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RESEARCH PAPER

A Phenetic Study of the Native Species of the Family Fabaceae Lindl. in Iraq.

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A B S T R A C T

Distinguishable morphological qualitative and quantitative traits for 310 native taxa of 46 genera within the Fabaceae family were selected. The taxa were treated numerically analyzed as OTUs; based on the selected characteristics variations the UPGMA dendrograms by the MVSP windows program were constructed. The relationships among studied taxa were determined and illustrated. The results exhibited that all taxa are monophyletic due to the similarity in the specific characteristics of the family, the divergences among groups, or among taxa of a single group caused by dissimilarities. At different levels, three groups and six sub-groups were set among the genera, the genus *Astragalus* L. had the most distance relationship from other genera at level GGSc=0.67, due to the abundance of its taxa and a large number of differences among them. The relationship degrees among all studied taxa except *Astragalus* taxa analyzed, two groups and seven subgroups were identified at levels GGSc= 0.74 and GGSc= 0.77, detailed and illustrated.

KEY WORDS: Cluster analysis; Fabaceae; Monophyletic; Multi Variate; Polyphyly
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1. INTRODUCTION

The third largest family of flowering plants is Fabaceae possess more than 1800 species belong to 650 genera, most of these species are important such as food, fodder, wood, ornamentals, and raw materials for industry. The features of Fabaceae are ability to fix the atmospheric nitrogen, thus these plants play an important ecological role. Before germination the woody legume seeds which require treatment because of poses impermeable seed coats, as it prevents water uptake, gaseous exchange and radicle emergence (Mirzaei *et al*., 2015; Toksoy *et al*., 2015; Von Denffer *et al*., 1971; Zohary, 1946; Simpson, 2006; Stace, 1980). According to (Townsend and Guest, 1974) there are about 367 taxa belonging to 310 species within 46 genera of the family that are naturally distributed in Iraq.

The family is specified by its distinctive characteristics of flowers and fruits (Metcalfe and Chalk 1957). Fabaceae members are the most common species distributed in Hujran Basin (Galalaey *et al*., 2021). Taia, (2004) examined seeds of some genera as *Medicago* L., *Melilotus* Mill., *Ononis* L., *Trifoliun* L., and *Trigonella* L. intention to evaluate the correlation among taxa (Zoric *et al*., 2009). Husaini and Iwo (1992) worked extensively on *Crotalaria* L. and reported the genus phenological information which is based on conventional taxonomic methods.

Multivariate analysis proved useful in delimiting the morphological variation in *Acacia senegal*. Both quantitative and qualitative characters were found to be useful for the delimitation of the taxa and hence for developing a field guide to identification of the taxa (Mulumba and Kakudidi 2010). Study of taxonomic relationships among important crops

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and their wild relatives is critical, especially because the germplasm of wild species could serve as a source of new attributes for crop plants. There are few attempts to introduce wild vetch species as alternative crops or as a breeding material (Abozeid *et al.* 2018). Abozeid *et al*., (2017) their studies based on morphological characteristics such as stems, flowers, and fruits. Proved cluster analysis has been used as a useful tool for construe relationships through different taxonomic levels. Abozeid *et al*., (2018) emphasized the morphological characters of leaves, especially the micro- morphological which may provide information for understanding species relationships in the genus *Vicia*, have not been studied to date (Abozeid *et al.* 2017) . Using the cluster analysis method, Al-joboury *et al.* (2017) studied the relationships among six species within different genera which were *Trifolium pretense* L., *Cicer arietinum* L., *Lathyrus vinealis* Boiss. *et* Noé, *Melilotus alba* Medic., Vorles, *Vicia sativa* L. and *Medicago polymorpha* (Benth.) Shinn.

Phenetic studies of exo-morphological characters can generate some precise estimations of relationships among the taxa. The modern phenetic study of family Fabaceae with subfamily Papilionoideae in Egypt, all Egyptian species of genus *Ononis* were grouped together in one phenon along with some species of each *Medicago* L., *Trifolium* L. and *Lathyrus* L. (Fayed *et al.* 2019). Morphometrics attempts to classify organisms based on morphological similarity. It can be used to describe the pattern of similarities among taxa by ordination or cluster analysis. Several angiosperm taxa have been reclassified using numerical taxonomy (Yaradua *et al*., 2019). Al-dabbagh and Saeed (2019) determined the relationship among all taxa of the Valerianaceae family that are widespread in Kurdistan region of Iraq by means of morphometric analysis.

The goal of this work was using morphological traits to show the relationships among the studied taxa, and to evaluate their implications in the taxonomy of the family.

2. MATERIALS AND METHODS

The phenetic analysis was based on the morphological features and individuals geographical distribution that taken from the (Townsend and Guest, 1974; Davis, 1970; Rechinger, 1979, 1984a ,1984b, 1999, 2001), in addition to those specimens which were reserved in College of Science, Salahaddin University-Erbil Herbarium (ARB). he data of this method using for comprehensive, evaluation and analysis in order to find the relationship among the genera and species which were studied. In numerical taxonomy, the programs of computer multivariate data analysis in morphological traits were used (Sneath and Sokal, 1973; Al-dabbagh & Saeed, 2019).

The qualitative and quantitative features were applied for OTUs that used as selected taxa of the family. Numerical analysis by UPGMA (Unweighted Pair-Group Method using arithmetic Averages). Cluster analysis was accomplished by MVSP (Multi Variate Statistical Package) for Windows, version 3.22. The variation key states which were taken for analyzing of each of the variants were 121 key characteristics for the all studied taxa and genera.

The similarity and dissimilarity have been analyzed by comparing each OUT with all other OTUs, all the data from the individual sets were incorporated to carry out the whole of 121 characters states analysis, including 367 taxa within 46 genera which belong to the family Fabaceae; 239 taxa belonging to 45 genera for all taxa excluding the genus *Astragalus* L. analyzing. Finally, the similarity coefficients were calculated by Gower that was used to set up cluster trees using UPGMA.

3. RESULTS

3.1. The relationships among taxa within the family:

The constructed dendrogram based on morphological characters of all taxa within the Fabaceae family, showed the similarity and dissimilarity relationships among all taxa depended on the presence or absence of various characteristics such as plant habits, petioles, type of compound leaves, modified tendrils of leaves, and stipules and or type of stipules, modified bract and bracteoles, pedicellate or sessile flowers, calyx tube, and different habitat of distribution and their natural growth (Fig. 1).

3.2. The general relationships among the studied genera:

The formed dendrogram depended on morphological traits of all distributed genera of the Fabaceae family in Iraq (Fig. 2). The first group at level GGSc= 0.67 which involves the three single members *Astragalus* L., *Phaseolus* L. and *Onobrychis* Mill. The second group at level GGSc= 0.75 includes two sub-groups; 2a- *Pisum* L., *Lathyrus* L., *Vicia* L., *Lens* Mill., *Cicer* L.,

Trifoliium L., *Medicago* L., *Trigonella* L., and *Ononis* L., on account of herb, perennial or annual, erect or decumbent, indumentum or glabrous, angular or cylindrical, unbranched or branched basically stems. Petiolate or semi sessile, pari, impari or tri pinnate compound leaves, absence of tendrils, variations of stipule size. Flowers are solitary or in elongated racemes, calyx tube, flowers are pedicellate or sub-sessile, vary in colors, yellow, purple to white or the petals with different colors, the fruits are oblong or ovoid legumes. This sub-group is distributed in steppe, mountain, hillsides, desert and mountain slopes. 2b- *Alhaji* Adans., *Scorpiurus* L. and *Sophora* L. due to similarity in these traits as herb, erect, indumentum, unbranched, branched at base, lack of tendrils, calyx tube, yellow color of flowers, and the growth location are steppe, desert and mountain slopes.

The similarity of the third group taxa at level GGSc= 0.81 includes three sub-groups, 3a- *Coronilla* L., *Hippocrepis* L., *Securigrera* DC., *Lotus* L., *Chesneya* Lindl. *e*x Edl., and *Factorovskya* Eig owing to the taxa being herb, glabrous or indumentum, cylindrical stem, branched at base, imparipinnate, lacking of tendril, presence of bracts, yellow flowers, and desert habitat. 3b- *Amorpha* L., *Oxytropis* L. and *Dorycnium* Mill., on account of perennial duration, ascending habit, indumentum, the stem is cylindrical in shape, branched at base, the leaves are bifoliate with reduced the tendrils, small stipules, calyx tube, flowers sub-sessile, petals by different colors, and oblong legumes. 3c- This sub-group consists of the rest genera of the group, they are *Psoralea* L., *Lablab* Adans., *Glycin* Willd., *Vigna* Savi, *Hymenocarpos* Savi, *Melilotus* Mill., *Sesbania* Adans., *Clitoria* L., *Sphaerophysa* DC., *Colutea* L., *Tipuana* Benth., *Dalbergia* L. f., *Robinia* L., *Spartium* L., *Genista* L., *Crotalaria* L., *Hedysarum* L., *Glycyrrhiza* L., *Taverniera* DC., *Argyrolobium* Eckl. *et* Zeyh, and *Anagyris* L., with the reason of a possesses the following distinguishing characteristics: perennial herbs, erect, stem cylindrical, unbranched or branched at base, leaves are petiolate, imparipinnate, absence of tendril, elongated raceme inflorescences, calyx tube, pedicellate flowers with vary in color, legume oblong, and the habitat steppe and desert.

3.3. The relationships among the studied taxa:

The founded dendrogram count on morphological features of distributed species of the family Fabaceae in Iraq except *Astragalus* taxa (Fig. 3), at level GGSc= 0.74 which includes four sub-groups; 1a- *Scorpiurus muricatus* var. *muricatus* and *S. muricatus* var. *subvillosus.* because of the species are annual herbs, erect, sub-cauline, indumentum, stem angular, branched or un-branched at base, leaves are sessile or semi sessile, simple, tendril absent, large stipules, solitary flowers, inflorescences are umbellate, bracts absent, calyx tube, pedicellate flower, petals are yellow with deep red color, coiled or contorted legumes, and the steppe and mountain slopes habitat. 1b- *Lens culinare* Medic. *L. orientalis* (Boiss.) Hand. -Mazz., *L. montbretii* (Fisch. *et* Mey.) Davis *et* Plitm., *Cicer anatolicum* Alef. and *C. oxyodon* Boiss. *et* Hoh. in cause of the similarity among the individuals in erect or decumbent trachomatous branched at base herbs, leaves almost sessile, paripinnate less than three leaflets, the presence of tendril, small stipules, solitary flowers or in elongate racemes, bracts are reduced, calyx tube, flowers sub-sessile or pedicellate, legumes oblong. 1c- *Pisum sativum* subsp. *sativum* L., *P. sativum* var. *sativum* L., *P. sativum* var. *arvense* (L.) Poir. and *P. sativum* var. *pumilio* Meikle, *Chesneya rytidosperma* Faud., *et* Spach, *Cicer arietinum* L., *C. bijugum* Rech. F., *C. pinnatifidum* Faub. *et* Spach, *Arachis hypogaea* L., *Factorovskya aschersoniana* (Urb.) Eig., Bull., in order to exist the distinct similarity in annual herbs, branched as base, leaves are petiolate, pinnate less than three leaflets, large stipules, flowers solitary or in elongated racemes, pedicellate, the absences of bracts, calyx tube. 1d- *Pisum formosum* var *pubescens* Townsend, *Oxytropis savellanica* Bunge ex Boiss. and *Amorpha fruticosa* L.,because of the members of this sub-group have perennial hairy herbs, branched at base, pinnate leaves, less than three leaflets, pedicellate solitary flowers, calyx connate at base, legumes straight and oblong.

However, in the level GGSc= 0.77 encompass three sub-groups; 2a- *Coronilla scorpioides* (L.) W. D. F. Koch, *Hippocrepis unisiliquosa* subsp. *Bisiliqua* (Forssk.) Bornm., *H. ciliata* Willd., *H. bicontorta* Lois., *Securigrera securidaca* (L.) Deg. *et* Doerfl., *Sophora japonica* L., *S. alopecuroidea* var *alopecuroidea* L., *S. alopecuroidea var tomentosa* (Boiss.) Bornm., *S. gibbosa* (DC.) Yakovl., *Coronilla varia* L., *Lotus halophilus* Boiss. *et* Sprun., *L. corniculatus* var. *corniculatus* L., *L. corniculatus* var. *tenuifolius* L., *L. aegeus* (*sulphureus*) (Griseb) Boiss., *L. gebelia* var. *gebelia* Vent., *L. gebelia* var. *hirsutissimus* (Ledeb) Dinsm. *L. lanuginosus* Vent., Jard. Malm.

and *Dorycnium pentaphyllum* subsp. *Haussknechtii* (Boiss.) Gams, because of the taxa are similar in annual or perennial, rhizomatous, prostrate or erect herbs, the presence of trichomes, basically branched, leaves are petiolate or sessile, imparipinnate less than three leaflets, tendril absent, small petioles, umbellate or spike-like inflorescences, bracts absent, calyx tube, flowers often subsessile or sessile, petals yellow or white, and legumes are straight. 2b- *Psoralea jaubertiana* Fenzl, *P. corylifolia* L. *Lablab purpureus* (L.) Sweet, *Phaseolus vulgaris* L., *Hymenocarpos circinnatus* (L.) Savi, *Glycin max* (L.) Merrill, *Vigna unguiculate* (L.) Walp. *V. radiata* (L.) Wilczek, *Melilotus officinalis* (L.) Pall., *M. alba* Medic., Vorles. Churpf., *M. indica* (L.) All. and *M. messanensis* (L.) All., due to similarity in annual erect or twining herbs, covered with different trichomes, petiolate, tripinnate with lacking of tendrils, stipules small, bracteate, synsepalous, flowers often subsessile, and inflated, oblong legumes. 2c- *Alhaji graecorum* (*maurorum*) Boiss., *A. camelorum* Fisch., *Sesbania sesban* (L.) Merrill, *S. cannabia* (Retz.) Poir., *S. bispinosa* (Facq) W. F. Wight, *Clitoria ternatea* L., *Glycyrrhiza glbra var. glabra* L., *G. glabra* var. *glandulifera* (Waldst. *et* Kit.) Regel et Herd., *Hedysarum pannosum* (Waldst. *et* Kit.) Regel *et* Herd., *H. singarense* Boiss. *et* Hausskn., *H. varium* subsp. *syriacum* (Boiss.) Townsend, *H. kotschyi* Boiss. *Sphaerophysa salsula* (Pall.) DC., *Colutea cilicica* Boiss. *et* Bal., *Tipuana tipu* (Benth.) O. Ktze., *Dalbergia sissoo* Roxb., *Robinia pseudacacia* L., *Spartium junceum* L., *Taverniera nummularia* DC. *Genista tinctorial* L., *Crotalaria juncea* L., *Argyrolobium crotalarioides* Faub., *A. roseum* (Cambess) Faub., and *Anagyris foetida* L., this sub-group is formed based on the particulars similarity in hairy, herbs, shrublets or tree, perennial plants, erect, cylindrical often branched stem, petiolate, less than three leaflets, imparipinnately compound leaves with small stipules, tendril absent, bracteolate flowers, and connected sepals.

4. DISCUSSION

This research paper, depended on the different clusters of morphological characters analysis as conducted by (Sneath and Sokal 1973) and (Stuessy 1990).

MVSP cluster analyzing of the essential characters of the studied taxa of the family revealed that all studied taxa are monophyletic, also showed various relationships distances caused by the partnership similarities and dissimilarity among the inherited traits of these taxa. As (Yaradua *et al*., 2019) confirmed that morphometric analysis involves the multivariate analysis of a set of quantitative and qualitative morphological characters of individual specimens of the taxa. This is often used to determine whether closely related species have discrete or overlapping morphologies, which may be important in the taxonomic revision of a group.

The Gower General Similarity coefficient for morphological data sets was cleared in the dendrogram formed by cluster analysis of studied genera morphometric figure (2). The absolute similarity is marked by 1.000, showed the higher similarity at group 3 at level GGSc=0.81.

The three groups G1, G2 and G3 are monophyletic via the specific distinctive characteristics of the family that made the constructed tree unified. The OTUs of group1; *Astragalus* and *Phaseolus* are synapomorphy at level GGSc=0.67 due to the similarity, the divergence with *Onobrychis* comes after the dissimilarity of imparipinnate leaves, small stipules, flowers sessile, color of petals, fruit semilunar, hirtellous, orbicular or reniform and the spiny legumes.

The convergence among the OTUs of group2 caused by the dissimilarity traits between sub-group 2a and sub-group 2b at level GGSc=0.75, the similarity among the OTUs of sub-group 2a is synplesiomorphy on account of the taxa being herb, erect, indumentum, unbranched or branched, lack of tendrils, calyx tube, yellow color of flowers, and steppe and mountain slopes distribution; the divergence considered by the differences in erect and procumbent , caespitose, creeping habit, stem winged, glabrous, petiolate, type of pinnate leaves, inflorescence types, flowers are sessile or pedicellate, colors of petals and/or with additional color, legumes are ovoid or oblong, curved or straight, flat or inflated. The similarity among the OTUs of sub-group 2b is synapomorphy due to similarity in traits as herb, erect, indumentum, unbranched, branched at base, lack of tendrils, calyx tube, yellow color of flowers, and the growth location are steppe, desert and mountain slopes; the divergence relating to annual or perennial duration, herbs, shrublets or tree plants, indumentum, glabrous, spinose or rhizomatous, leaves paripinnate or imparipinnate, type of

inflorescences, straight, curved or coiled, sinuses, ovoid, inflated legumes.

OTUs of group3 are monophyletic at level GGSc=0.81, due to high morphometric similarity among this group of taxa. The correlation between sub-group 3b and sub-group 3c is polyphyletic on account of perennial herbs, the stem is cylindrical in shape, branched at base, the leaves are bifoliate imparipinnate with reduced the tendrils, calyx tube, petals with different colors, and oblong legumes; the parallelism between sub-group 3a and sub-group 3c is false synapomorphy caused by the similarity in distinguishing traits such as herb, cylindrical stem, branched at base, leaves are imparipinnate, lacking of tendril, sepals are connected at base, and desert habitat; these characteristics are tangled among most OTUs of the three sub-groups. The reason for the sub-groups divergences through the taxa are contrastive in plant habit and duration, leaves petiolate or sessile, stipule sizes, inflorescence types, flowers are sessile, subsessile or pedicellate, petals colors, legumes are oblong, linear or ovoid, straight or curved, flatted or inflated, and the difference in growth places.

The constructed dendrogram to determine the similarity degrees among the studied taxa of the Fabaceae family excluded the taxa of the genus *Astragalus*, demonstrated that all groups are monophyletic. The sub-group 1a meets other sub-groups of group1 at level GGSc=0.74 in cause of the similarity among the individuals in trachomatous herbs, branched at base, leaves are sessile or semi sessile, absence of bracts, pedicellate flowers, connate at base calyx tube; the divergence caused by the variances in characteristics such as the species are annual, decumbent, subcaulescent, hairy, leaves are simple, sessile or almost sessile, stipules conspicuous small lanceolate, umbellate inflorescence, flowers yellow, petals yellow with deep red color, legumes contorted and coiled, and distribute in steppe to mountain slopes. The close rapport between sub-group 1b and sub-group 1c is synapomorphy due to the similarity in branched as base herbs, flowers solitary or in elongate racemes, pedicellate, calyx tube; the divergences owing to the dissimilarity in the taxa being annual or perennial, hairy or glabrous, erect, decumbent or scrambling herbs, the presence of woody rootstock, petiole of leaves, paripinnate or imparipinnate, tendrils, stipules, pedicellate, sub-sessile or sessile flowers, petals color, legumes shape, and the distribution locations. The appearance of the *Cicer* taxa in both sub-groups is polyphyletic; *Cicer anatolicum* and *C. oxyodon* of nested species in sub-group 1b is false synapomorphy caused by the great similarity among these taxa with the other taxa of sub-group; this applies to *Cicer arietinum*, *C. bijugum*, *C. pinnatifidum* in sub-group 1c as well, as a rule, implies that divergence of the taxa of *Cicer* is caused by parallelism due to these counteractive traits respectively; perennial and annual, scrambling with woody rootstock and erect, cylindrical and angular stems, leaves less than three leaflets (paripinnate) and imparipinnate leaves, leaves modified to tendril and leaves unmodified, and flowers blue and purple. Forth sub-group 1d is synplesiomorphy caused by the close similarity within the taxa of sub-group with other sub-groups of group1because of the members of this sub-group are branched at base hairy herbs, flowers solitary or in elongate racemes, pedicellate, calyx tube; the divergence because of the dissimilarity in herb or shrub, inflorescences spike-like, flowers solitary, sessile or subsessile, ebracteate, legumes ovoid oblong, curved or straight. The nested species *Pisum formosum* var *pubescens* is divergence due to being perennial with rootstock, pubescent, procumbent herb, leaves imparipinnate, semi sessile, stipules are small, flowers in bracteate capitate-like inflorescence, flowers sessile or sub-sessile, inflated ovoid oblong legumes, and mountain habitat growth.

Sub-groups 2a, 2b and 2c within group 2 are meet at GGSc= 0.77, they have synplesiomorphy relation due to the great similarity among taxa. The similarity between sub-group 2a and sub-group 2b because of the taxa are similar in annual prostrate or erect herbs, covered with different trichomes, leaves are petiolate, lacking of tendrils, flowers often subsessile, calyx tube, legumes are straight; the divergence due to the differences in annual and perennial, hairy and glabrous, erect, prostrate, sprawling, twining and rhizomatous herbs, leaves petiolate, subsessile and sessile, umbellate and elongate inflorescences, legumes shape and type, and differences distribution location. Sub-group 2c with sub-groups 2a and 2b are false synapomorphy caused by parallelism similarity in perennial erect herbs, presence of trichomes, petiolate imparipinnate compound leaves, absence of tendrils, and connected sepals; the polyphyletic caused by dissimilarity in perennial hairy shrubs

or trees, flowers pedicellate, fruits lomentum or straight oblong.

5. CONCLUSION

The results showed that the similarities and dissimilarity of the inherited morphological traits had an important role in determining each taxon within the rank assigned to the studied taxa according to their relationships. The taxa that have the most similar characteristics are grouped into a single group, nesting the taxon in certain groups due to sharing many characteristics with the other distant taxa group.

Conflict of Interest (1)

There is no conflict of Interest

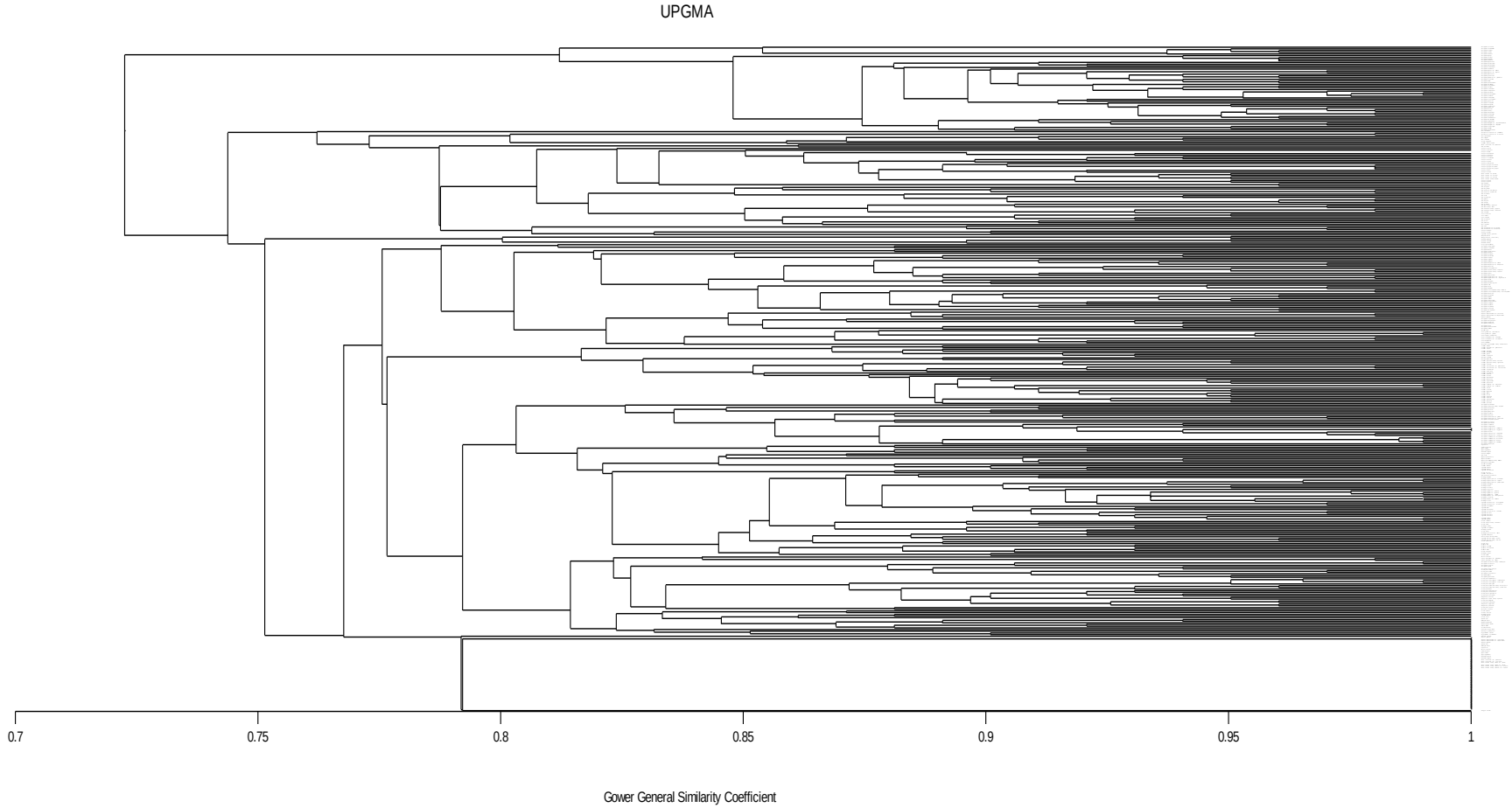

Figure 1. Dendrogram of the similarity degrees among the taxa of the Fabaceae family. (Enlarge the diagram to show the details more clearly).

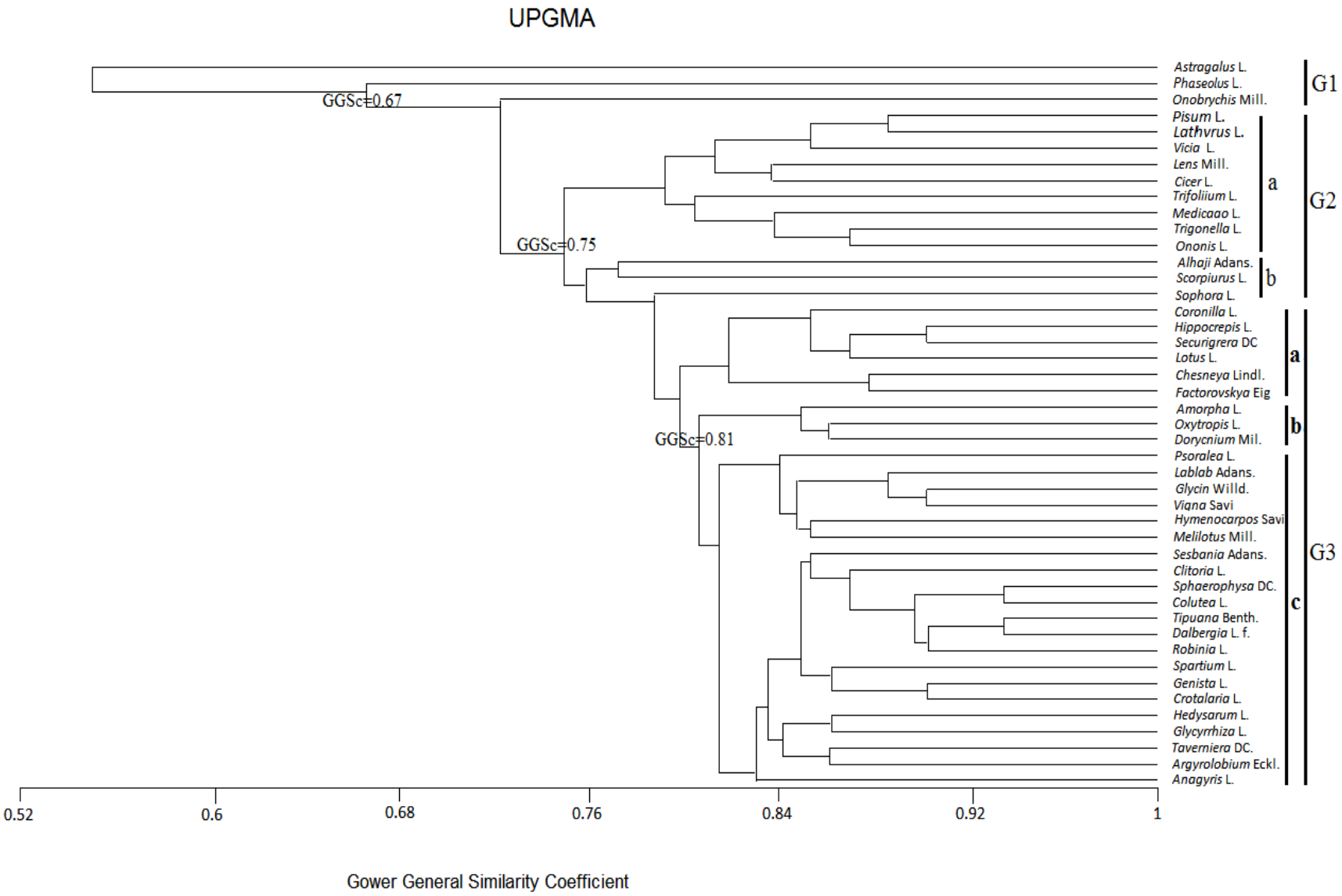

Figure 2. Dendrogram of the similarity degrees among the genera of the Fabaceae family.

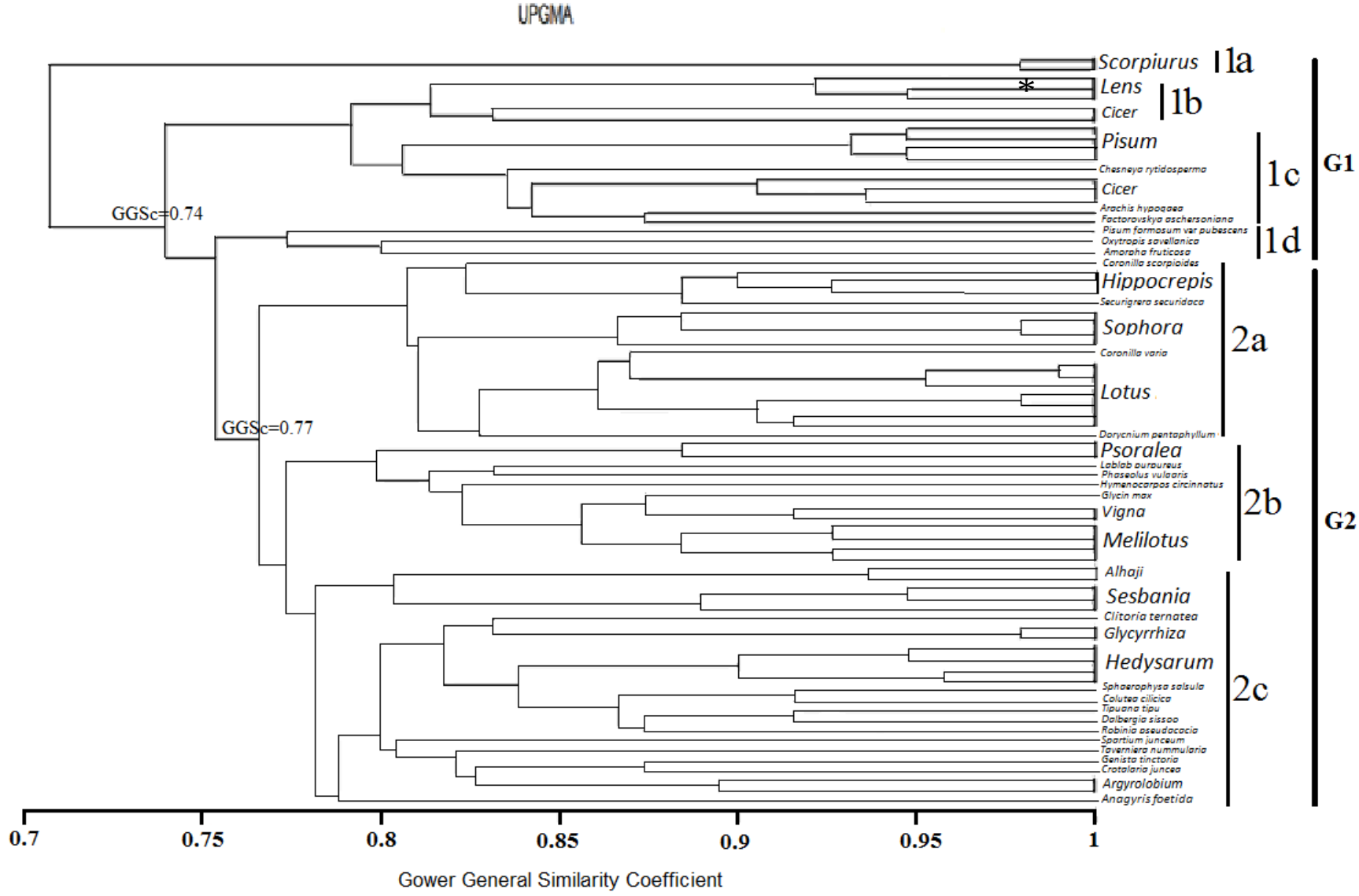

Figure 3. Dendrogram of the similarity degrees among the studied taxa of the Fabaceae family except *Astragalus* taxa.
* The taxa are mentioned by order in the text.

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