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Numerical Taxonomic Evaluation of Leaf Architecture of Some Species of Genus *Ficus* L.

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ABSTRACT

Leaf architectural aspects were investigated in 24 taxa of *Ficus* L. (Moraceae) representing the three subgenera *Ficus*, *Sycomorus* and *Urostigma*. The 96 characters obtained were analyzed by the NTsys pc program package, using the UPGMA clustering method. The produced phenogram showed a close similarity between certain taxa of the subgenera *Urostigma* and *Sycomorus* (viz. *F. infectoria* Roxb. and *F. glomerata* Roxb. and *F. lyrata* Warb. and *F. sycomorus* L.). *Ficus carica* L. was relatively isolated from the rest of the studied taxa. The two studied taxa belonging to the subgenus *Ficus* (viz. *Ficus carica* L. and *F. deltoidea* Jack.) were distantly related. An identification key for the studied taxa of *Ficus*, based on the investigated aspects was presented.

Key Words: *Ficus*; Leaf architecture; Numerical analysis

INTRODUCTION

The genus *Ficus* L. with its more than 800 species forms a distinctive monophyletic clade within the Moraceae, dating back at least to the early tertiary (Stewart & Rothwell, 1993; Mabberley, 1997). In the 19th century, *Ficus* was splitted into several genera (Gasparrini, 1844; Miquel, 1862) that became the basis for a subgeneric classification after the genus was united (Miquel, 1867a, b). Several infra-generic classifications of *Ficus* were put; the most accepted one being that of Corner (1965). Numerous studies were made on *Ficus* to clarify the phylogenetic relationships and evolution within certain subgenera, sections and lower taxonomic ranks. However, the use of data sets from leaf architecture as a clue to solve taxonomic problems was generally neglected. This was mainly due to the lack of a detailed, standardized and unambiguous classification of these features (Hickey, 1973). In this respect, a relatively recent approach has been mainly centered on trying to identify systematically informative leaf features that allow species to be recognized on the basis of dispersed leaves (Hickey, 1973; Hickey & Wolfe, 1975; Hickey & Taylor, 1991; LAWG, 1999). The main use of leaf architectural criteria as an aid in the delimitation of genera and species were performed in palaeobotany (Mouton, 1966; Dilcher, 1974), certain genera from different families as the Araceae, Fagaceae and Rosaceae (Merriell, 1978; Jensen, 1990; Ray, 1992), or even entire families as the Lauraceae (Klucking, 1987; Hyland, 1989; Yu & Chen, 1991; Christophel & Rowett, 1996). Concerning the work on *Ficus*, few studies on the leaf architecture of its taxa were performed. The most remarkable were those of Kumar and Jain (1986) on some Indian taxa of *Ficus.*

In the present work, 24 taxa of *Ficus* cultivated in Egypt were studied in order to: 1- Clarify the importance of leaf architecture features and their taxonomic value, 2- Evaluate and compare the 24 taxa of *Ficus* based on the aforementioned criteria to find out their relationships, 3- Construct an identification key to facilitate the differentiation between the studied taxa.

MATERIALS AND METHODS

Fresh mature leaf materials of 24 horticultural species of *Ficus* L. grown in some botanical and public gardens in Egypt were studied (Table I). Identification was confirmed by Bailey and Bailey (1976) and authentic herbarium specimens at the Orman Botanical Garden, Giza, Egypt. Fine leaf architectural investigations of the studied taxa were performed accordingto the method of Foster (1952), with modifications of Hickey (1973); 5% sodium hypochlorite was applied for further clearing, toluene was used as solvent for the mounting medium. The resulting cleared leaves were either scanned via computer, or bench drawn. The terminologies of leaf architectural aspects are those of Hickey (1973) and LAWG (1999). For the numerical analysis, the NTsys.pc program (Rohlf, 1989) was used. Clustering was performed using the unweighted pair group method (UPGMA).

RESULTS AND DISCUSSION

Fine leaf architectural attributes of the studied taxa are summarized in Table II, and illustrated in Plates 1 and 2. The constructed phenogram (Fig. 1) according to the 96

Table I. The studied taxa and their sources

No.	Species	*Subgenus	Source
1	*F. afzelii* G. Don. (= *F. saussurana* DC.)	*Urostigma*	OBG
2	*F. asperrima* Roxb. (= *F. exasperata* Vahl.)	*Urostigma*	OBG
3	*F. benghalensis* L. (= *F. indica* L.)	*Urostigma*	BGA
4	*F. benjamina* L. (= *F. waringiana* Acut.)	*Urostigma*	BGA
5	*F. carica* L.	*Ficus*	BGA
6	*F. cuninghamii* Miq.	*Urostigma*	OBG
7	*F. deltoidea* Jack. (= *F. diversifolia* Blume.)	*Ficus*	BGA
8	*F. elastica* Roxb. ex.Hornem. (= *F. decora* Hort.)	*Urostigma*	BGA
9	*F. glomerata* Roxb. (= *F. racemosa* Wall.)	*Sycomorus*	OBG
10	*F. hispida* L.	*Urostigma*	OBG
11	*F. infectoria* Roxb. (= *F. virens* Aiton.)	*Urostigma*	ZOO
12	*F. laurifolia* Hort. Ex.Lam. (= *F. glabrata* H.B.K.; *F. anthelmintica* Mart.)	*Urostigma*	ZOO
13	*F. lyrata* Warb.	*Urostigma*	BGA
14	*F. macrophylla* Desf. Ex.Pers. (= *F. magnolioides* Borzi.)	*Urostigma*	OBG
15	*F. mysorensis* Heyne Ex. Roth. (= *F. drupacea* var. *pubescens* (Roth.) Corner	*Urostigma*	BGA
16	*F. nitida* Thunb. (= *F. retusa* L.)	*Urostigma*	BGA
17	*F. platypoda* (Miq.)A. Ex. Miq. (= *Urostigma platipodum* Miq.)	*Urostigma*	OBG
18	*F. pseudosycomorous* Decne.(= *F. palmata* Forssk.)	*Sycomorus*	OBG
19	*F. pyriformis* Hook. & Arn.	*Urostigma*	OBG
20	*F. religiosa* L.	*Urostigma*	BGA
21	*F. spragueana* Mildbr. & Burret.	*Urostigma*	OBG
22	*F. sycomorus* L.	*Sycomorus*	OBG
23	*F. trigona* L.	*Urostigma*	OBG
24	*F. vasta* Forssk.	*Urostigma*	ZBG

OBG: Orman Botanical Garden, Ministry of Agriculture, Giza, Egypt.
BGA: Botanical Garden, Ain Shams University, Faculty of Science, Abbassia, Cairo, Egypt.
ZOO: Zoo-Garden, Giza, Egypt.
ZBG: Zohria Botanical Garden, Ministry of Agriculture, Gezzera, Cairo, Egypt.
*Subgenera are presented as in Corner,s classification 1965.

Table II. Leaf architecture of the taxa studied of *Ficus* L.

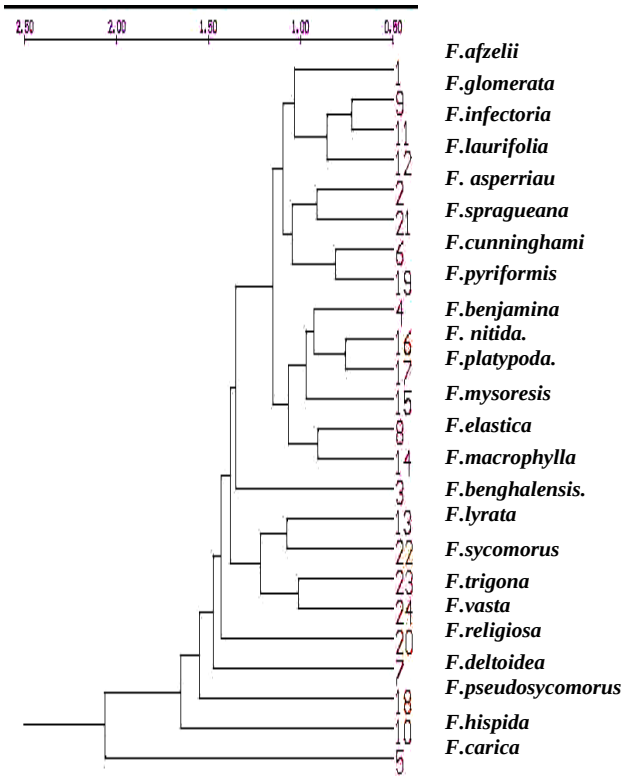
No.	Character Taxa	Leaf attachm-ent	Petiole outline	Petiole length (cm)	No. of lateral veins/ side	Laminar shape	Laminar L/W ratio	Base angle	Apex angle	Base shape	Apex shape	Margin type	Lobation	1°vein category
1	*F. afzelii*	Spiral	Cylindrical	6	8-14	Obovate	18/6:20/9	Acute	Acute	Cuneate	Acuminate	Entire	Unlobed	Pinnate
2	*F. asperrima*	"	Reniform	2.5	6-8	Elliptic	16/6:18/8	"	"	Convex	"	"	"	"
3	*F.benghalensis*	Alternate	Oval	7.5	5-7	Ovate	13/7:15/9	Obtuse	Obtuse	Truncate	Rounded	"	"	Actino-dromous
4	*F. benjamina*	"	Reniform	2.5	8-12	Elliptic	7/4:8/5	Acute	Acute	Rounded	Acuminate	"	"	Pinnate
5	*F. carica*	"	Cylindrical	7	3-5	"	8/9:15/14	Wide obtuse	Odd.lobed acute	Lobate	Convex	Dentate	Palmetly lobed	Palinac-tinodromous
6	*F.cunninghamii*	Spiral	"	5	4-6	"	15/8:20/11	Acute	Acute	Rounded	"	Entire	Unlobed	Pinnate
7	*F. deltoidea*	Alternate	Reniform	1.5-2	6-8	Obovate	7/6:9/7	"	Truncate	Cuneate	Acuminate	"	"	"
8	*F. elastica*	Spiral	Elliptical	10	25-30	Elliptic	7/4:18/10	"	Acute	Rounded	"	"	"	"
9	*F. glomerata*	Alternate	"	10.5	7-10	Ovate	15/7:20/9	Obtuse	"	"	"	"	"	"
10	*F. hispida*	"	Reniform	7.5	5-9	Elliptic	12/7:15/9	"	Obtuse	"	"	"	"	"
11	*F. infectoria*	"	"	10	7-10	Ovate	9/4:11/5	"	Acute	Truncate	"	"	"	"
12	*F. laurifolia*	Spiral	"	9	8-11	"	10/4:14/7	Acute	"	Convex	"	"	"	"
13	*F. lyrata*	Alternate	"	7.5	3-5	Lyrate	14/10:20/15	Wide obtuse	Obtuse	Cordate	Rounded	"	"	Actino-dromous
14	*F.macrophylla*	Spiral	Elliptical	10	13-16	Elliptic	15/8:25/13	Acute	Acute	Rounded	Convex	"	"	Pinnate
15	*F. mysoricusis*	Alternate	"	4.5	9-15	"	14/8:22/12	Obtuse	Obtuse	"	Acuminate	"	"	"
16	*F. nitida*	Spiral	Reniform	0.5-1.5	6-8	"	7/4:9/5	"	"	"	Rounded	"	"	"
17	*F. platypoda*	Alternate	Subglubose	2	10-12	"	8/4:10/5	"	Acute	"	Convex	"	"	"
18	*F.pseudosycomorus*	"	Cylindrical	4.5	3-5	Rounded	10/8:15/12	"	Obtuse	"	"	"	"	Actinod-romous
19	*F. pyrifermis*	"	Reniform	1.5	4-6	Elliptic	11/4:13/5	Acute	Acute	Cuneate	Acuminate	"	"	Pinnate
20	*F. religiosa*	Spiral	Cylindrical	7.5-10	8-10	Aspen-like	14/7:18/9	Obtuse	"	Truncate	Straight	"	"	"
21	*F. spragueana*	Alternate	Reniform	1.5	9-11	Elliptic	10/4:15/7	Acute	"	Convex	Acuminate	"	"	"
22	*F. sycomorus*		Sagitate	6.5	3-5	Ovate	9/5:12/6	Obtuse	Obtuse	Cordate	Convex	"	"	Actino-drmous
23	*F. trigona*	Spiral	Corate-sagitate	5-7	5-7	Rounded	9/9:15/13	Wide obtuse	"	"	Rounded	"	"	Suprabasalactinodromous
24	*F. vasta*	"	Elliptically to ovate	10-13	7-9	Cordate	8/9:17/14	"	"	"	Convex	"	"	"

(Continued)

Table II. Cont.

No.	Character Taxa	2°vein category organization	Agrophic veins	2°vein spacing	2°vein angle	Inter 2° veins	3°vein category	3°vein course	3°vein angle to 1°vein	3°vein angle variability	4°vein category	5°vein category	Areolation development	F.E.V.S
1	*F. afzelii*	Weak brochidromus	Simple	Uniform	Uniform	Weak	Alternate percurrent	Admedially ramified	Obtuse	Inconsistent	Regular polygonal reticulate	Regular polygonal reticulate	Well	Absent
2	*F. asperrima*	Brochidedromous	"	Irregular	One pair acute basal secondaries	Strong	"	sinuous	Acute	"	"	"	Moderate	2 or more branched
3	*F. benghalensis*	Weak brochidromus	"	Decreasing toward base	Smoothly decreasing toward base	Weak	Random reticulate	"	Obtuse	"	"	"	Well	Absent
4	*F. benjamina*	Intermarginal vein	"	Irregular	Uniform	Strong	"	"	Perpen-dicular	"	Dichotomi-zing	Dichotomi-zing	Poor	"
5	*F. carica*	Interior	Compound	Increasing toward base	Smoothly decreasing toward base	Weak	Mixed alt. opp.	Exmedially ramified	Obtuse	Increasing exmedially	Regular polygonal reticulate	Regular polygonal reticulate	Well	"
6	*F. cunninghamii*	Brochidodromous	Simple	"	One pair acute basal secondaries	Absent	Regular polygonal reticulate	Sinuous	"	Increasing basally	"	"	"	"
7	*F. deltoidea*	Intermarginal vein	"	Decreasing toward base	Smoothly decreasing toward base	Weak	"	"	"	Inconsistent	"	"	"	"
8	*F. elastica*	"	"	Uniform	Uniform	Strong	Alternate percurrent	"	"	"	"	"	Poor	"
9	*F. glomerata*	"	"	"	"	Absent	"	Admedially ramified	"	Increasing basally	"	"	Well	"
10	*F. hispida*	Semicraspedodro-mous	"	Decreasing toward base	Smoothly decreasing toward base	"	Opposite percurrent	"	Perpen-dicular	Uniform	"	"	"	"
11	*F. infectoria*	Brochidodromous	"	Uniform	Uniform	Weak	Alternate percurrent	"	Obtuse	Increasing basally	"	"	"	"
12	*F. laurifolia*	"	"	Irregular	"	Absent	"	"	"	"	"	"	"	"
13	*F. lyrata*	"	Compound	Increasing toward base	Two pair acute basal secondaries	Weak	"	Sinuous	"	Increasing exmedially	"	"	"	2 or more branched
14	*F. macrophylla*	Intermarginal vein	Simple	Uniform	Uniform	Strong	"	Straight	"	Inconsistent	"	"	Poor	Absent
15	*F. mysoricusis*	"	"	"	Smoothly increasing toward base	"	"	Sinuous	"	Increasing basally	Dichotomi-zing	Dichotomi-zing	Well	"
16	*F. nitida*	"	"	"	One pair acute basal secondaries	"	Random reticulate	"	"	"	"	"	"	"
17	*F. platypoda*	"	"	"	Uniform	"	"	"	"	Inconsistent	Regular polygonal reticulate	"	"	2 or more branched
18	*F.pseudosyco-morus*	Brochidodromous	Compound	Increasing toward base	One pair acute basal secondaries	Absent	Alternate percurrent	Straight	"	Increasing exmedially	"	Regular polygonal reticulate	Well	Absent
19	*F. pyrifermis*	"	Simple	Irregular	"	"	Regular polygonal reticulate	Sinuous	"	Increasing basally	"	"	"	2 or more branched
20	*F. religiosa*	"	"	Uniform	Uniform	Strong	Alternate percurrent	Admedially ramified	"	"	"	"	"	"
21	*F. spragueana*	"	"	"	"	"	Random reticulate	Sinuous	"	"	"	"	Moderate	"
22	*F. sycomorus*	"	"	Increasing toward base	One pair acute basal secondaries	Weak	Alternate percurrent	"	"	"	"	"	Well	Absent
23	*F. trigona*	"	Compound	"	Two pair acute basal secondaries	"	"	Admedially ramified	"	Acute	"	"	"	"
24	*F. vasta*	"	Simple	irregular	"	"	"	"	"	"	"	"	"	"

Fig. 1. UPGMA- Phenogram; based on 96 leaf architecture aspects illustrating the average taxonomic distance (dissimilarity) between the taxa studied of *Ficus* L.



characters from leaf architecture revealed the following:

Subgenus *Ficus*. The two studied taxa of the subgenus *Ficus* viz *F. carica* and *F. deltoidea* were distantly related. They shared only the following characters: secondary vein angles smoothly decreasing toward base with weak intersecondary veins, obtuse tertiary vein angles to the primary vein, both of fourth and fifth venation are regular polygonal reticulate and well developed areolation. *Ficus carica* was splitted from the rest of the studied taxa at a dissimilarity level of 2.075 due to possession of some characteristic features as the dentate blade margin, wide obtuse base angle, lobate base shape, odd-lobed-acute apex, palinactindromous primary vein category, interior organization of secondary veins, mixed tertiary veins, exmedially ramified tertiary veins courses, and compound agrophic veins. Mabberley (1997) stated that this south west Asian taxon was in cultivation for over 4000 years, and eventually lost in this process many of the characters that distinguish the nearly extinct wild form. *Ficus deltoidea* was splitted at the dissimilarity level of 1.475 due to its obovate laminar shape with truncate apex and regular polygonal reticulate tertiary veins.

Subgenus *Sycomorus*. *Ficus pseudosycomorus* splitted from the rest of the studied taxa at the dissimilarity level of 1.55 mainly due to its possessing rounded laminar shape, serrate blade margin, obtuse base angle, straight tertiary veins courses, increasing exmedially tertiary veins angles variability and compound agrophic veins. There is a close similarity between certain taxa of the subgenera *Urostigma* and *Sycomorus*. Thus, *Ficus glomerata* (subgenus *Sycomorus*) clustered with *Ficus infectoria* (subgenus *Urostigma*) at a dissimilarity level of only 0.725 due to possessing ovate laminar shape with entire margin, acuminate apex, pinnate primary vein category, uniform secondary vein spacing and angle, alternate percurrent tertiary vein with admedially ramified course, obtuse tertiary vein angle to primary vein with increasing basal angle, both fourth and fifth venation categories are regular polygonal reticulate with well developed areolation. A similar conclusion was also attained with *F. lyrata* (subgenus *Urostigma*) and *F. sycomorus* (subgenus *Sycomorus*), both taxa clustered at the dissimilarity level of 1.075. This was due to possessing cordate blade base, equal number of lateral veins (3-5) at each side, obtuse apex, actinodromous primary vein category, brochidodromous secondary veins with increasing toward base spacing, presence of weak intersecondary veins, alternate percurrent tertiary veins with sinuous course, both of fourth and fifth venation with regular polygonal reticulate nature, and occurrence of well developed areolation.

Subgenus *Urostigma*. The constructed phenogram showed that *F. hispida* splitted from the rest of the studied taxa at the dissimilarity level of 1.65 mainly due to its possessing opposite arrangement of leaves, semicraspedodromous organization of secondary veins, opposite percurrent tertiary veins and uniform tertiary veins angle variability. A close similarity was observed between *F. nitida* and *F. platypoda*. Both taxa clustered at the dissimilarity level of 0.75 due to sharing the following characters: elliptical laminar shape with entire margin and rounded base, acute apex angle, pinnate primary vein category, intermarginal secondary veins with uniform spacing, presence of strong intersecondary veins, round reticulate tertiary veins with sinuous course, and that the fourth and fifth vein category is dichomizing with poor areolation development. Also, a similarity was observed between other taxa as: *F. elastica* and *F. macrophylla* (dissimilarity level: 0.88), *F. trigona* and *F. vasta* (dissimilarity level: 1.025).

Finally, a concluding remark can be drawn from this study: The constructed phenogram according to fine leaf architectural attributes did not fit with the traditional infrageneric classification of the genus as presented in Corner's classification (1965). The studied taxa were widely separated and distributed allover the phenogram (Fig. 1). This might give some support to the views of Berg (1989), Weiblen (2000) and Dixon (2001) utilizing different criteria as morphology, molecular aspects and reproductive biology. These authors stated that the widely accepted infrageneric classification of *Ficus* that was put by Corner (1965) and the subgenera of the genus as currently circumscribed are in need of revision.

Plates 1(Figs. 1-12) & 2 (Figs. 13-24) Leaf architecture of the studied taxa of *Ficus* L.

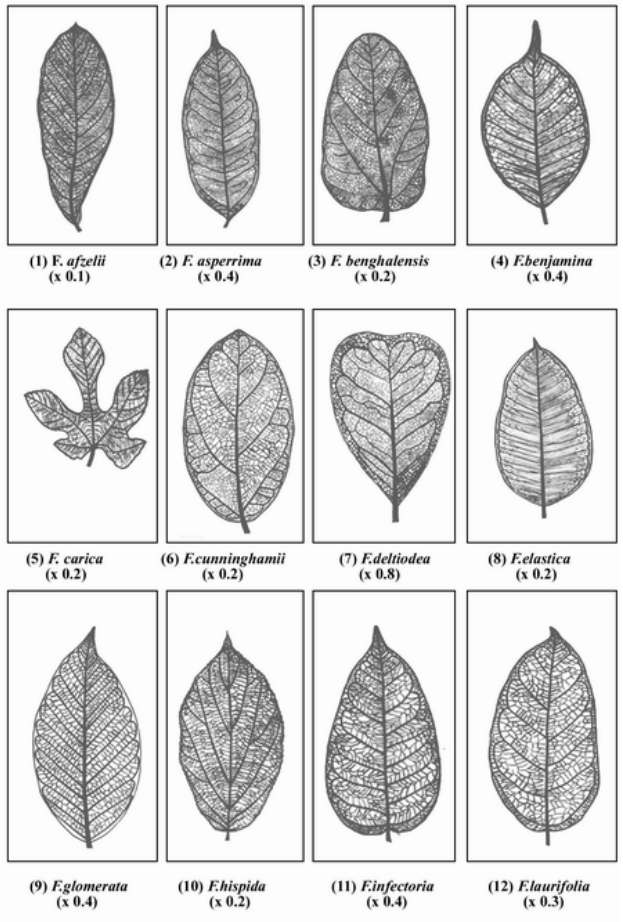


Plate1

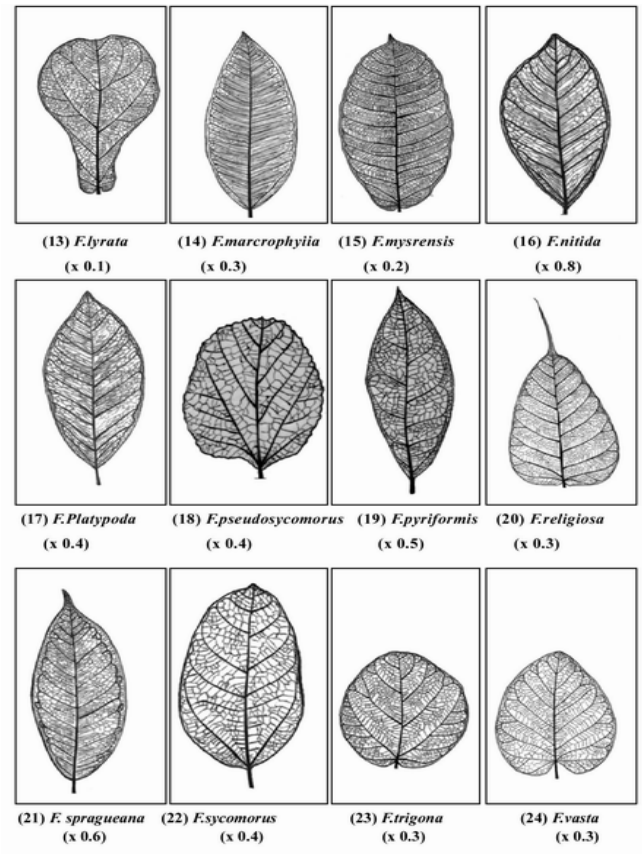


Plate2

An identification key of the studied taxa of *Ficus* L, based on the investigated aspects is presented as under:

#. Leaf palmately lobed.....…….…… (5) *F. carica*
##. Leaf unlobed ……...…….. The remaining taxa
A. Serrate margin
B. Blade Ovate …..... (10) *F. hispida*
BB. Blade Rounded ……..…… (18) *F. pseudosycomorus*
AA. Entire margin
C. Primary vein pinnate.
D- Tertiary vein category regular polygonal reticulate
E- Secondary vein spacing irregular…….... (19) *F. pyriformis*
EE- Secondary vein spacing increasing toward base ... (6) *F. cunninghamii*
EEE- Secondary vein spacing decreasing toward base …… (7) *F. deltoidea*
DD- Tertiary vein random reticulate
F- Secondary vein category intermarginal
G- Secondary vein spacing irregular……..……. (4) *F. benjamina*
GG- Secondary vein spacing uniform
H- Secondary vein angle one pair acute basally ……..…. (16) *F.nitida*
HH- Secondary vein angle uniform……..… (17) *F. platypoda*
FF- Secondary vein category brochidodromous…….. (21) *F. speragueana*
DDD- Tertiary vein category alternate percurrent
I- Secondary vein category brochidodromous
J- Secondary vein spacing uniform
K- Tertiary vein angle to primary vein perpendicular… (11) *F. infectoria*
KK- Tertiary vein angle to primary vein obtuse
L- Tertiary vein angle variability inconsistent……..(1) *F. afzelii*
LL- Tertiary vein angle variability increasing basally..... (20) *F. religiosa*
JJ- Secondary vein spacing irregular
M- Secondary vein angle one pair acute basaly……..…... (2) *F. asperrima*
MM- Secondary vein angle uniform……..... (12) *F. laurifolia*
II- Secondary vein category intermarginal
N- Secondary vein angle smoothly increasing toward base……(15) *F. mysorensis*
NN- Secondary vein angle uniform
O-Intersecondary vein absent.....…(9) *F.glomerate*
OO- Intersecondary vein strong
P- Tertiary vein course sinuous……(8) *F. elastica*
PP- Tertiary vein course straight……..…… (14) *F. macrophyll*a
CC- Primary vein actinodrmous
Q- Tertiary vein random reticulate……....…… (3) *F. benghalensis*
QQ- Tertiary vein alternate percurrent…..... (22) *F. sycomorus*
CCC- Primary vein suprabasalactinodromous
U- Secondary vein spacing irregular…….... (24) *F. vasta*
UU- Secondary vein spacing increasing toward base ……... (23) *F. trigona*

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