbers, figs without interfloral bract subgen. *Synoecia*
 - Plants monoecious, trees or shrubs, figs with interfloral bracts subgen. *Spherosuke*

I- Subgenus *Ficus*

This subgenus is represented in Egypt by four species belonging to 2 sections: *Ficus* and *Eriosycea* (Miq.) Miq., 1867. These species are trees, with spiral leaf arrangement, wrinkled dry figs, 4-7 bilabiate ostiolar bracts, 3 basal bracts, up to 4 mm/each. Diagram (3) represents the two-way clustering analysis of the morphological matrix for the 21 characters of the four species of the subgenus *Ficus*. At the first distance level 28.250 of differentiation, *F. neriifolia* Sm., 1810 (Pl.1A) is separated from the other 3 species by its glabrous petiole, leaf lower surface and dry fig wall surface; both fig length or width are less than 1 cm., these characters are bordered in pink color (Diag. 3). At the second distance level 14.667, *F. hirta* Vahl, 1806 (Pl.1B) is separated from the other two species by the characters surrounded by the yellow borders; leaf apex acuminate, figs sessile and globose, petiole surface sparsely hairy, both fig length and width are 2-3 cm (Diag. 3). Moreover; *F. palmata* (Pl.1C)

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and *F. carica* (Pl.1D) are separated at the third distance level 6.500 by the characters that surrounded by the green borders (Diag. 3).

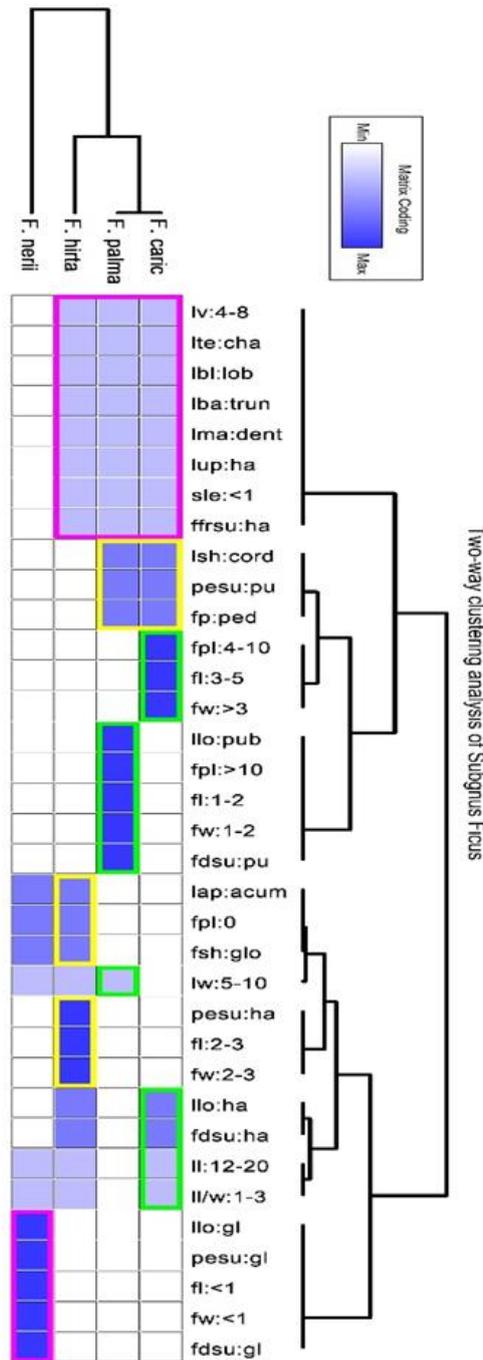


Diagram (3): The two-way clustering analysis using the Euclidean Distance Measure with Ward's Method of the 4 species of subgenus *Ficus* (for abbreviations see Table 1). The changes in borders' colors (pink, yellow and green) indicate the levels of differentiation.

Diagram (4) shows the principal component analysis of the morphological matrix of the four species of subgenus *Ficus*. It is noticed that some of these characters are restricted to definite species. For instance, *F. nerifolia* is characterized by its figs length and width less than 1 cm, glabrous leaf lower surface, petiole, and fig wall surface when dry. Furthermore, the characters as figs length and width 2-3 cm, sparsely hairy petiole are restricted to *F. hirta*. On the other hand, in *F. palmata* figs length is 1-2 cm (vs. 3-5 in *F. carica*), width is 1-2 cm (vs. 3 cm in *F. carica*), peduncle is 4-10 mm long (vs. more than 10 mm in *F. carica*) and the fig wall surface is pubescent when dry (vs. sparsely hairy in *F. carica*).

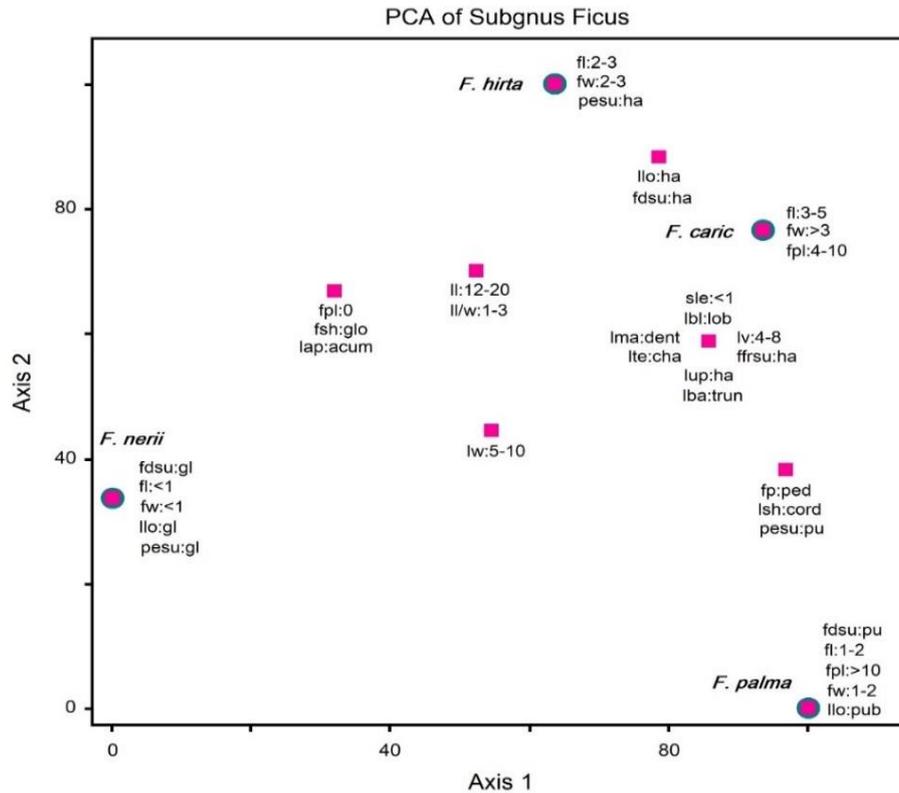


Diagram (4): The principal component analysis of the morphological matrix of the 4 species of subgenus *Ficus*. (For abbreviations, see Table 1).

The application of the two-way clustering analysis (CA) and the principal component analysis (PCA) helped in the construction of the identification key for the 4 species of subgenus *Ficus* in Egypt.

Identification Key to the species of subgenus *Ficus*

1. 3-5 lobed lamina, with 4-8 pairs of lateral veins, chartaceous with dentate margin and truncate base, petiole surface sparsely hairy, figs length 1-5 cm, 1-5 cm in diameter 2
 - Simple lamina, with 9-14 pairs of lateral veins, coriaceous, with entire margin, petiole surface glabrous, figs length up to 1 cm and up to 1 cm in diameter *F. neriiifolia*
2. Lamina cordate with acute or obtuse to rounded apex, petiole surface pubescent; figs pedunculate, obovoid to \pm pyriform 3
 - Lamina elliptic or ovate-oblong with acuminate apex, petiole surface with sparse hair, figs sessile, globose *F. hirta*
3. Lamina nearly as long as broad; number of leaf lobes 3-5; figs 1-2 cm long and 1-2 cm in diameter; peduncle length more than 10 mm; pubescent when dry *F. palmate*
 - Lamina usually longer than broad; number of leaf lobes 1-3, figs 3-5 cm long and 3-5 cm in diameter, peduncle length less than 10 mm, sparsely hair sparse when dry *F. carica*

II- Subgenus *Terega*

The subgenus *Terega* (= *Ficus* subg. *Sycidium* (Miq.) Mildbr. & Burret) is represented in Egypt by two taxa; *F. aspera* G. Forst., 1786 (Pl.1E) in Section *Sycidium* (Miq.) Miq., 1867, and *F. tinctoria* subsp. *gibbosa* (Blume) Corner, 1959 (Pl.1F) in Section *Palaeomorpha* King., 1887. These are characterized by 4-8 lateral vein pairs, leaf asymmetric, elliptic, figs globose, bi-labiate with numerous ostiolar bracts and 3 basal bracts.

Identification key to taxa of the subgenus *Terega*

- 1- Leaf margin dentate, with subcordate base, figs 1-2 cm in diameter, with pubescent hairs, pedunculate, peduncle more than 10 mm *F. aspera*
 - Leaf margin entire, with cuneate base, figs 0.5-0.8 cm in diameter, with sparse hairs, subsessile, peduncle 1-3 mm *F. tinctoria* subsp. *gibbosa*

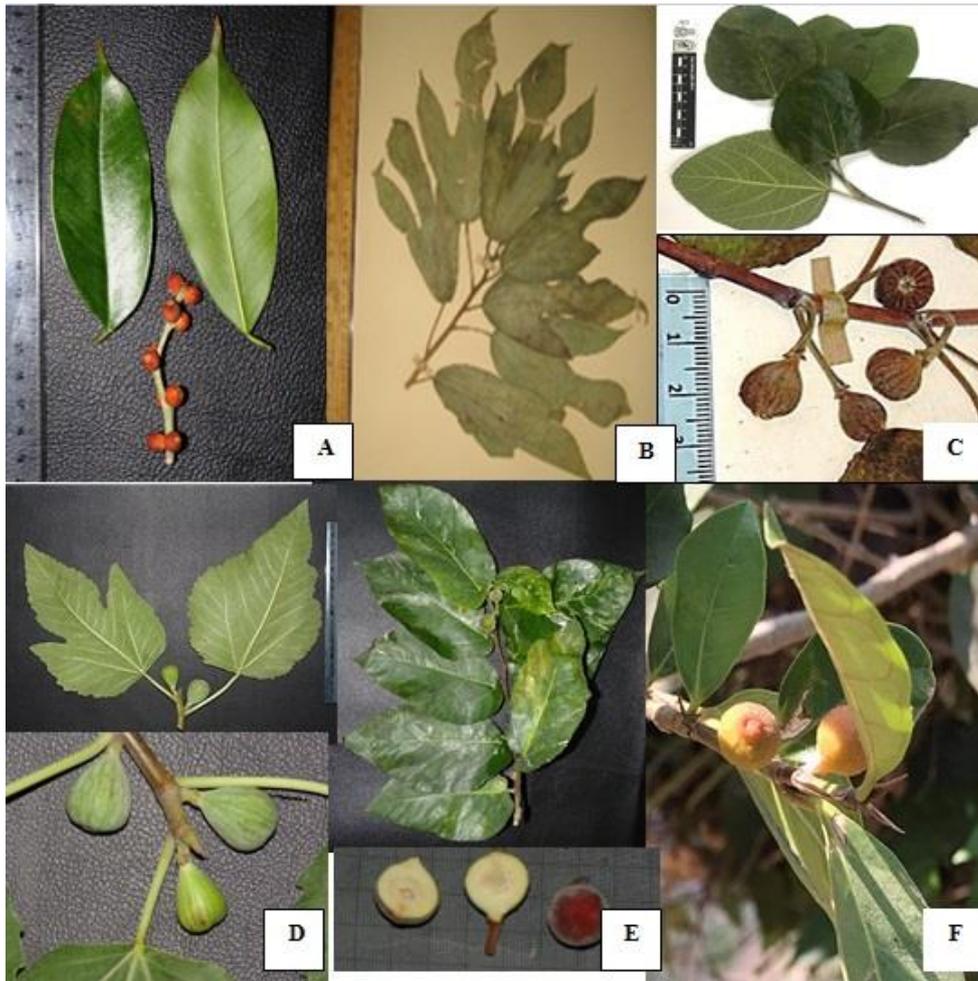


Plate (1): Photographs of *Ficus* species subgenus *Ficus* (A-D); (A) *F. nerifolia*, upper and lower surface of leaves and fruiting twigs; (B) *F. hirta*, a twig with leaves; (C) *F. palmata*, a twig with leaves and fruits; (D) *F. carica*, a twig with leaves and fruits. Subgenus *Terega* (E-F); (E) *F. aspera*, a twig with leaves and fruits; (F) *F. tinctoria* subsp. *gibbosa*, a twig with leaves upper and lower surfaces and fruits.

III- Subgenus *Sycomorus*

The subgenus *Sycomorus* is represented in Egypt by 6 species (*F. septica* Burm. f., 1768 (Pl. 2A); *F. hispida* L.f., 1781 (Pl. 2B); *F. sur* Forssk., 1775 (Pl. 2C); *F. auriculata* Lour, 1790 (Pl. 2D); *F. sycomorus* (Pl. 2 E); *F. racemosa* L., 1753 (Pl. 2F) characterized by elliptic to ovate-elliptic leaf, entire margin, 4-8 lateral vein pairs, fig peduncle more than 10 mm, circular ostiole with 4-7 ostiolar bracts. Eighteen characters were used to differentiate between the 6 species of subgenus *Sycomorus* (Diag. 5). The main characters separate between species are leaf arrangement, texture and length of lamina.

At the first level of differentiation (distance level 25.667), *F. racemosa* and *F. sycomorus* were separated from the other 4 species by spiral leaf arrangement, leaf 6-12 cm long, and figs when dry wrinkled (characters are surrounded by the pink borders). The leaf morphology differentiates between these two species, *F. racemosa* characterized by its glabrous leaf upper surface while *F. sycomorus* has a chartaceous leaf texture, dentate margin, lower surface sparsely hairy and ratio of length/width equal one, these characters are surrounded by brown borders. On the other branch includes four species, *F. septica* is separated by fig wall surface glabrous when dry, others are wrinkled (characters are surrounded by yellow borders). *F. hispida* differentiated from the other two species by its globose. *F. sur* is separated from *F. auriculata* by leaf length 12.1-20 cm, leaf base truncate to sub-cordate and figs ratio of length/width equal one, these characters are surrounded by green borders.

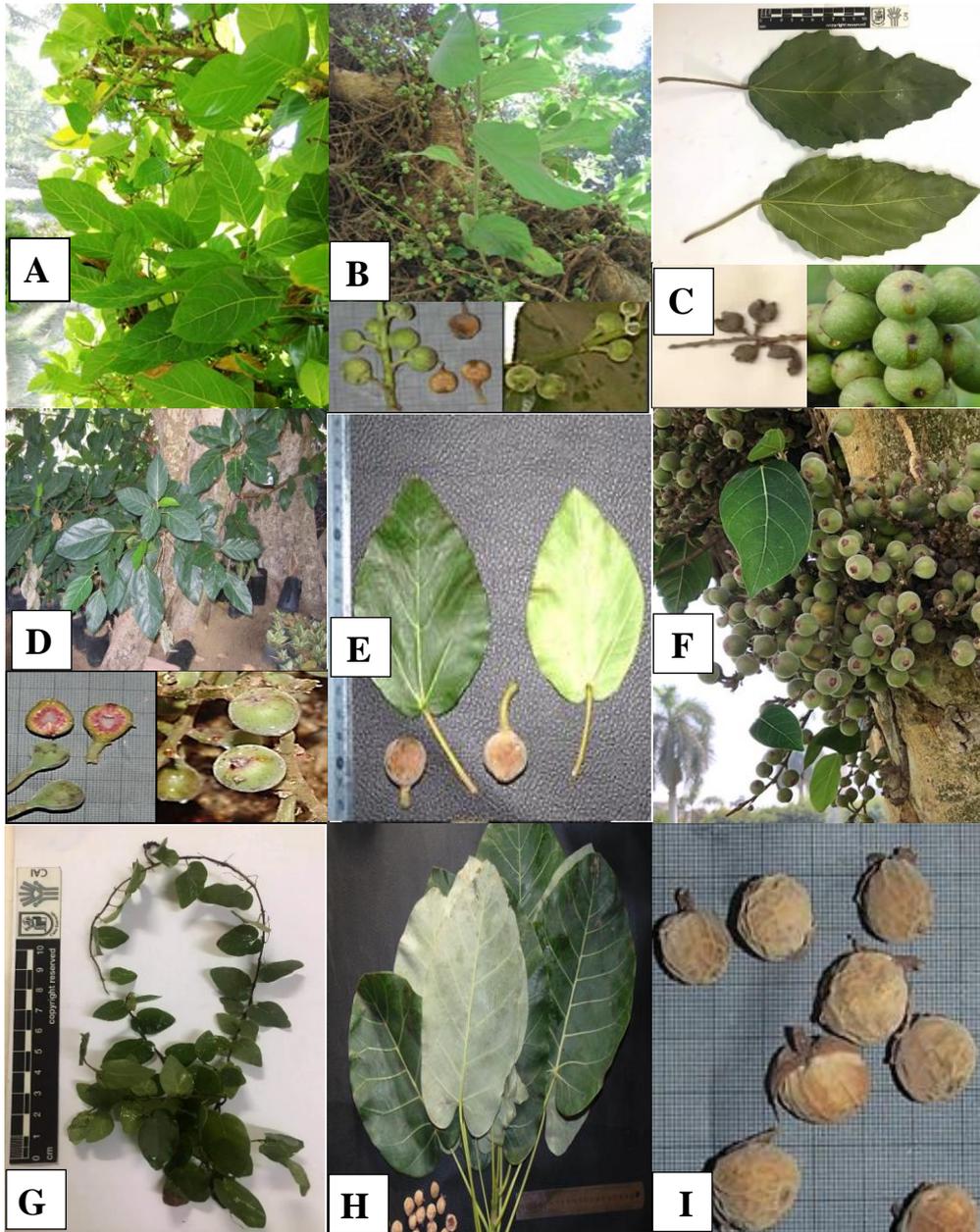


Plate (2): Photographs of *Ficus* species subgenus *Sycomorus* (A-F); (A) *F. septica*, a twig with leaves; (B) *F. hispida*, a twig with leaves and fruits; (C) *F. sur*, upper and lower surface of leaves and fruiting twigs; (D) *F. auriculata*, a twig with leaves and fruits; (E) *F. sycomorus*, upper and lower surface of leaves and fruits; (F) *F. racemosa*, a twig with leaves and fruits. Subgenus *Synoecia*: (G) *F. pumila*, a twig with leaves. Subgenus *Spherosuke*-Section *Americana* (H-I); (H) *F. nymphaeifolia*, upper and lower surfaces of leaves; (I) *F. nymphaeifolia*, fruits.

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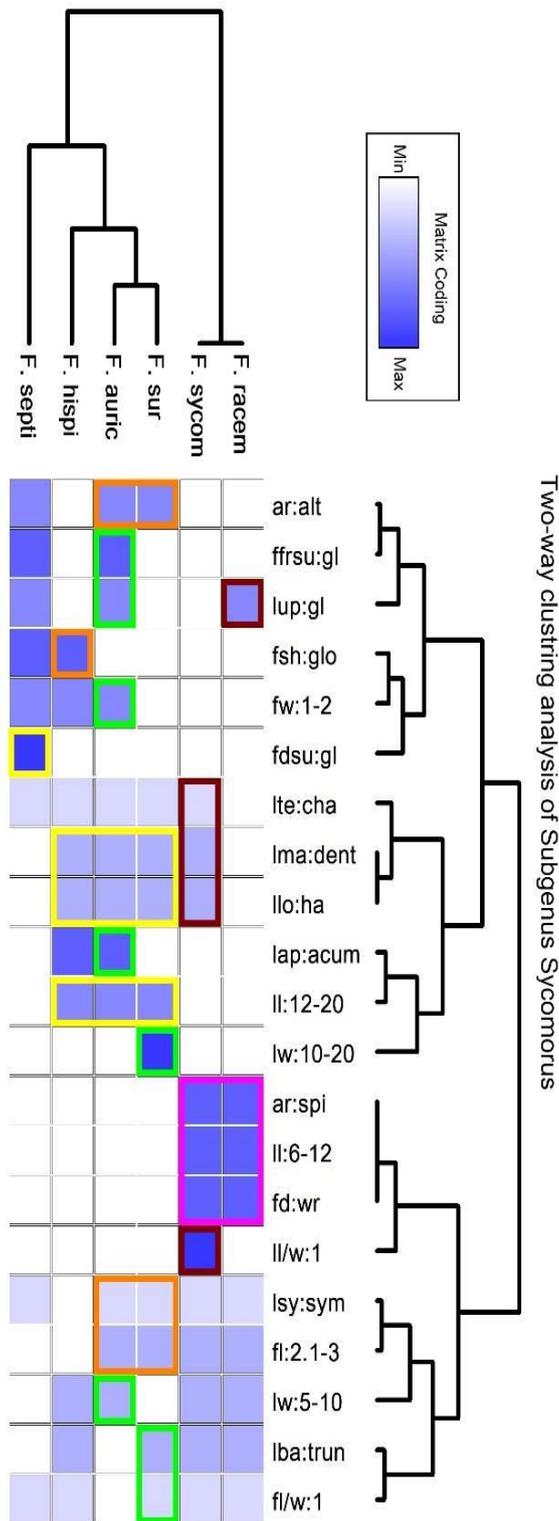


Diagram (5): The two-way clustering analysis using the Euclidean Distance Measure with Ward's Method of the 6 species of subgenus *Sycomorus*, (for abbreviations, see Table 1). The changes in borders' colors (pink, yellow, brown and green) indicate the different levels of differentiation.

Diagram (6) shows the principal component analysis of the morphological matrix of the six species of subgenus *Sycomorus*. It is noticed that some of these characters are restricted to definite species. For instance, the character of the glabrous dry wall of the fig is confined to *F. septica*, the leaf diameter 10-20 cm wide is confined to *F. sur* and the equal ratio of the leaf length to width is confined to *F. sycomor*.

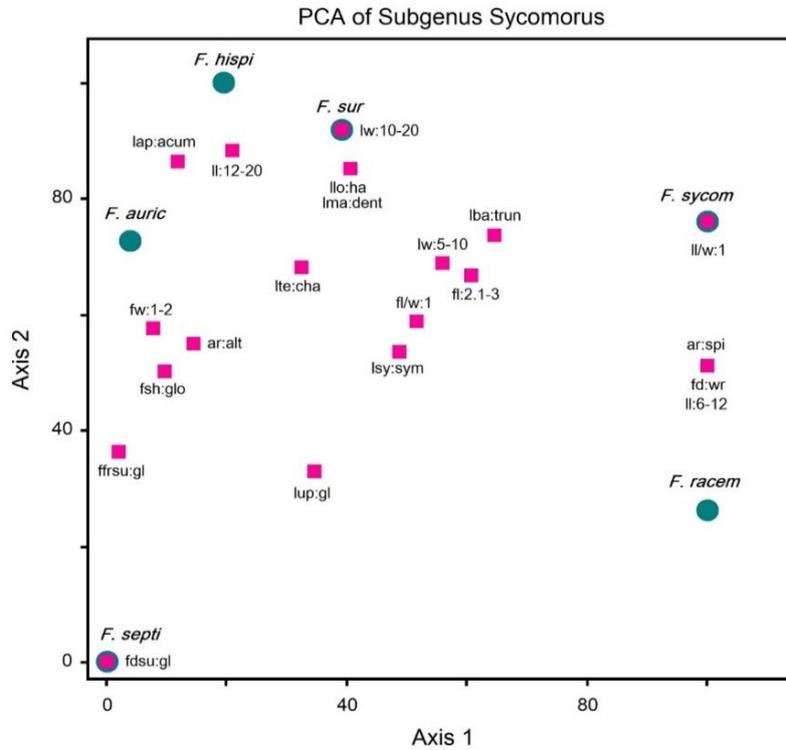


Diagram (6): The principal component analysis of the morphological matrix of the 4 species of subgenus *Sycomorus* (for abbreviations, see Table 1).

The application of the two-way clustering analysis (CA) and the principal component analysis (PCA) helped in the construction of identification key for the 6 species of subgenus *Sycomorus* in Egypt.

Identification Key to the species of the subgenus *Sycomorus*:

1. Leaf arrangement opposite or alternate, lamina more than 12 cm long, fig when dry mostly smooth..... 2
 - Leaf arrangement spiral, lamina 6-12 cm long, fig when dry mostly wrinkled 5
2. Lamina 20-35 cm long and more than 20 cm in diameter, margin entire, figs wall surface glabrous when dry *F. septica*
 - Lamina 12-20 cm long and less than 20 cm in diameter, margin dentate, figs wall surface with sparse hair when dry 3
3. Leaf arrangement opposite, asymmetrical, figs globose, 1-2 cm long *F. hispida*
 - Leaf arrangement alternate, symmetrical, figs obovoid, length 2-3 cm long 4
4. Leaf base truncate, apex obtuse, leaf width 10-20 cm, figs 2-3 cm in diameter *F. sur*
 - Leaf base obtuse/round, apex obtusely acuminate, leaf width 5-10 cm, figs up to 2 cm in diameter *F. auriculata*
5. Lamina chartaceous, margin dentate, surface with sparse hair, 1-1.5 times as long as broad *F. Sycomorus*
 - Lamina coriaceous, margin entire, surface glabrous, 1.6-2 times as long as broad *F. racemose*

IV- Subgenus *Synoecia*

This subgenus is represented in Egypt by one species; *F. pumila* L., 1753 (Pl. 2 G). This species is distinguished from the other *Ficus* species in being creeping plant and has dimorphic leaf shape.

V- Subgenus *Spherosuke*

The Subgenus *Spherosuke* is the largest subgenus of *Ficus* in Egypt; represented by 4 sections, *Americanae* (Miq.) Corner, 1960; *Platyphyllae* Mildbr. & Burret, 1911; *Cordifoliae* G.Don, 1830 and *Urostigma* (Endl.) Griseb., 1859.

i. Section Americanae

This section is represented in Egypt by one species; *F. nymphaeifolia* Mill., 1768 (Pl.2H, I), which characterized by its two basal bracts number, 1-1.5 cm long.

ii. Section Platyphyllae

This section is represented in Egypt by 12 species (*F. lingua* subsp. *lingua* Warb. ex De Wild. & T. Durand 1901 (Pl. 3A); *F. thonningii* Blume, 1836 (Pl. 3B); *F. craterostoma* Warb. ex Mildbr. & Burret, 1911 (Pl. 3C); *F. natalensis* subsp. *leprieurii* (Miq.) C.C.Berg, 1988 (Pl. 3D); *F. lutea* Vahl, 1805 (Pl. 3E); *F. laurifolia* Lam, 1788 (Pl. 3F); *F. abutilifolia* (Miq.) Miq.1867 (Pl. 3G), *F. sp.* (Pl. 3H) *F. saussureana* DC, 1841 (Pl. 3I); *F. cyathistipula* Warb, 1894 (Pl. 3J); *F. lyrata* Warb, 1894 (Pl. 3K); *F. umbellata* Vahl, 1805 (Pl. 3L)). Twenty-four characters were used to distinguish between species. The main characters used to separate species were; length of the lamina, shape of leaf base and apex, reaching of the midrib to the leaf apex. All the species characterized by their coriaceous leaf (except *F. umbellata*, having chartaceous leaf), 2-3 ostiole bracts (except *F. lyrata*, having 4-7 ostiole bracts), 3 basal bracts (except *F. lingua* subsp. *lingua* and *F. thonningii* which have 2 basal bracts), spiral leaf arrangement (except *F. natalensis* subsp. *leprieurii*, having alternate leaf).

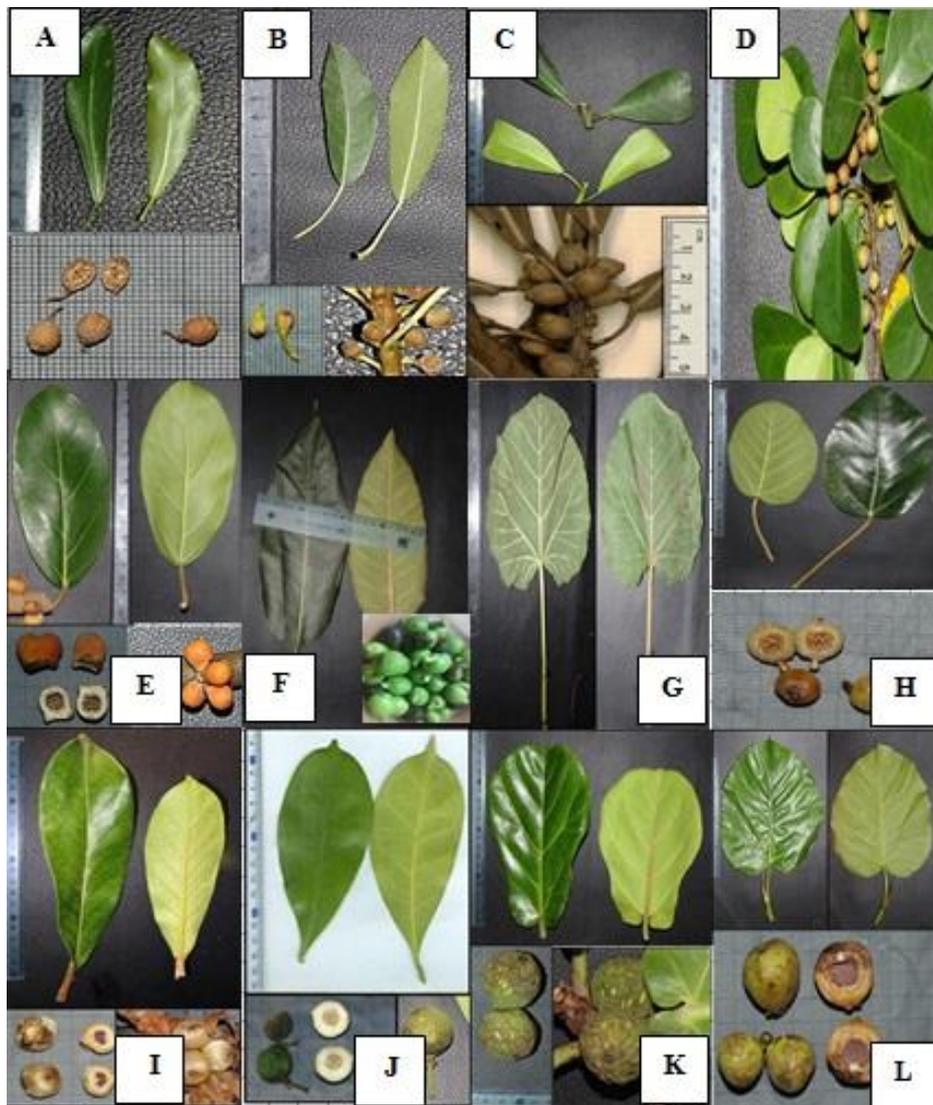


Plate (3): Photographs of *Ficus* taxa: Spherosuke-Section Platyphyllae (A-L); (A) *F. lingua* subsp. *lingua* upper and lower surface of leaves and fruits, (B) *F. thonningii*, upper and lower surface of leaves and fruits, (C) *F. craterostoma*, upper and lower surface of leaves and fruiting twigs; (D) *F. natalensis* subsp. *leprieurii*, a twig with leaves and fruits; (E) *F. lutea* upper and lower surface of leaves and fruits; (F) *F. laurifolia*, upper and lower surface of leaves and fruits; (G) *F. abutilifolia*, upper and lower surface of leaves-Upper and lower surface of leaves and fruits; (H) *F. sp.*; (I) *F. saussureana*; (J) *F. cyathistipula*; (K) *F. lyrata*, (L) *F. umbellata*.

The clustering analysis of Section *Platyphyllae*

At the first level (distance level 133.75) of differentiation (Diag. 7), four taxa are grouped in one branch, namely, *F. lingua* subsp. *lingua*, *F. thonningii*, *F. craterostoma* and *F. natalensis* subsp. *leprieurii* due to the presence of leaf width less than 5 cm, petiole length up to 2 (-3) cm, figs length and width less than 1 cm. (Characters are bordered in pink color). These 4 species are subdivided into two groups, group one includes *F. lingua* subsp. *lingua* and *F. thonningii* which characterized by the ratio of the lamina length to width more than 3, acute-obtuse or rounded apex, glabrous petiole, and figs with 2 basal bracts and wall surface sparsely hairy when dry. However; group two includes *F. craterostoma* and *F. natalensis* subsp. *leprieurii*, characterizing by the ratio of the lamina length to width less than 3, truncate to emarginate apex, sparsely hairy petiole, and figs with 3 basal bracts and wall surface glabrous when dry (Characters bordered by green color). The other 8 species are divided into two groups.

The first group contains 4 species; *F. umbellata*, *F. lyrata*, *F. cyathistipula* and *F. saussureana*, characterizing by stipule length 3.1-5 cm and fig width 2.1-3 cm (Characters bordered by yellow color). The other 4 species are further subdivided into two branches, *F. sp.* and *F. abutilifolia* characterized by the ratio of the lamina length/width less than 1, leaf length 12.1-20 cm, with cordate base and basal bracts length less than 4 mm while *F. laurifolia* and *F. lutea* are characterized by the ratio of the lamina length/width ranging from 1-3, lamina usually length 20-35 cm long, oblanceolate-obovate, with truncate to sub-cordate base, and figs basal bracts 4-9 mm long (Characters bordered by brown color).

Numerical taxonomy of genus *Ficus*

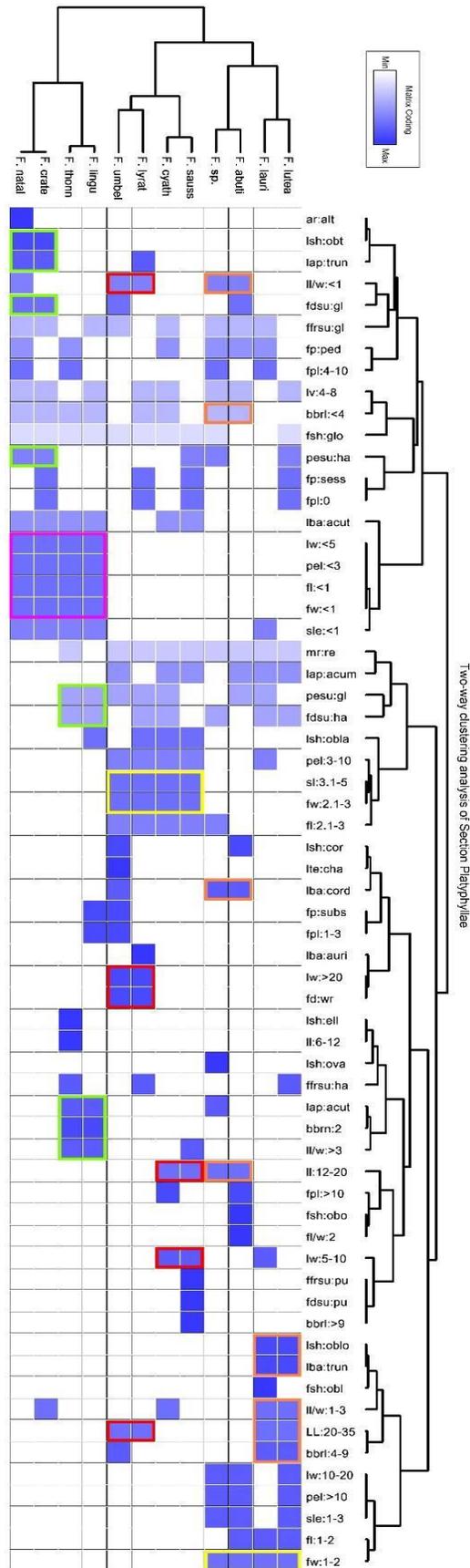


Diagram (7): The two-way clustering analysis using the Euclidean Distance Measure with Ward's Method of the 12 species of Section *Platyphyllae*, (for abbreviations see Table 1). The changes in borders' colors (pink, yellow, brown and green) indicate the different levels of differentiation.

Diagram (8) shows that some characters are confined to definite species, such as, figs oblong, 1.5-2 times as long as broad in *F. abutilifolia*, leaf shape ovate to ovate-elliptic in *F. sp.*, leaf arrangement alternate in *F. natalensis* subsp. *leprieurii*, leaf length 6-12 cm long and elliptic in *F. thonningii*, leaf base auriculate in *F. lyrata*, fig wall surface pubescent and basal bracts 9 mm long in *F. saussureana*, chartaceous leaf texture in *F. umbellata* and fig shape oblong in *F. laurifolia*.

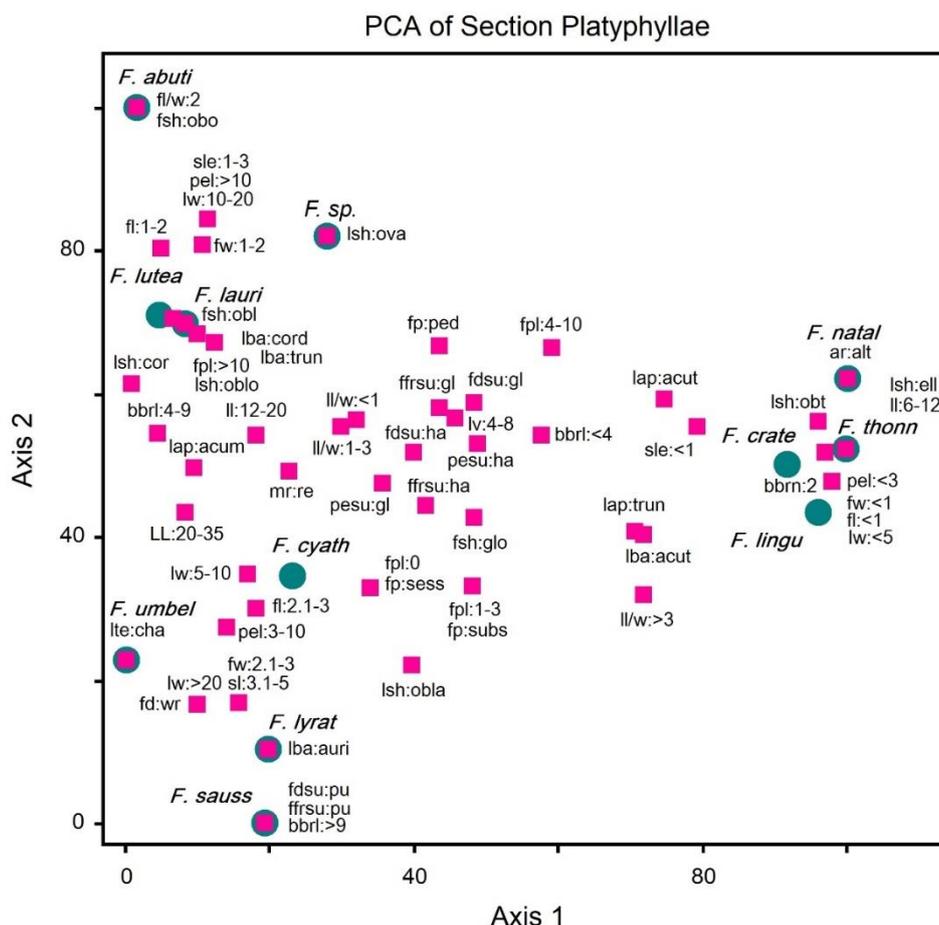


Diagram (8): The principal component analysis of the morphological matrix of the 12 species of Section *Platyphyllae* (for abbreviations, see Table 1)

The application of the two-way clustering analysis (CA) and the principal component analysis (PCA) helped in the construction identification key for the 6 taxa of section *Platyphyllae* in Egypt.

Identification Key to the taxa of Section *Platyphyllae*

1. Lamina up to 5 cm in diameter 2
 - Lamina more than 5 cm in diameter 5
2. Leaf apex obtuse or rounded, ratio of leaf length/width more than 3; petiole glabrous; fig wall surface sparsely hairy when dry; 2 basal bracts 3
 - Leaf apex truncate to emarginate, ratio of leaf length/width less than 3; petiole with sparse hair; fig wall glabrous when dry; 3 basal bracts 4
3. Lamina oblanceolate to obovate; lateral veins 4-8 pairs, less than 8 cm long; petiole less than 1.5cm long;fig subsessile (1-3 mm long.) *F. lingua* subsp. *lingua*
 - Lamina elliptic to ovate-elliptic; lateral veins 9-14 pairs, 8-12 cm long; petiole 2.5-4.5 cm long; fig peduncle length 4-10 mm long *F. thonningii*
4. Leaf arrangement spiral, surface glabrous, ratio of leaf length/width =1-3, fig 1-2 cm in diam., sessile *F. craterostoma*
 - Leaf arrangement alternate, surface with sparse hair, ratio of leaf length/width =1, fig less than 1cm in diam., peduncle length 4-10 mm *F. natalensis* subsp. *leprieurii*
5. Stipules less than 3 cm long, fig 1-2 cm in diameter 6
 - Stipules 3-5 cm long, fig 2-3 cm in diameter 9

Numerical taxonomy of genus *Ficus*

6. Lamina oblong, elliptic-oblong or ovate-oblong, 20-35 cm long, base truncate to sub-cordate, the ratio of leaf length/width =1.5-3, basal bracts 4-9 mm long7
 - Lamina ovate to cordate, 12-20 cm long, base cordate, the ratio of leaf length/width=1, basal bracts up to 4 mm long 8
7. Lateral vein 4-6 pairs, lower surface and petiole with sparse hair; petiole 9-20 cm long, stipules 1-3 cm long, fig sessile, globose, with sparse hair, when fresh *F. lutea*
 - Lateral vein 9-10 pairs, lower surface and petiole glabrous, petiole 4-8 cm long, stipules up to 1cm long, fig pedunculate, oblong, glabrous when fresh *F. laurifolia*
8. Lamina cordiform (broadly ovate), apex obtusely acuminate, upper surface and petiole glabrous; fig obovoid, 1-2 cm long, the ratio of fig length/width =1.5-2, dry fig wall glabrous, peduncle 0.6-1.5 cm long *F. abutilifolia*
 - Lamina ovate, apex obtuse to round, upper surface and petiole with sparse hair; fig globose, 2-3cm long, the ratio of fig length/width =1(-1.3), dry fig sparsely hairy, peduncle length 0.3-0.5 cm *Ficus* sp.
9. Leaf lamina 12-20 cm long, 3.5-8 cm in diam., with obtuse to cuneate base, dry fig wall not wrinkled10
 - Leaf lamina 20-35 cm long, 10-27 cm in diam., with auriculate or cordate base, dry fig wall distinctly wrinkled..... 11
10. Lateral veins 8-12 pairs, leaf lower surface and petiole with sparse hair; ratio of leaf length/width = 3-3.5; fig sessile, fresh and drywall surface pubescent, basal bracts 9-15 mm long..... *F. saussureana*
 - Lateral veins 4-7 pairs; leaf lower surface and petiole glabrous; ratio of leaf length/width =2.2-2.8; fig pedunculate, fresh glabrous and with sparse hair when dry, basal bracts 3-4 mm long *F. cyathistipula*
11. Lateral veins 4-5 pairs; lamina oblanceolate to obovate, coriaceous, base auriculate, apex truncate to emarginate, basal bracts less than 4 mm long, ostiolar bracts several (more than 3) *F. lyrata*
 - Lateral veins 6-9 pairs; lamina cordiform (broadly ovate), chartaceous, base cordate, apex acuminate, basal bracts 4-9 mm long, 2-3 ostiolar bracts *F. umbellate*

iii. Section Cordifoliae

This section is represented in Egypt by 11 taxa including (*F. drupacea* Thunb., 1786 (Pl. 4A), *F. drupacea* var. *pubescens* (Roth) Corner, 1959 (Pl. 4B), *F. microcarpa* L. f., 1781 (Pl. 4C); *F. benjamina* L., 1767 (Pl. 4D); *F. amplissima* Sm., 1810 (Pl. 4E); *F. cordata* subsp. *salicifolia* (Pl. 4F), *F. virens* Aiton, 1789 var. *virens* Pl. 4G); *F. virens* var. *sublanceolata* (Miq.) Corner 1959 (Pl. 4H); *F. benghalensis* L., 1753 (Pl. 4I); *F. religiosa* L., 1753(Pl. 4J); *F. rumphii* Blume, 1825 (Pl. 4K). All species shared the spiral leaf arrangement (except *F. benjamina*, having alternate leaves), all with coriaceous leaves (except *F. virens*, which have chartaceous). Twenty-three characters were used to distinguish between the taxa of *Cordifoliae* section. The main characters separated between taxa are the number of lateral vein pairs, lamina length, width, leaf arrangement, and leaf apex, figs (wrinkling (when dry), surface, shape, pedunculate or sessile), and basal bracts length.

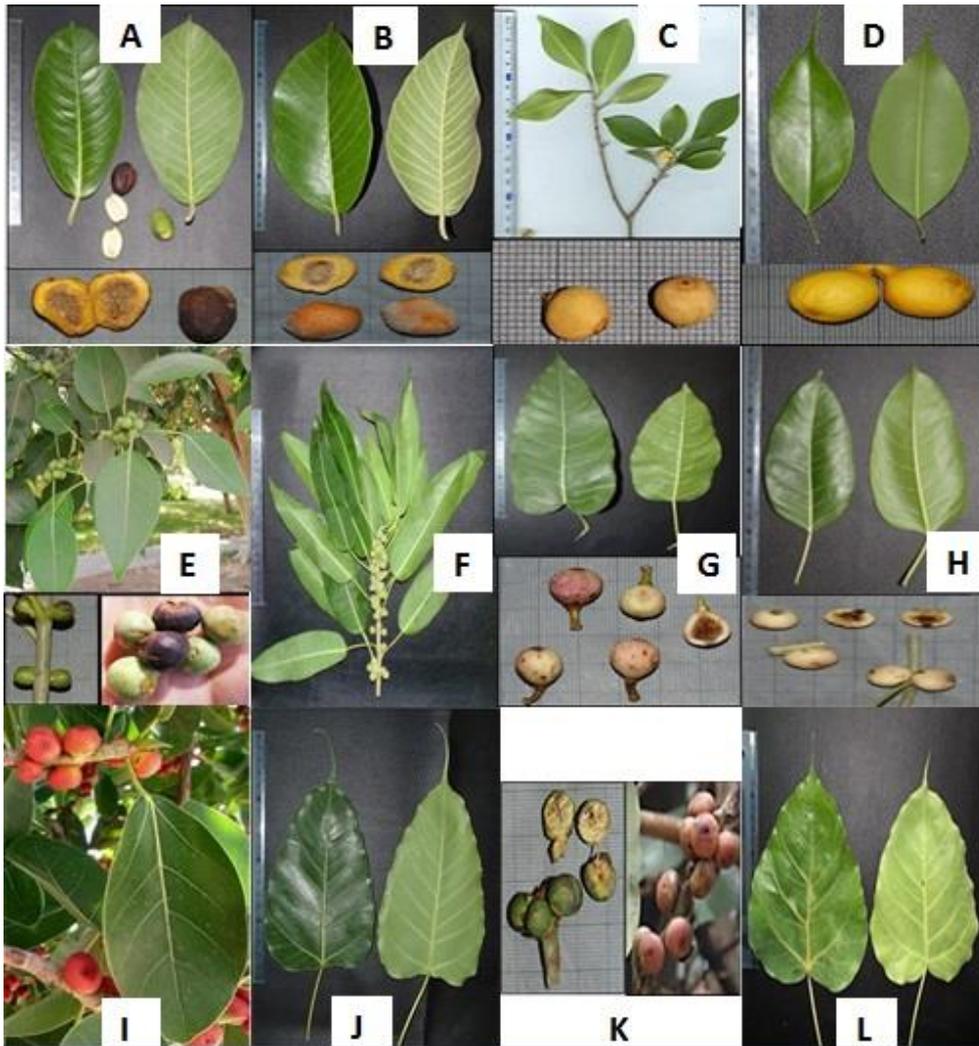


Plate (4): Photographs of *Ficus* taxa Spherosuke-Section Cordifoliae (A-L); (A) *F. drupacea* upper and lower surface of leaves and fruits; (B) *F. drupacea* var. *pubescens*, upper and lower surface of leaves and fruits; (C) *F. microcarpa*, a twig with leaves and fruits; (D) *F. benjamina*, upper and lower surface of leaves and fruits; (E) *F. amplissima* a twig with leaves and fruits; (F) *F. cordata* subsp. *salicifolia*, a twig with leaves and fruits; (G) *F. virens* var. *virens*, upper and lower surface of leaves; (H) *F. virens* var. *sublanceolata*, upper and lower surface of leaves; (I) *F. benghalensis*, a twig with leaves and fruits; (J); (K) *F. religiosa* upper and lower surface of leaves and fruits; (L) *F. rumphii*, upper and lower surface of leaves.

Diagram (9) shows the Cluster analysis of 11 taxa of Cordifoliae section at the first level (distance level 92.727) of differentiation, (characters bordered in pink color), *F. drupacea* and *F. drupacea* var. *pubescens* are separated by the presence of oblong fig with 2.1-3 cm long, the other 9 species are characterized by glabrous upper and lower surface of the lamina. At the second level (distance level 72.000) of differentiation, three species namely *F. rumphii*, *F. religiosa*, and *F. benghalensis* are separated by the presence of leaf length/width less than 1.5, while the other 6 species this ratio may reach 3 and the figs basal bracts are 4 mm long (characters bordered by yellow).

Numerical taxonomy of genus *Ficus*

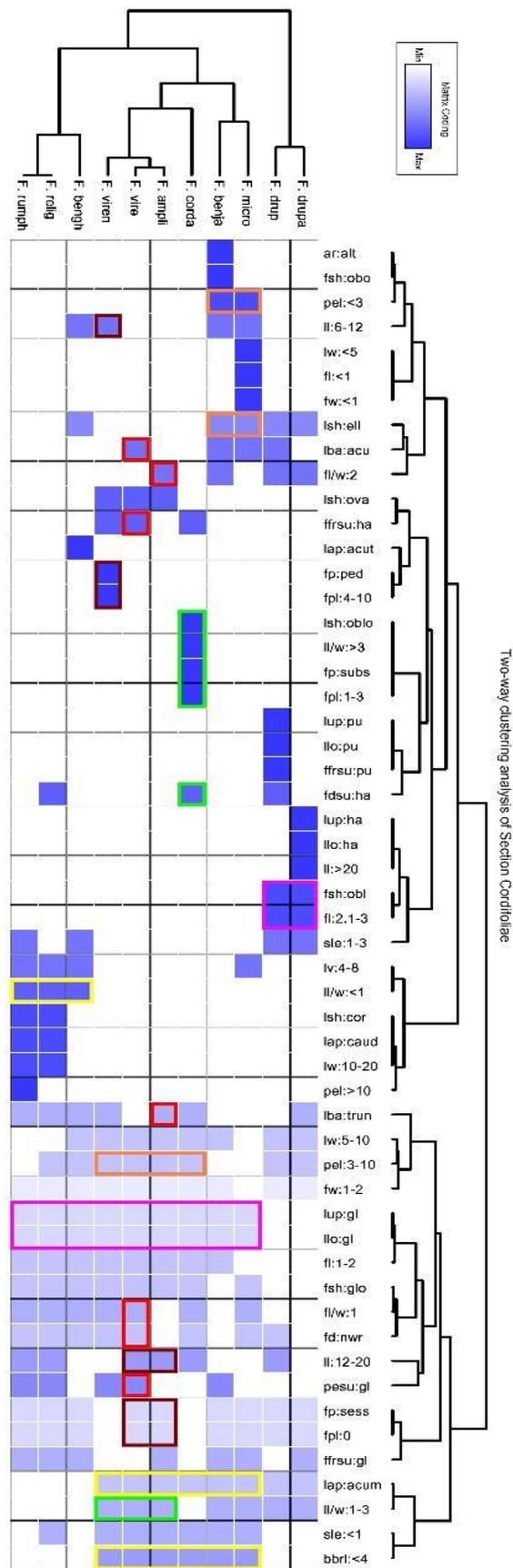


Diagram (9): The two-way clustering analysis using the Euclidean Distance Measure with Ward's Method of the 11 species of section *Cordifoliae*, (for abbreviations see Table 1. The changes in borders' colors (pink, yellow, brown, green and red) indicate the levels of differentiation.

Diagram (10) shows the results of the PCA of section *Cordifoliae*, it is clear that some species are characterized by distinct morphological characters. For instance, leaf shape oblong-lanceolate, elliptic-oblong, 3-4 times as long as broad, figs sessile, peduncle 1-3 mm long in *F. cordata* subsp. *salicifolia*, whereas in *F. virens* var. *virens* the fig pedunculate, 4-10 mm long. Moreover, in *F. benjamina* the figs are obovoid and leaf arrangement alternate. However, in *F. microcarpa* the leaf width less than 5 cm, fig length and width are less than one. Furthermore, the leaf apex acute to obtuse or rounded in *F. benghalensis*. On the other hand, lamina and fig surfaces are pubescent in *F. drupacea* var. *pubescens*, while in *F. drupacea* leaf length more than 20 cm and covered with sparse hair leaf surfaces, petiole more than 10 cm long in *F. rumphii*.

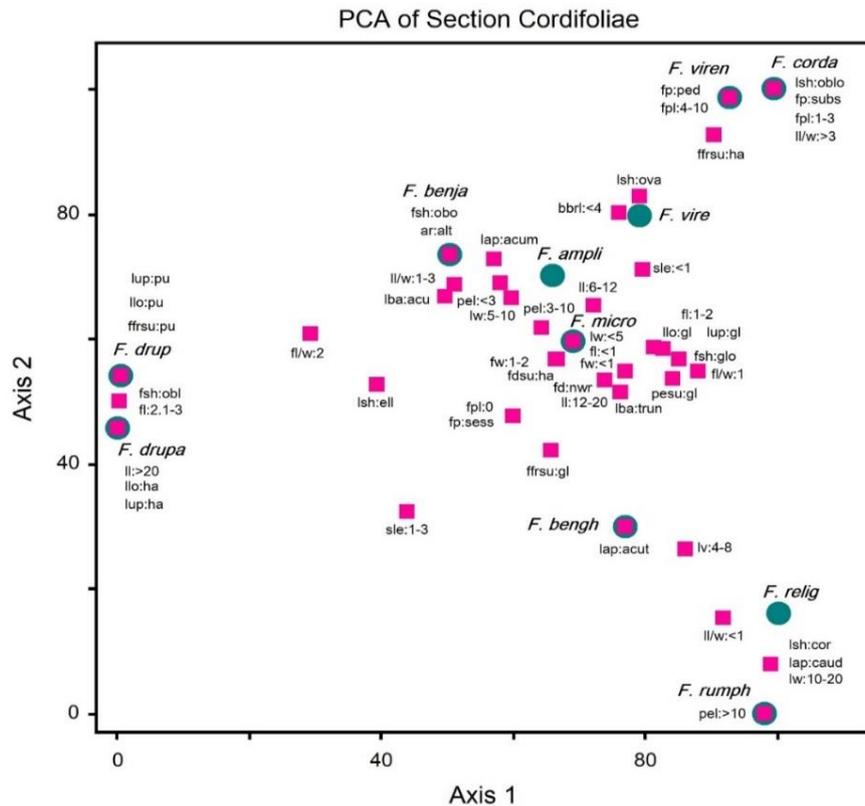


Diagram (10): The principal component analysis of the morphological matrix of the 11 species of Section *Cordifoliae* (for abbreviations see, Table 1).

The application of the two-way clustering analysis (CA) and the principal component analysis (PCA) helped in the construction of Identification Key for the 6 taxa of section *Cordifoliae* in Egypt.

Identification key to the taxa of Section Cordifoliae

1. Abaxial and adaxial lamina surface with sparse hair to pubescent; figs oblong 2
 - Abaxial and adaxial lamina surface glabrous; figs globose to obovoid 3
2. Abaxial and adaxial lamina surface with sparse hair; length 20-35 cm, fresh figs glabrous, wrinkled when dry *F. drupacea*
 - Abaxial and adaxial lamina surface pubescent; length 12-20 (-25) cm, fresh figs pubescent, not wrinkled when dry *F. drupacea* var. *pubescens*
3. Leaf apex acuminate or obtusely acuminate; lamina 1.5-4 as long as broad; figs basal bracts less than 4 mm long 4
 - Leaf apex caudate or obtuse to rounded; lamina 1-1.5 as long as broad; figs basal bracts 4-9 mm long 9
4. Fresh figs wall glabrous 5
 - Fresh figs wall with sparse hair 7
5. Lateral veins 5-8 pairs; lamina up to 5 cm in diam.; figs less than 1cm long, less than 1 cm in diameter; the ratio of fig length/width=1, wall of dry fig not wrinkled *F. macrocarpa*

- Lateral veins 10-14 pairs; lamina 5-9 cm in diam.; fig 1-2.5 cm long and 1-2 cm in diam.; the ratio of fig length/width= 1.5-2, wall of dry; fig wrinkled 6
- 6. Leaf arrangement alternate, lamina elliptic, with acute to round base, 6-12 cm long; petiole glabrous, 1-2.5 cm long; figs obovoid *F. benjamina*
 - Leaf arrangement spiral, lamina ovate-lanceolate, with subcordate base, 12-20 cm long; petiole with sparse hair, 5-8 cm long, figs globose *F. amplissima*
- 7. Lamina oblong to oblong-lanceolate, coriaceous, ratio of lamina length/width = 3-4, petiole and fig wall with sparse hair when dry..... *F. cordata* subsp. *salicifolia*
 - Lamina elliptic to ovate-elliptic, chartaceous, ratio of lamina length/width =1.2-2.7, petiole and fig wall glabrous when dry..... 8
- 8. Leaf base subcordate to truncate, 6-12(-15) cm long, fig pedunculate *F. virens* var. *virens*
 - Leaf base acute to cuneate, 12-20 cm long, fig sessile *F. virens* var. *sublanceolata*
- 9. Lamina elliptic to ovate-elliptic, apex obtuse to round, 6-12 (-15) cm long, 5-10(-12) cm in diameter, petiole with sparse hair..... *F. benghalensis*
 - Lamina broadly ovate, apex caudate, 15-25cm long, 10-20 cm in diam., petiole glabrous ... 10
- 10. Leaf apex caudate nearly half as long as lamina, petiole length 6-10 cm, stipules length up to 1.5 cm; figs with sparse hair when dry *F. religiosa*
 - Leaf apex caudate about ¼ as long as lamina, petiole length 10-14 cm, stipules length 1.5-3 cm; figs glabrous when dry *F. rumphii*

iv. Section Urostigma

This section is represented in Egypt by four species (*F. elastica* Roxb. ex Hornem., 1819 (Pl. 5A); *F. macrophylla* Desf. ex Pers., 1806 (Pl. 5B); *F. platypoda* (Miq.) A.Cunn. ex Miq., 1847 (Pl. 5C); *F. rubiginosa* Desf. ex Vent., 1803 (Pl. 5D) characterized by their coriaceous leaf and lamina 1.5-3 times as long as broad. Twenty-one morphological characters are used to differentiate between species of section *Urostigma*. The main characters separated between taxa of this section are the number of lateral vein pairs, figs peduncle, and basal bracts length.

At the first level (distance level 27.000) of the clustering analysis, *F. platypoda* and *F. rubiginosa* are separated from the other 2 species by the presence of lateral 9-14 vein pairs, lamina 6-12 cm long with truncate-subcordate base, figs globose (characters with pink borders, Diag.11). *Ficus rubiginosa* can be separated from *F. platypoda* by less than 3 cm long sparsely hairy petiole, stipule less than 1 cm in length, figs sessile (1-3 mm long) and its basal bracts up to 4-9 mm long (characters with brown borders, Diag.11). While *F. macrophylla* is characterized by its lamina 12.1-20 cm in length, with 15-20 lateral vein pairs, figs pedunculate, more than 10 mm long, bi-labiate ostiole, and figs wrinkled when dry (characters surrounded by yellow borders, Diag.11).

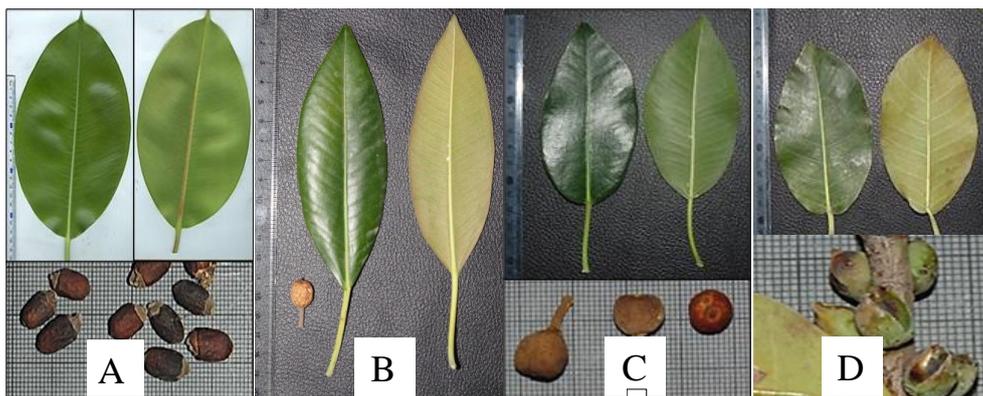


Plate (5): Photographs of *Ficus* species Spherosuke-Section *Urostigma*, upper and lower surface of leaves and fruits (A-D); (A) *F. elastica*; (B) *F. macrophylla*; (C) *F. platypoda*; (D) *F. rubiginosa*.

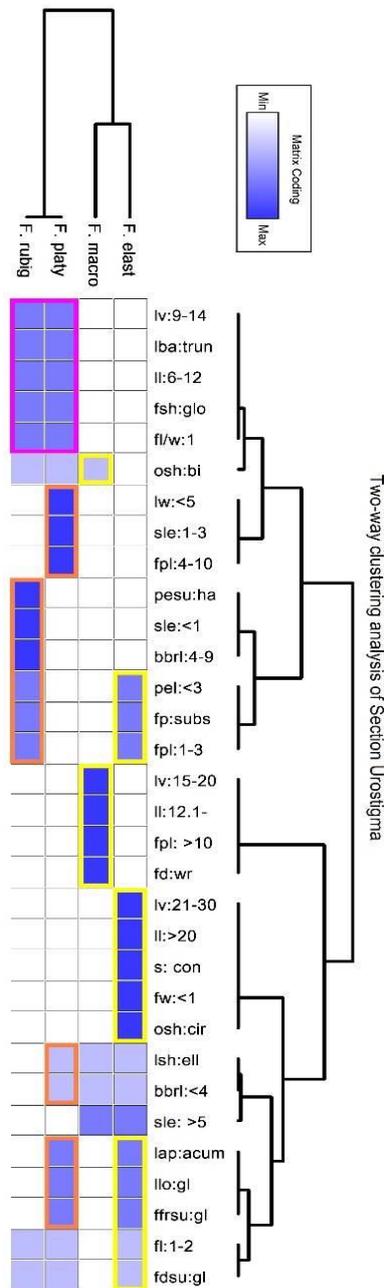


Diagram (11): The two-way clustering analysis using the Euclidean Distance Measure with Ward's Method of the 4 species of section *Urostigma* (for abbreviations see Table 1). The changes in borders' colors (pink, yellow and brown) indicate the levels of differentiation.

Numerical taxonomy of genus *Ficus*

Diagram (12) records the affinity of some characters to definite species, such as; lamina length (more than 20 cm long) number of lateral veins (21-30 lateral vein pairs), stipule connate, figs diameter (less than 1 cm in diameter), and circular ostiole which are confined to *F. elastica*; however; sparsely hairy petiole, stipule length (less than 1 cm) and figs basal bracts length (4-9 mm long) are confined to *F. rubiginosa*; whereas, lamina less than 5 cm long, stipule length 1-3 cm, and figs peduncle 4-10 mm long are confined to *F. platypoda*. Furthermore; lamina length (12.1-20 cm long), number of lateral veins (15-20 lateral vein pairs), figs pedunculate, (more than 10 mm in length) and wrinkled when dry confined to *F. macrophylla*.

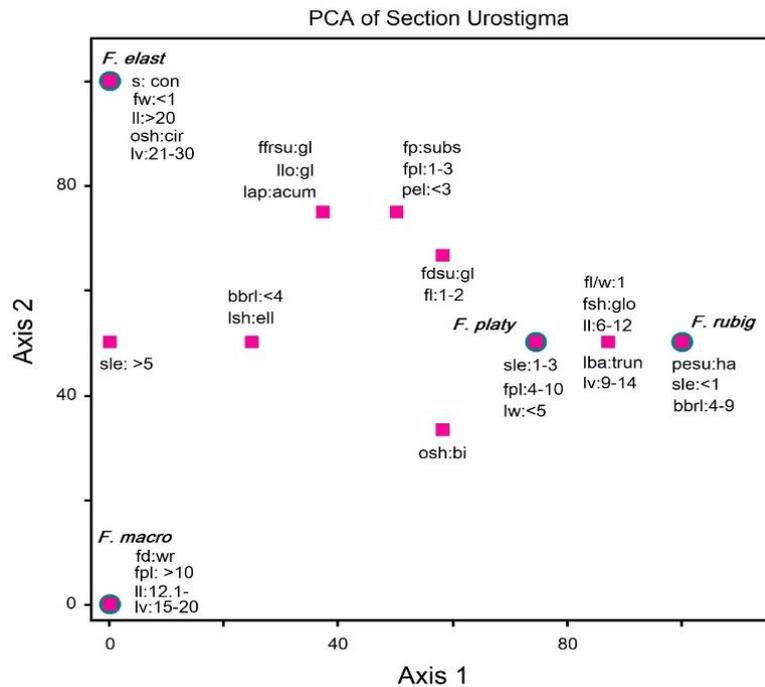


Diagram (12): The principal component analysis of the morphological matrix of the 4 species of section *Urostigma*, (for abbreviations see Table 1).

The application of the two-way clustering analysis (CA) and the principal component analysis (PCA) helped in the construction of the Identification Key for the 4 species of subgenus *Urostigma* in Egypt.

Key to the species of Section *Urostigma*

1. Lateral veins 15-30 pairs; lamina more than 12 cm long; leaf base acute, obtuse-rounded or cuneate; figs oblong 2
- Lateral veins 9-14 pairs; lamina less than 12 cm long; leaf base truncate to subcordate; figs globose. 3
2. Leaf apex acuminate; figs sessile 1-3 mm long; figs glabrous and not wrinkled when dry *F. elastica*

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- Leaf apex acute, obtuse or rounded; figs pedunculate, 10-25 mm long; figs with sparse hair and wrinkled when dry ***F. macrophylla***
- 3. Petiole and fresh figs glabrous; peduncle 4-10 mm long, basal bracts 2-3 mm long ***F. platypoda***
- Petiole and fresh figs with sparse hair to pubescent; peduncle 1-3 mm long, basal bracts 7-9 mm long ***F. rubiginosa***

Diagram (13) gives a diagrammatic illustration of the relationship between the 41 *Ficus* taxa growing in Egypt, which are classified into 5 subgenera, 11 sections, 33 species, 3 subspecies and 4 varieties depending on the above achieved two-way clustering analyses

Numerical taxonomy of genus *Ficus*

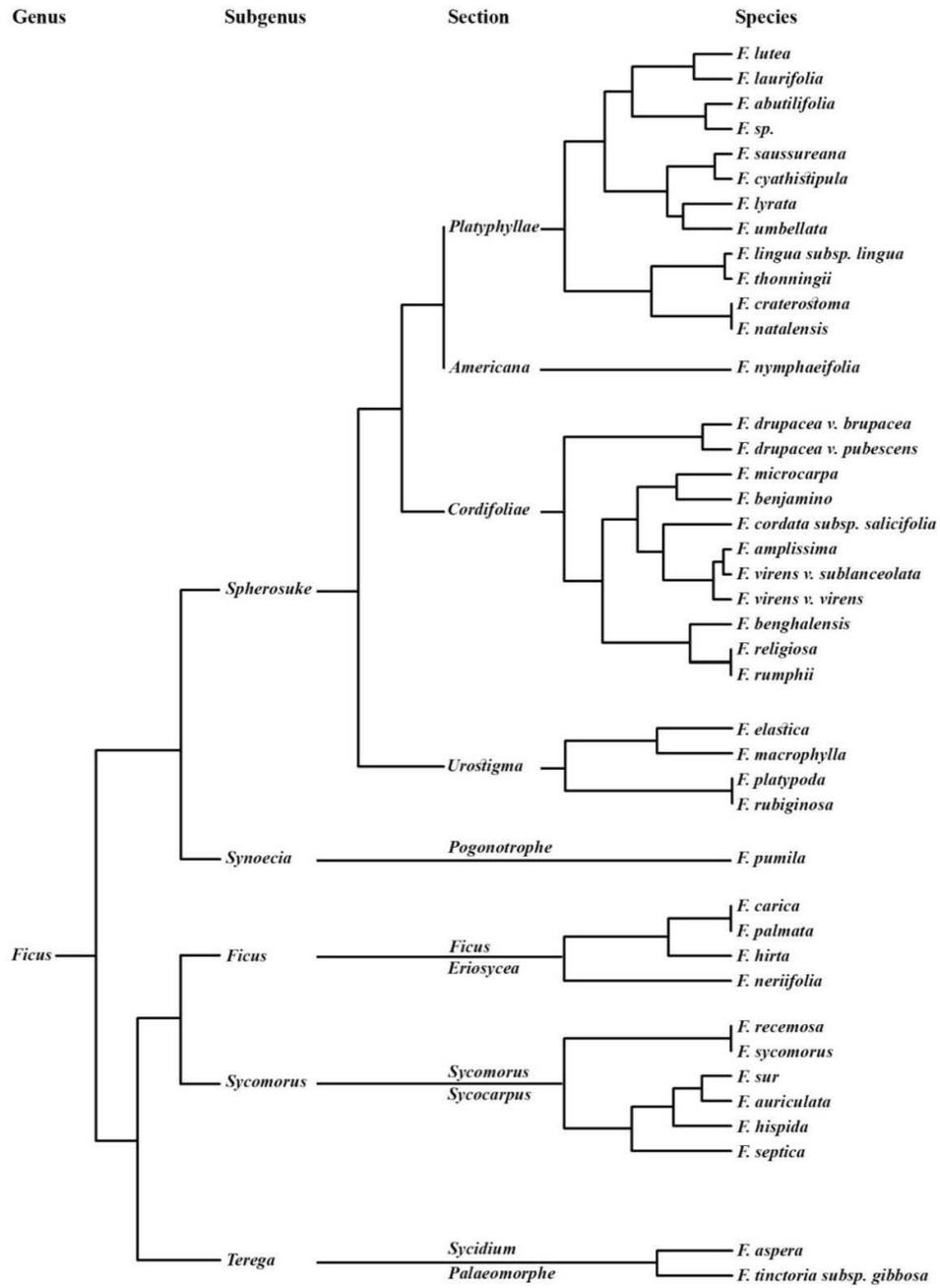


Diagram (13): A diagrammatic key illustrating the 41 *Ficus* L. taxa growing in Egypt, which are classified in to 5 subgenera, 11 sections, 33 species, 3 subspecies and 4 varieties.

DISCUSSION

The application of the multivariate analysis in understanding and solving systematic problems is adopted by many authors (Gómez-Campo *et al.*, 2001; Rahman *et al.*, 2013; Teleb and Salah-El-din, 2014; Yaradua *et al.*, 2018; López-Palacios *et al.*, 2019; Hssaini *et al.*, 2020; Kamran *et al.*, 2020; Muhammad *et al.*, 2021). Numerical analysis is a comprehensive way of evaluating and analyzing the data and producing a phenetic classification (Sneath and Sokal, 1973). Methods of numerical taxonomy have been used in classifying many species and interpreting the results of taxonomic studies (Chiapella, 2000; Gomez-Campo *et al.*, 2001; Hssaini *et al.*, 2020; Muhammad *et al.*, 2021).

The application of the two-way clustering analysis and the principal component analysis revealed that the qualitative characters; presence or absence of lateral, peduncular or ostiolar bracts and the leaf margin shows a highly significant in the differentiation between the 5 subgenera of genus *Ficus*. Whereas the qualitative characters of leaf; leaf arrangement, shape of lamina, leaf apex, and quantitative characters such as the number of lateral veins, length of lamina and stipules are significantly separating the species within the different sections. These findings correlate more or less to numerous previous researches (Ghafoor, 1985; Mubo *et al.*, 2004; Loutfy *et al.*, 2005; Chaudhary *et al.*, 2012; Esmail *et al.*, 2014; Jangam *et al.*, 2017).

Mubo *et al.* (2004) noted that the genus *Ficus* had followed several curious lines of evolution; its taxonomy was still puzzling because of the extreme morphological variability and ambiguous boundaries between taxa. However, he used the morphometric analysis based on ten quantitative parameters like leaf length, leaf width, lamina length, lamina width, petiole length of *Ficus* species leaves in Nigeria that gave highly significant positive correlations, which is parallel with our results.

Jangam *et al.* (2017) made a morphometric quantitative analysis on nine species of genus *Ficus* based on their leaf characters, it has been revealed that, the quantitative characters like leaf length, leaf breadth, petiole length, lamina length are positively correlated and contribute significant role in arranging the species together within a genus while, the leaf base nerve number, ratio of leaf length to leaf breadth and ratio of leaf lamina length to petiole length significantly separates the species from each other. This is again in correspondence with our results.

Bruun-Lunda *et al.* (2018) showed that figs usually follow the evolutionary museum model, with a progressive accumulation of species through time and a relatively low extinction rate and no major change in development. These states of characters are seen in most phylogenetic species and imply that they are essential innovations or syndromes, which can lead to the success of figs with regard to species diversity and accumulation of high species diversity on an evolutionary time scale.

The 36 morphological characters used to differentiate between the 41 taxa within the genus *Ficus* in Egypt were adopted earlier in previous works; Berg and Hijman (1989) differentiated between subgenera and sections of *Ficus* depending on some characters as ostiole shape; circular (section *Sycidium*; *Sycomorus* and *Cordifolae*) or bi-labiate (section *Platyphyllae*), the number of ostiolar bracts; few (section *Cordifolae*) or several (section: *Sycomorus* and *Sycidium*); plant monoecious (subgenus *Sycomorus* and *Spherosuke* section *Cordifolae*) or dioecious (subgenus *Terega*: section *Sycidium*, known previously as subgenus *Sycidium*).

Numerical taxonomy of genus *Ficus*

Numerical taxonomy studies are important for identifying novel morphological features. In comparing our results and previous studies on genus *Ficus* in Egypt (Diwan *et al.*, 2004; Hamdy *et al.*, 2007; Hamdy, 2010; Youssef and Hamdy, 2013); 4 new taxa were grown in Egyptian gardens and newly added to the garden flora of Egypt; *F. lingua* subsp. *lingua*, *F. pumila*, *F. rumphii* and *F. sur*. In addition; 7 taxa that were previously unidentified, misidentified or confused with other *Ficus* species are revised and taxonomically nested within their subgenera or sections. Based on investigated specimens and utilizing the available taxonomical literature (Corner, 1977; Berg and Hijman, 1989; Berg, 1991). *Ficus palmata* Forssk. is one of the unidentified taxa; characterized by its ovate-orbicular lamina, pubescent in texture, peduncle more than 1 cm long, figs axillary, green turn into dark purple at maturity. Moreover; *Ficus septica* N.L. Burman is another example for unidentified taxa; it can be distinguished by its glabrous, spirally arranged leaves, lamina mostly elliptic, 20-35 cm long, often narrowed at the base, figs axillary and cauliflorous, mostly depressed globose bearing white or yellow spots appear on the surface of the dry figs.

Speaking about the misidentified taxa; *F. tinctoria* G. Forst. was documented as *F. pyriformis* Hook. & Arn. It is characterized by its ovate-elliptic to \pm rhombic lamina, strongly asymmetric, adaxially rough becoming glabrous with age; fig globose, base attenuate into a stalk, with a circular navel-like ostiole. Furthermore, *Ficus tinctoria* G. Forst. is a polymorphic species and it can be easily classified into 3 subspecies on the basis of habit and fig diameter. Based on Rong shu (2003) *F. tinctoria* G. Forst. subsp. *gibbosa* (Blume) Corner was recognized with its shrubby habit and narrow figs 0.5-0.8 cm in diameter.

Another misidentified *F. racemosa* L. for *F. palmata* Forssk. Both species shared the same range of leaves (size, apex, base, lateral veins and petiole); however, *F. racemosa* L. has elliptic (vs. ovate) shape, coriaceous (vs. chartaceous), entire-undulate (vs. subdentate-distinctly serrate) margin, stipule 1.5-3 cm long (vs. up to 1 cm.), fig color reddish orange (vs. dark purple) at maturity (Rong shu, 2003; Upadhyay and Kumar, 2010; Tiwari *et al.*, 2014). Furthermore, *F. auriculata* Lour. was misidentified as *F. tinctoria* G. Forst. subsp. *gibbosa* (Blume) Corner (known as *F. gibbosa* Blume in our gardens) while there leaves and figs characters are distinguishable. *Ficus auriculata* Lour. leaf is 12-20 cm long (vs 6-12 cm in *F. tinctoria* G. Forst. subsp. *gibbosa* (Blume) Corner); petiole length 4-10 cm long (vs. less than 3 cm long), stipule 1.5-3 cm long (vs. less than 1 cm), fig pedunculate (vs. sessile), obovate with 8-12 conspicuous longitudinal ridges (vs. globose), broader 1-2 cm diameter (vs. narrower 0.5-0.8 cm diameter). As well, *F. umbellata* Vahl. was documented as *F. platyphylla* Delile. Both shared many characters such as the size of the leaves and the shape of the tree. Nonetheless, the former figs are sessile, 2.5-3.5 cm in diameter, glabrous and wrinkled when dry while pedunculate, 1-2 cm in diameter, puberulous, warted and wrinkled in *F. platyphylla* Delile.

Based on leaf and fig characters it was possible to separate and reidentify *F. nymphaeifolia* Mill. (Burger, 1977) from *F. petiolaris* Kunth. Both shared many similar characters but the former is characterized by its sessile figs with a lustrous velutinous surface (satin-like) and its large subcordate lamina with a basal lobe extending below the petiole attachment while being pedunculate with cordate-orbicular to broadly ovate lamina in *F. petiolaris* Kunth.

CONCLUSIONS

The current study shows the significance of numerical analysis in detecting variation and taxonomic relationships among *Ficus* species growing in Egyptian gardens as it is attested by previous studies based on leaf architecture, pollen, and anatomical characters.

CONFLICTS OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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Appendix (1): The coordinates of the gardens where fresh specimens were collected.

Locality	Geographic coordinates
Alexandria: Antoniades garden	31° 12' 20" N, 29° 56' 49" E
Aswan: Aswan botanic garden	24° 05' 37" N, 32° 53' 13" E
Cairo: El Zohriya garden	30° 02' 38" N, 31° 13' 43" E
Cairo: Groppi garden	30° 03' 07" N, 31° 14' 49" E
Cairo: near Cairo opera house	30° 02' 29" N, 31° 13' 38" E
Giza: El Saff, Alfred Bircher's garden	29° 35' 24" N, 31° 16' 36" E
Giza: Mazhar botanical garden	30° 03' 35" N, 31° 08' 41" E
Giza: Orman botanical garden	30° 01' 44" N, 31° 12' 46" E
Giza: Cairo University	30° 01' 37" N, 31° 12' 28" E
Giza: Agriculture Research Center	30° 01' 12" N, 31° 12' 34" E
Giza: Al Mansouria, private garden, Mansoureya area	30° 01' 06" N, 31° 07' 16" E
Giza: Zoological garden	30° 01' 40" N, 31° 12' 57" E
Giza: Faculty of Agriculture	31° 01' 05" N, 31° 12' 29" E

Appendix (2): List of *Ficus* taxa, arranged alphabetically along with their voucher specimens used in the present study.

Taxon	Locality	Date of Collection	Collector, Collection number and Herbarium
<i>F. abutilifolia</i> (Miq.) Miq., 1867	Giza: Orman botanic garden	09/10/1959	V. Täckholm s.n. (CAI)
	Giza: Mazhar botanic garden	03/04/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. amplissima</i> Sm., 1810	Giza: Orman botanic garden	22/06/1967	M. El Mahdi s.n. (CAI)
	Giza: Orman botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. aspera</i> G. Forst., 1786	Aswan: Aswan botanic garden	10/01/1960	M. Drar s.n. (CAI)
	Giza: Mazhar botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. auriculata</i> Lour., 1790	Giza: Orman botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. benghalensis</i> L., 1753	Giza: Zohriya garden	Spring 1962	S. El Sisi s.n. (CAI)
	Giza: Cairo University	04/04/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. benamina</i> L., 1767	Aswan: Aswan botanic garden	20/12/1995	H. Rofeel 29115 (CAIM)
	Giza: Agriculture Research Center	16/03/2019	R. Mahdy s.n. (CAI)

<i>F. carica</i> L., 1753	Gebel Elba	04/03/1938	J.R. Shabetai s.n. (CAIM)
	Cairo: Groppi garden	18/05/2019	R. Mahdy s.n. (CAI)
<i>F. cordata</i> subsp. <i>salicifolia</i> (Vahl) C.C. Berg, 1988	Gebel Elba	01/03/2019	K. El Haddad & A. Soliman s.n. (CAI)
	Giza: Orman botanic garden	18/05/2019	R. Mahdy s.n. (CAI)
<i>F. craterostoma</i> Warb. ex Mildbr. & Burret, 1911	Giza: Zohriya garden	17/11/1959	V. Täckholm s.n. (CAI)
	Giza: Mazhar botanic garden	10/01/2020	R. Hamdy s.n. (CAI)
<i>F. cyathistipula</i> Warb., 1894	Giza: Orman botanic garden	15/04/2019	R. Mahdy s.n. (CAI)
<i>F. drupacea</i> Thunb. 1786	Aswan: Aswan botanic garden	23/05/1969	M. El Mahdi s.n. (CAI)
	Cairo: Zohriya garden	16/03/2019	R. Mahdy s.n. (CAI)
<i>F. drupacea</i> var. <i>pubescens</i> (Roth) Corner, 1959	Giza: Orman botanic garden	14/10/1959	V. Täckholm s.n. (CAI)
	Giza: Zoo garden	16/03/2019	R. Mahdy s.n. (CAI)
<i>F. elastica</i> Roxb. ex Hornem., 1819	Giza: Orman botanic garden	09/10/1959	V. Täckholm s.n. (CAI)
	Giza: Agriculture Research Center	16/03/2019	R. Mahdy s.n. (CAI)
<i>F. hirta</i> Vahl, 1806	Aswan: Aswan botanic garden	23/05/1969	M. El Mahdi s.n. (CAI)
	Aswan: Aswan botanic garden	16/03/2019	H. Rofeel s.n. (CAIM)
<i>F. hispida</i> L.f., 1781	Aswan: Aswan botanic garden	12/08/1997	Hafeez Rofeel 29298 (CAIM)
	Giza: Mazhar botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. laurifolia</i> Lam., 1788	Giza: Agricultural Museum's garden	07/12/1992	M. Moharram s.n. (CAIM)
	Giza: K. El Haddad private garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. lingua</i> subsp. <i>lingua</i> Warb. ex De Wild & T. Durand, 1901	Giza: K. El Haddad private garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. lutea</i> Vahl, 1805	Giza: Orman botanic garden	09/10/1959	V. Täckholm s.n. (CAI)
	Giza: Orman botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. lyrata</i> Warb., 1894	Aswan: Aswan botanic garden	14/04/1964	M. El Mahdi s.n. (CAI)
	Giza: Agriculture Research Center	15/04/2019	R. Mahdy & R. Hamdy s.n. (CAI)

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<i>F. macrophylla</i> Desf. ex Pers., 1806	Aswan: Aswan botanic garden	17/02/2007	T. Labib s.n. (CAIM)
	Giza: Orman botanic garden	19/06/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. microcarpa</i> L.f., 1781	Faculty of Agriculture	02/11/1959	V. Täckholm s.n. (CAI)
	Giza: Orman botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. natalensis</i> Hochst. subsp. <i>leprieurii</i> (Miq.) C.C.Berg, 1988	Giza: Agriculture Research Center	15/04/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. nerifolia</i> Sm., 1810	Giza: Faculty of agriculture	12/01/1960	M. Drar s.n. (CAI)
	Giza: Orman botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. nymphaeifolia</i> Mill., 1768	Cairo: Zohriya garden	16/03/2019	R. Mahdy s.n. (CAI)
<i>F. palmata</i> Forssk., 1775	Aswan: Aswan botanic garden	25/02/1942	J.R. Shabetai G1495 (CAIM)
	Giza: Orman botanic garden	15/04/2019	R. Mahdy s.n. (CAI)
<i>F. platypoda</i> (Miq.) A.Cunn. ex Miq., 1847	Giza: Orman garden	09/10/1959	V. Täckholm s.n. (CAI)
	Giza: Mazhar botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. pumila</i> L. 1753	Giza: Zohriya garden	04/08/1968	M. El Mahdi s.n. (CAI)
	Giza: Mazhar botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. racemosa</i> L. 1753	Giza: Orman botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. religiosa</i> L. 1753	Giza: Zohriya garden	20/12/1928	G. Täckholm s.n. (CAI)
	Giza: Orman botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. rubiginosa</i> Desf. ex Vent., 1803	Aswan: Aswan botanic garden	23/05/1969	M. El Mahdi s.n. (CAI)
	Alexandria: Antoniades Garden	15/04/2019	R. Mahdy & N. Hassan s.n. (CAI)
<i>F. rumphii</i> Blume 1825	Giza: Mazhar botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. saussureana</i> DC. 1841	Giza: Mazhar botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. septica</i> Burm. f. 1768	Giza: Orman botanic garden	06/09/1933	A.K. G1492 (CAIM)
	Giza: Mazhar botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. sur</i> Forssk. 1775	Giza: Mazhar botanic garden	03/04/2019	R. Mahdy & R. Hamdy s.n. (CAI)

<i>F. sycomorus</i> L. 1753	Giza: Agricultural Museum's garden	27/01/1965	M. El Mahdi s.n. (CAI)
	Giza: Orman garden	18/01/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. thonningii</i> Blume 1836	Giza: Mazhar botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. tinctoria</i> subsp. <i>gibbosa</i> (Blume) Corner 1959	Cairo: Orman botanic garden	27/10/1959	V. Täckholm s.n. (CAI)
	Giza: Orman botanic garden	15/04/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. umbellata</i> Vahl 1805	Aswan: Aswan botanic garden	21/05/1969	M. El Mahdi s.n. (CAI)
	Giza: Orman botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. sp.</i>	Giza: Orman botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. virens</i> var. <i>sublanceolata</i> (Miq.) Corner 1959	Giza (El Saff): Alfred Birchers garden	27/05/1961	V. Täckholm s.n. (CAI)
	Giza: Orman botanic garden	18/05/2019	R. Mahdy & R. Hamdy s.n. (CAI)
<i>F. virens</i> Aiton 1789 var. <i>virens</i>	Giza: Orman botanic garden	03/12/1977	M. El Mahdi s.n. (CAI)
	Cairo: near Cairo opera house	18/12/2020	R. Hamdy s.n. (CAI)

التصنيف العددي لجنس *Ficus* L. 1753 عائلة Moraceae مع اضافة أنواع جديدة لمصر

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الخلاصة

يعتبر تصنيف جنس *Ficus* L., 1753 محيراً بسبب التباين المظهري الشديد والالتباس بين أنواعه؛ لذلك تناولت هذه الدراسة 36 صفة من الصفات المظهرية لأنواع الاصنوفات taxa قيد الدراسة. كشفت الدراسة أن هذا الجنس ممثل في الحدائق المصرية بإحدى وأربعين اصنوفة (33 نوعاً ، 4 تحت صنفى و 4 أصناف) ، مقسمة إلى 5 جُنَيْسَات شملت: *Ficus* (Miq.) Miq., 1867 ، *Sycomorus* Raf., 1838، Raf., 1838 *Terega* .Corner, 1960 من بين هؤلاء سبعة أنواع كانت غير معرفة وقد تم تعريفها. وقد تم ادراج أربعة نويغات جديدة من الفيكس إلى مصر وهي: *F. lingua* subsp. *F. Blume*, 1825 و *F. pumila* L.,1753 و *lingua* Warb. ex De Wild. & T. Durand, 1901 و *F. sur* Blume, 1825 و *rumphii* Blume, 1825.

كشف تطبيق التحليلات متعددة المتغيرات في النظاميات النباتية: تحليل التجميع ثنائي الاتجاه وتحليل المكون الرئيسي ، أن الصفات النوعية مثل وجود أو عدم وجود قنابات سويقية أو فومية وكذلك صفة حافة الأوراق تميز الجُنَيْسَات داخل ضمن هذا الجنس؛ في حين أن الخصائص النوعية للورقة مثل ترتيب الأوراق ، والشكل ، وطول النصل ، ونسبة طول النصل

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إلى عرضه ، وشكل قاعدة ، وقمة الورقة ، وعدد العروق الجانبية ، وعنق الثمرة ، وشكلها ، وعرضها ميزت بشكل كبير الأنواع داخل أقسام هذا الجنس المختلفة.

صممت سبعة مفاتيح تشخيصية للأصنوفات المدروسة بناءً على الصفات المظهرية المدروسة، بالإضافة إلى ذلك تم عمل مفتاح تخطيطي يجمع بين جميع الاصنوفات قيد الدراسة.