Numeric taxonomy of some Apioideae species, based on general morphology and carpological features

Magdy M. MOURAD
Abdelsalam AL-NOWAIHI
Department of Botany, Faculty of Science,
Ain Shams University, Abbassia, Cairo (Egypt)
mouradmagdy@yahoo.com
abdelsalamalnowaihi@hotmail.com

Mourad M. M. & Al-Nowaihi A. 2013. — Numeric taxonomy of some Apioideae species, based on general morphology and carpological features. *Adansonia*, sér. 3, 35 (2): 375-389. http://dx.doi.org/10.5252/a2013n2a9

ABSTRACT
The gross morphology as well as fruit morphological and anatomical characters of twenty four taxa of subfamily Apioideae was investigated to show their taxonomic location as compared to Drude's classification (1898). The classification of the studied taxa is summarised as follows: 1) *Pimpinella* L. of Drude's tribe Ammineae is segregated alone in a separate branch; 2) some of the genera of tribe Ammineae namely *Ammi* L., *Apium* L., *Petroselinum* Hill, *Ridolfia* Moris and *Carum* L. are agglomerated in subgroup I of group I; 3) *Chaerophyllum* L. of tribe Scandicineae subtribe Scandicinae, *Torilis* Adans. of tribe Scandicineae subtribe Caucalinae and *Cuminum* L. of tribe Ammineae are separated in the form of separate branches from subgroup I of group I; 4) *Bifora* Hoffm. and *Coriandrum* L. of tribe Coriandreae are also separated together in subgroup II of group I; 5) *Anethum* L. of tribe Ammineae and *Malabaila* Hoffm. of tribe Peucedaneae subtribe Tordyliinae are clustered with *Foeniculum* Mill. of tribe Ammineae in subgroup III of group I; 6) *Daucus* L. of tribe Dauceae and *Pseudorlaya* (Murb.) Murb. of tribe Scandicineae subtribe Caucalinae are clustered together in group II; and 7) *Deverra* DC. species and *Bupleurum semicompositum* L. of tribe Ammineae are clustered together in group III. The obtained data were numerically analyzed by the NTsys-PC program package using the UPGMA clustering method.

KEY WORDS
Apiaceae,
Apioideae,
Umbelliferae,
gross morphology,
fruit morphology
and anatomy.

RÉSUMÉ

Taxonomie numérique de quelques espèces d'Apioideae, fondée sur des données de morphologie générale et de carpologie.

La structure d'ensemble, ainsi que les caractères morpho-anatomiques du fruit de 24 taxons d'Apiaceae de la sous-famille des Apioideae ont été examinés afin de déterminer leur signification taxonomique dans la classification de Drude (1898). Il en résulte le nouveau classement suivant : 1) Pimpinella L. de la tribu des Ammineae selon Drude est isolé dans une branche séparée ; 2) certains genres de la même tribu, à savoir *Ammi* L., *Apium* L., *Petroselinum* Hill, *Ridolfia* Moris et *Carum* L. sont réunis au sous-groupe I du groupe I ; 3) en revanche, *Chaerophyllum* L. de la tribu des Scandicineae (subtrib. Scandicinae), *Torilis* Adans. de la même tribu (subtrib. Caucalinae) et *Cuminum* L. de la tribu des Ammineae sont séparés du sous-groupe I du groupe I, et forment des branches indépendantes ; 4) *Bifora* Hoffm. et *Coriandrum* L. de la tribu des Coriandreae sont tous deux retirés du sous-groupe II du groupe I ; 5) *Anethum* L. (tribu des Ammineae) et *Malabaila* Hoffm. (tribu des Peucedaneae, subtrib. Tordyliinae) sont rassemblés avec *Foeniculum* Mill. (tribu des Ammineae) dans le sous-groupe III du groupe I ; 6) *Daucus* L. (tribu des Dauceae) and *Pseudorlaya* (Murb.) Murb. (tribu des Scandicineae, subtrib. Caucalinae) sont réunis dans le groupe II ; et 7) *Deverra* DC. et *Bupleurum semi-compositum* L. de la tribu des Ammineae sont tous deux placés dans le groupe III. Les données obtenues ont été analysées par le logiciel NTsys-PC, suivant la méthode de classification hiérarchique UPGMA.

MOTS CLÉS
Apiaceae,
Apioideae,
Umbelliferae,
caractères morpho-anatomiques du fruit.

INTRODUCTION

Apioideae are the largest and most taxonomically complex of the three subfamilies of Apiaceae, including many familiar and edible plants. Apiaceae are represented by 24 genera and 49 species in the wild flora of Egypt (subfamilies Apioideae and Saniculoideae) sensu Drude (1898) and Boulos (2000). The current traditional treatments (De Candolle 1830; Bentham 1867; Drude 1898 and Koso-Poljansky 1916) are constructed mainly on the basis of morphological and anatomical characters of the fruit since it exhibits many distinctive variations. Comparison of the accounts of these treatments shows widely diverging opinions on the definition and composition of its tribes and subtribes. These characters are distinctive and represented by the inferior 2-carpelled ovary, the schizocarpic fruits with two one seeded generally five-ribbed mericarps, the presence of carpophores, the presence of intrajugal oil ducts and vallecular vittae, extension of commissure, fruit wings and presence or absence of crystals. While such focus on fruit structure has been rejected by many (Heywood 1971; Theobald 1971; Cronquist 1982; Spalik *et al.* 2001; Liu 2004; Liu *et al.* 2006), the highly criticized century-old system of Drude (1898) remains the most commonly used treatment.

Several studies have demonstrated the utility of molecular data in elucidation of evolutionary relationships in Apiaceae, including studies at the interspecific level (Soltis & Novak 1997; Downie *et al.* 2010), at the tribal level (Downie *et al.* 1996, 2000a, b, 2010; Magee *et al.* 2010), and the subfamilial level (Downie & Katz-Downie 1996; Downie *et al.* 1996, 2000a, b; Plunkett & Downie 1999).

Recent molecular studies, however, provided a radically different picture of relationships, call-

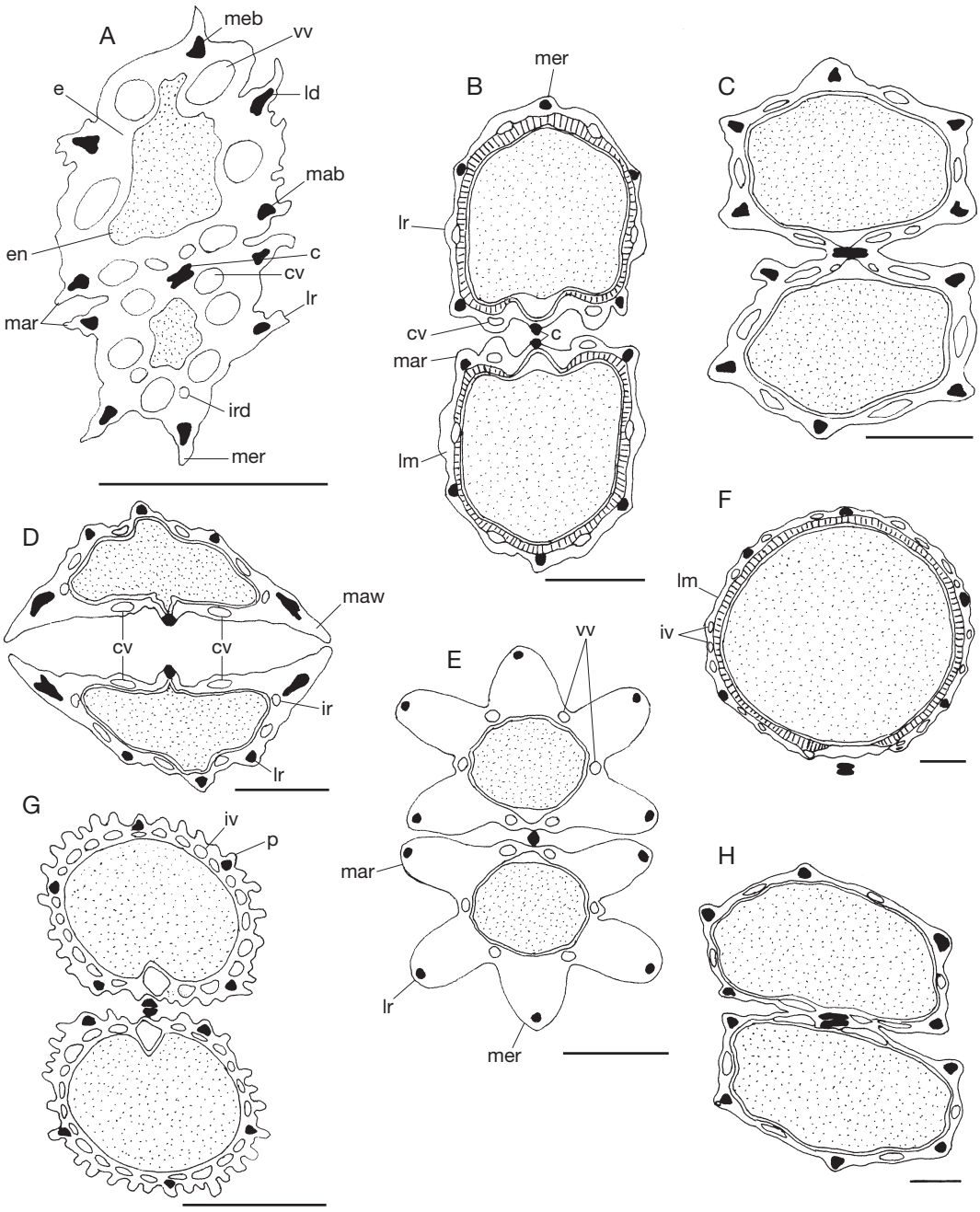

Fig. 1. — Fruit structure of representatives of the studied taxa: **A**, *Ammi majus* L.; **B**, *A. visnaga* L.; **C**, *Anethum graveolens* L.; **D**, *Apium graveolens* L.; **E**, *A. leptophyllum* (Pers.) F. Muell. ex Benth.; **F**, *Bifora testiculata* (L.) Spring. (one mericarp); **G**, *Bupleurum semicompositum* L.; **H**, *Carum carvi* L. **Open circles**, secretory oil ducts (vittae); **filled circles**, vascular bundles and carpophore; **hatching**, lignification. Abbreviations: **c**, carpophore; **cv**, commissural vittae; **e**, endocarp; **en**, endosperm; **ird**, internal rib oil duct; **iv**, irregular vittae; **lb**, lateral bundles; **lm**, lignified mesocarp; **lr**, lateral rib; **mab**, marginal bundle; **mar**, marginal rib; **maw**, marginal wing; **meb**, median bundle; **mer**, median rib; **p**, papilla; **vv**, vallecular vittae. Scale bars: 0.5 mm.

ing into question the utility of fruit characters. They also concluded that fruit anatomy closely corresponded with phylogenetic position of the genera, as suggested by molecular studies. A few recent studies have made important contributions to the study of micro-morphological and anatomical characters, particularly fruit anatomy (e.g., Spalik *et al.* 2001; Liu 2004; Liu *et al.* 2006: Magee *et al.* 2010). For this the present study aims at evaluation of the gross-morphology and the morphological and anatomical characters of the fruit for understanding the classification of the studied taxa of the largest and more complicated subfamily, the Apioideae.

Materials and methods

23 species and one variety belonging to 18 genera of wild and cultivated Egyptian representatives of Apioideae were collected and identified by the aid of the Flora of Egypt (Täckholm 1974) and Boulos (2000). The studied taxa (Table 1) were collected either from living or from herbarium specimens kept in Ain Shams University herbarium, Seed Bank of Flora and Cytotaxonomy Department, Cairo Museum (CAIM). The gross morphology and the external aspects of the fruit were investigated with Zeiss stereomicroscope. For anatomical studies, fresh and dry herbarium fruits were rehydrated and placed in FAA for a minimum of 24h and then treated according to the customary methods of infiltration and embedding of Johansen (1940), sections were cut at 8-12 µm, then stained in a safranin-fast green combination and mounted in Canada Balsam. Drawings were done using a camera lucida. Focus was made on mericarp shape, wings, ribs, intrajugal secretory ducts, presence or absence of small vittae scattered in the mesocarp, presence or absence of lignifications of the mesocarp and endocarp, commissural width, carpophores and endosperm shape (Figs 1-3).

Data preparation

The data editor program NT edit 2.2 was used for creating the matrix of computation, whereas the program NTSYS-pc 2.2 was used in all subsequent analysis (Rohlf 2005). Multistate characters were transformed to two-state characters in coding and the raw data matrix was standardized with STAND module.

Phenetic analysis

Similarity matrix was generated by SIMQUAL model based on Jaccard's coefficient (J) which is equivalent to Gower's coefficient when a two-state character matrix is used (Sneath & Sokal 1973). A phenogram was constructed by the unweighted pair-group method, arithmetic average (UPGMA). In order to test reliability of results, the correlation coefficient (r) value which measures the distortion between the produced phenogram and the relevant similarity matrix (Sokal & Rohlf 1981) was estimated as follows: the phenogram was computed using COPH module and compared to the related distance matrix using MXCOMP module.

RESULTS AND DISCUSSION

The results are presented in Table 2 showing the coded gross-morphology, and morphological and anatomical characters of the fruit of the studied taxa of Apioideae. Table 1 shows the arrangement of the studied taxa according to Drude's classification (1898) of the subfamily Apioideae.

The constructed phenogram (Fig. 4) produced from cluster analysis of the studied taxa based on the used 79 carefully chosen applicable attributes shows that the distribution of the studied taxa across the phenogram is in accordance with Drude's classification (1898). All the studied taxa have a highest average taxonomic distance value of 1.25. At the level of 1.22, *Pimpinella anisum* L. of the tribe Ammineae (Apieae) (Drude 1898 and Pimenov & Leonov 1993) is split off from all other taxa. Its most remarkable characters are the hairiness of the plant, the once-pinnate dissected leaves with the sheaths having scarious margins, the ovoid fruit which is laterally compressed, the mesocarp with many unequal scattered vallecular vittae and the presence of rib oil ducts (intrajugal oil duct, intrajugal vittae, or companion canals) on the ventral side of vascular bundles (Fig. 3E). *Pimpinella* L. species are also isolated from other apioids into a separate clade by the work of Downie *et al.* (2000a, b) on the basis of molecular data. Danderson & Downie (2007) stated that, within the apioid superclade (Plunkett & Downie 1999), seven tribes are confirmed as monophyletic (Apieae, Careae,

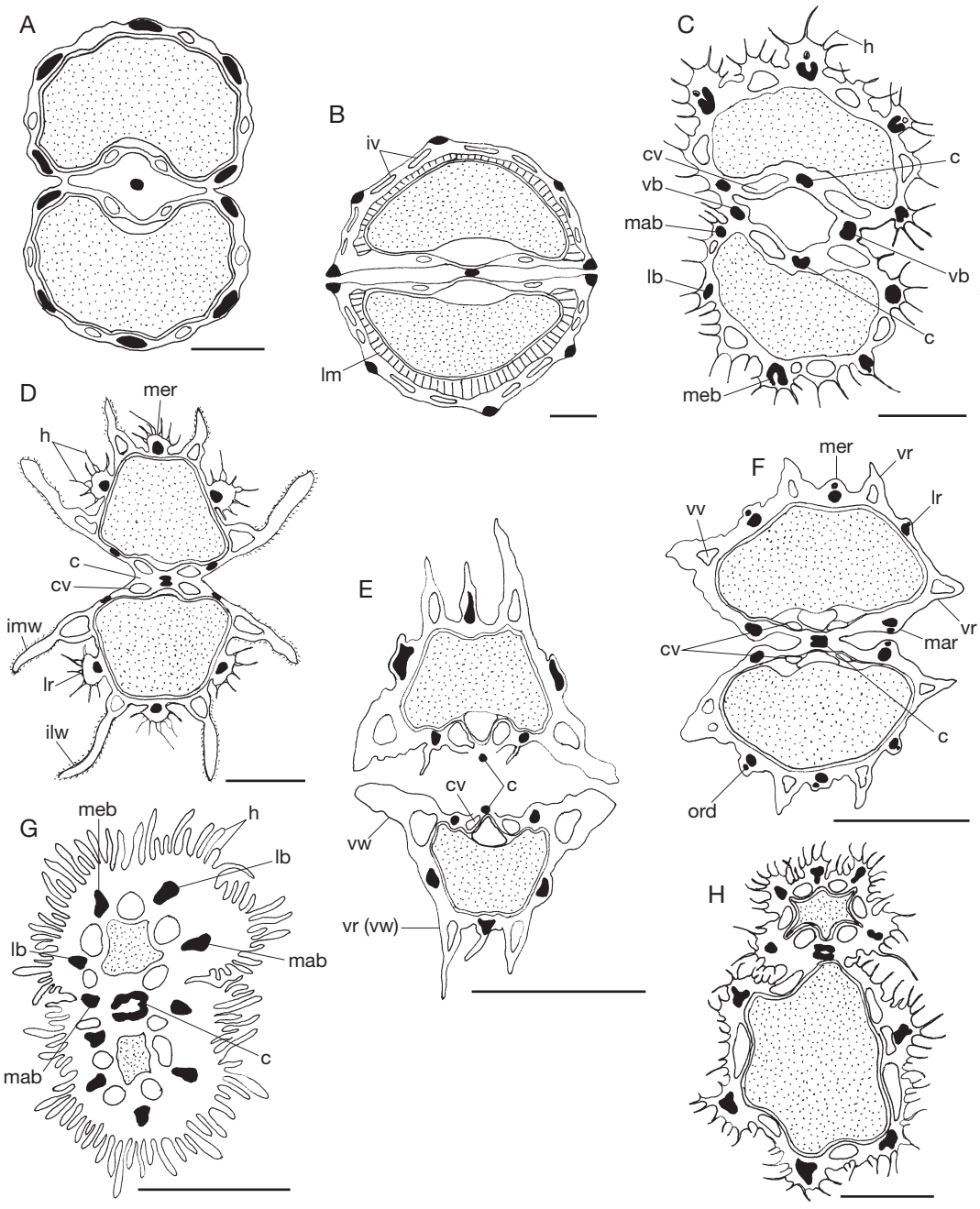

FIG. 2. — Fruit structure of the studied taxa: **A**, *Chaerophyllum bulbosum* L.; **B**, *Coriandrum sativum* L.; **C**, *Cuminum cyminum* L.; **D**, *Daucus aureus* Desf.; **E**, *D. carota* L.; **F**, *D. carota* var. *boissieri* Schweinf.; **G**, *Deverra tortuosa* (Desf.) DC.; **H**, *D. triradiata* Hochst. ex Boiss. Abbreviations: **h**, hairs; **ilw**, inter-rib lateral wing; **imw**, inter-rib marginal wing; **ord**, outer rib duct; **vb**, ventral bundle; **vr**, vallecular rib; **vv**, vallecular vittae; **vw**, vallecular wing (other abbreviations as in Fig. 1). Scale bars: 0.5 mm.

Echinophoreae, Pimpinelleae, Pyramidoptereae, Selineae, and Tordylieae). After Shiha *et al.* (2008), as a result of a phenogram based on fruit sculpture, *Pimpinella* L. species are grouped together and separated from the rest of the apioid taxa. Downie *et al.* (2008) supported four monophyletic tribes (Apieae, Selineae, Tordylieae, and Pimpinelleae) as a result of previous molecular data sets and phylogenetic analysis of only ITS sequences.

The remaining taxa are clustered in three major groups at the dissimilarity levels of 1.11, 1.14 & 1.17 respectively. The first major group (1.11) includes 16 taxa; the second (1.14) includes *Daucus* L. species and *Pseudorlaya pumila* (L.) Grande; the third (1.17) includes *Bupleurum semicompositum* L. and *Deverra* DC. species.

Within the first major group, taxa are clustered in three subgroups at the dissimilarity levels of 1.05, 0.87 & 1.01 respectively (Fig. 4). The first subgroup (1.05) includes *Ammi majus* L. (Fig. 1A), *Petroselinum crispum* (Mill.) Nym. (Fig. 3D), *Apium graveolens* L. (Fig. 1D) and *A. leptophyllum* (Pers.) F. Muell. Ex Benth. (Fig. 1E). These taxa were then grouped (clustered) with *Ridolfia segetum* (L.) Moris at the dissimilarity level of 0.86 due to their linear leaf segments, narrow sheath, glabrous fruit surface, 2-cleft carpophore, and a single layer of endocarp. *Ammi visnaga* (L.) Lam. (Fig. 1B) and *Carum carvi* L. (Fig. 1H) were grouped together (0.9) and clustered with *Chaerophyllum bulbosum* L. (Fig. 2A) at the dissimilarity level of 0.99 due to the following characters: 2-3 pinnately dissected leaves, linear segments, conic stylopodium, glabrous fruit and single lignified layer of endocarp. *Torilis radiata* Moench (Fig. 3H) and *Cuminum cyminum* L. (Fig. 2C) forms two separate branches of high dissimilarity levels of 1.02 and 1.05 respectively, and clustered with the previous taxa of the first subgroup due to their conic stylopodium as well as regular vallecular vittae: 1) furrow; and 2) commissure.

The first subgroup includes taxa belonging to tribe Apieae (Drude 1898): *Ammi* L., *Apium* L., *Carum* L., *Cuminum* L., *Petroselinum* Hill, *Ridolfia* Moris). Pimenov & Leonov (1993) placed *Cuminum* L. in tribe Caucalideae with *Daucus* L., *Torilis* Adans. and *Pseudorlaya* (Murb.) Murb. Downie *et al.* (2000a, b) and Katz-Downie *et al.* (1999) placed *Chaerophyllum* L., *Cuminum* L. and *Torilis* Adans. in tribe Scandiceae subtribes Scandicinae, Daucinae and Torilidinae respectively on the basis of molecular data sets. Downie *et al.* (2000c) placed *Ammi* L., *Apium* L., *Petroselinum* Hill, *Ridolfia* Moris with *Anethum* L. and *Deverra* DC. in a separate clade (Apium clade) on the basis of molecular data. Shiha *et al.* (2008) stated that *Torilis* Adans. species were splitted from the rest of the apioid taxa, on the basis of fruit sculpture.

The second subgroup contains *Bifora testiculata* (L.) Spreng. (Fig. 1F) and *Coriandrum sativum* L. (Fig. 2B) which clustered together at the level of 0.87 due to their membranous sheath margins, lacking of bracts, fruit glabrous and have irregular vittae (with different sizes), shallowly concave endosperm and single carpophores. Drude (1898) and Pimenov & Leonov (1993) placed the two taxa in tribe Coriandreae. Plunkett & Downie (1999) placed *Coriandrum* L. in Angelica group and *Bifora* Hoffm. in an uncertain group on the basis of molecular data.

The third subgroup contains *Anethum graveolens* L. (Fig. 1C) and *Malabaila suaveolens* Delile (Fig. 3C) which grouped together at the dissimilarity level of 0.99 due to their narrow leaf segments, lacking of bracts and bracteoles, the marginal ribs (of primary ribs) are more projecting (forming wings) than median and dorsal, single continuous lignified layer of endocarp, regular vittae and carpophore of two opposite vascular bundles. The two species are clustered with *Foeniculum* Mill. species (Fig. 3A, B) at high dissimilarity level of 1.01 due to the following syndrome: lacking of bracts and bracteoles, single, continuous and lignified layer of endocarp and number of vallecular and commissure vittae. Drude (1898) placed *Anethum* L. and *Foeniculum* Mill. in tribe Ammineae and *Malabaila* Hoffm. in tribe Peucedaneae subtribe Tordyliinae. Pimenov & Leonov (1993) placed *Anethum* L. in tribe Peucedaneae, *Malabaila* Hoffm. in tribe Tordylieae and *Foeniculum* Mill. in tribe Apieae. Downie *et al.* (2000c) placed *Anethum* L. and *Foeniculum* Mill. in Apium clade and *Malabaila* Hoffm. in Heracleum clade, the latter clade coincides with Drude's classification (1898).

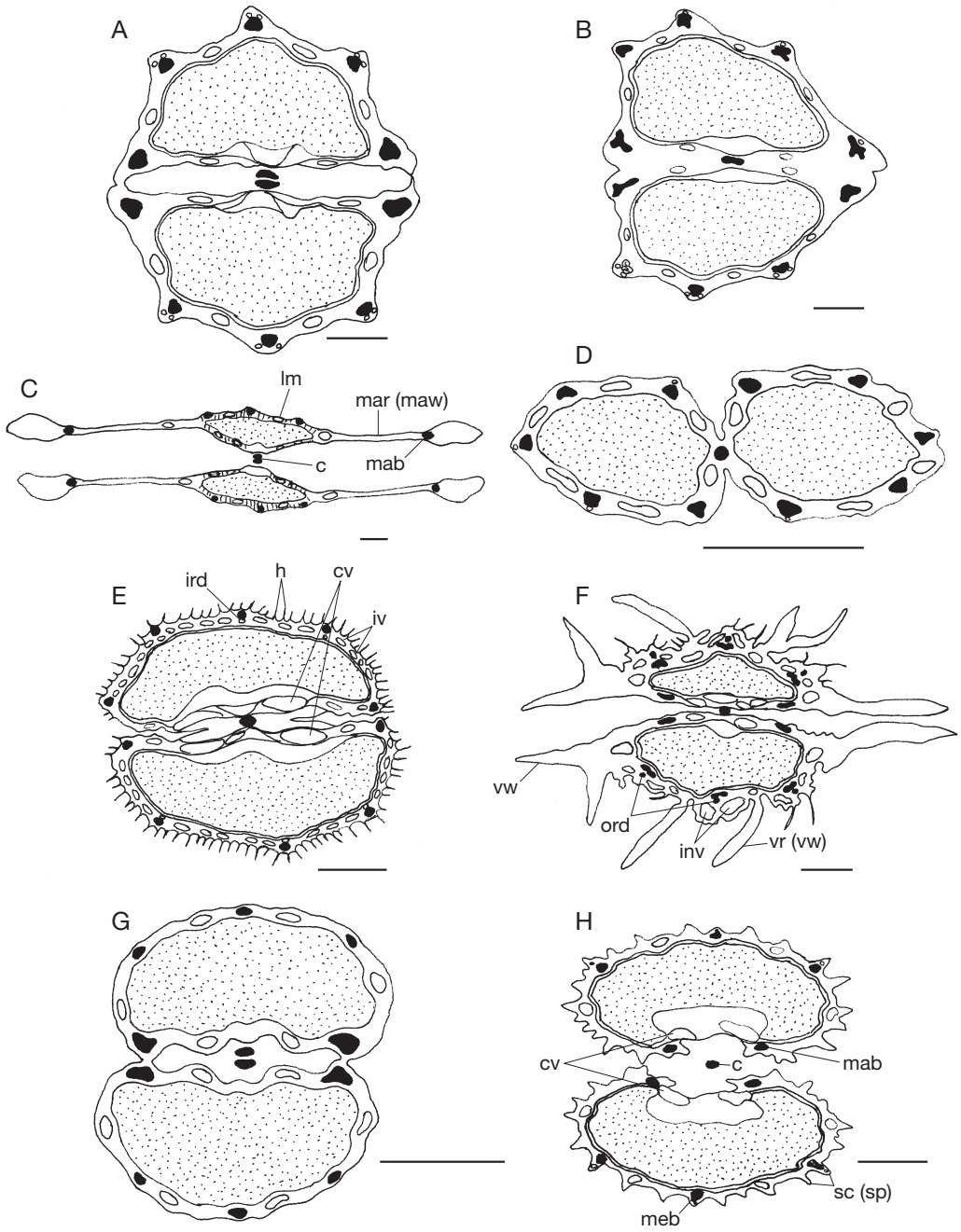

Fig. 3. — Fruit structure of the studied taxa: **A**, *Foeniculum capillaceum* Gilib.; **B**, *F. vulgare* Mill.; **C**, *Malabaila suaveolens* Delile; **D**, *Petroselinum crispum* (Mill.) Nym.; **E**, *Pimpinella anisum* L.; **F**, *Pseudorlaya pumila* (L.) Grande; **G**, *Ridolfia segetum* (L.) Moris; **H**, *Torilis radiate* Moench. Abbreviation: **inv**, intrajugal vittae. Other abbreviations as in Figures 1 and 2. Scale bars: 0.5 mm.

The second major group includes *Daucus* L. species (Fig. 2D-F) and *Pseudorlaya pumila* (L.) Grande (Fig. 3F) which grouped together (1.14) due to their sharing of the following characters: hairiness of the plant, presence of bracts and bracteoles, fruits hairy and prickly, entire carpophores, secondary ribs more projecting than primary ribs, single, continuous and lignified layer of endocarp and presence of regular vittae (1/furrow and 2/commissure). Drude (1898) placed *Daucus* L. in tribe Dauceae and *Pseudorlaya* (Murb.) Murb. in tribe Scandicineae subtribe Caucalinae. Pimenov & Leonov (1993) placed the two genera in tribe Caucalideae. Downie *et al.* (2000a, b) and Katz-Downie *et al.* (1999) placed the two genera in tribe Scandiceae subtribe Daucinae. Plunkett & Downie (1999) stated that the two genera were grouped together in group *Daucus* subgroup *Daucus* on the basis of molecular data. Lee & Downie (1999) and Shiha *et al.* (2008) stated that the genus *Daucus* L. may not be monophyletic, with some of its species closely allied to *Pseudorlaya* (Murb.) Murb.

Lee *et al.* (2001) mentioned that previous molecular studies have indicated that the spiny-fruited umbellifers (Apiaceae tribe Caucalideae sensu Heywood 1971) comprise two major lineages, recently delimited as Scandiceae subtribes Daucinae (*Daucus* L., *Pseudorlaya* (Murb.) Murb., *Cuminum* L.) and Torilidinae (*Torilis* Adans.), with the former including representatives of tribe Laserpitieae sensu Drude (1898). These taxa are allied with the monophyletic Scandiceae subtribe Scandicinae (*Chaerophyllum* L.) whose members lack spiny fruits. The relationships among these three subtribes are equivocal when nuclear ribosomal DNA internal transcribed spacer sequences are compared. Evidence from plastid DNA, however, suggests that Daucinae and Torilidinae are sister taxa. They provided results of a phylogenetic study of these spiny-fruited umbellifers based on morphology in order to study the evolution of these characters and to ascertain their utility for resolving relationships by comparison to the result of previous molecular analysis. Maximum parsimony analysis of 56 morphological characters resulted in a paraphyletic Torilidinae (*Torilis* Adans.) from which a monophyletic Daucinae subtribe (*Cuminum* L., *Daucus* L., *Pseudorlaya* (Murb.) Murb, etc.) is derived. Scandicinae subtribe (*Chaerophyllum* L.) is maintained as monophyletic, sister to Daucinae plus Torilidinae.

The third major group is represented by *Deverra* DC. species (Fig. 2G, H) which grouped together at the dissimilarity level of 0.75, clustering with *Bupleurum semicompositum* L. (Fig. 1G) at a high dissimilarity level of 1.17 due to the following syndrome: absence of leaf petiole, presence of bracts and bracteoles, conic stylopodium, 2-cleft carpophores. Drude (1898) and Pimenov & Leonov (1993) placed the two genera in tribe Ammineae (Apieae). Downie *et al.* (2000a) found strong molecular evidence showing the isolated position of *Bupleurum* L. within Apiaceae and concluded that *Bupleurum* L. should be included within the monogeneric tribe Bupleureae Spreng. Downie *et al.* (2008) showed that, among ten erected or confirmed monophyletic tribes, tribe Bupleureae is one of them as a result of molecular data sets. Shiha *et al.* (2008) stated that most *Bupleurum* L. species are clustered with *Deverra* DC. species, on the basis of fruit sculpture, the genus *Bupleurum* L. exhibiting moreover many similarities and/or relationships with most of the studied taxa of Apioideae. This is mainly because *Bupleurum* L. diverged early in the history of Apioideae, and its relationships to other genera remain uncertain as reported by Neves & Watson (2004). However, more studies are still needed on the relationships of this genus with other genera of the Apioideae.

CONCLUSION

The classification of the studied taxa compared to Drude's classification (1898) of the Apioideae on the basis of general morphology and fruit morphological and anatomical characters is summarised as follows: *Pimpinella* of Drude's Ammineae tribe is segregated alone in a separate branch. *Pimpinella* species are also isolated from other apioids into a separate clade or tribe by

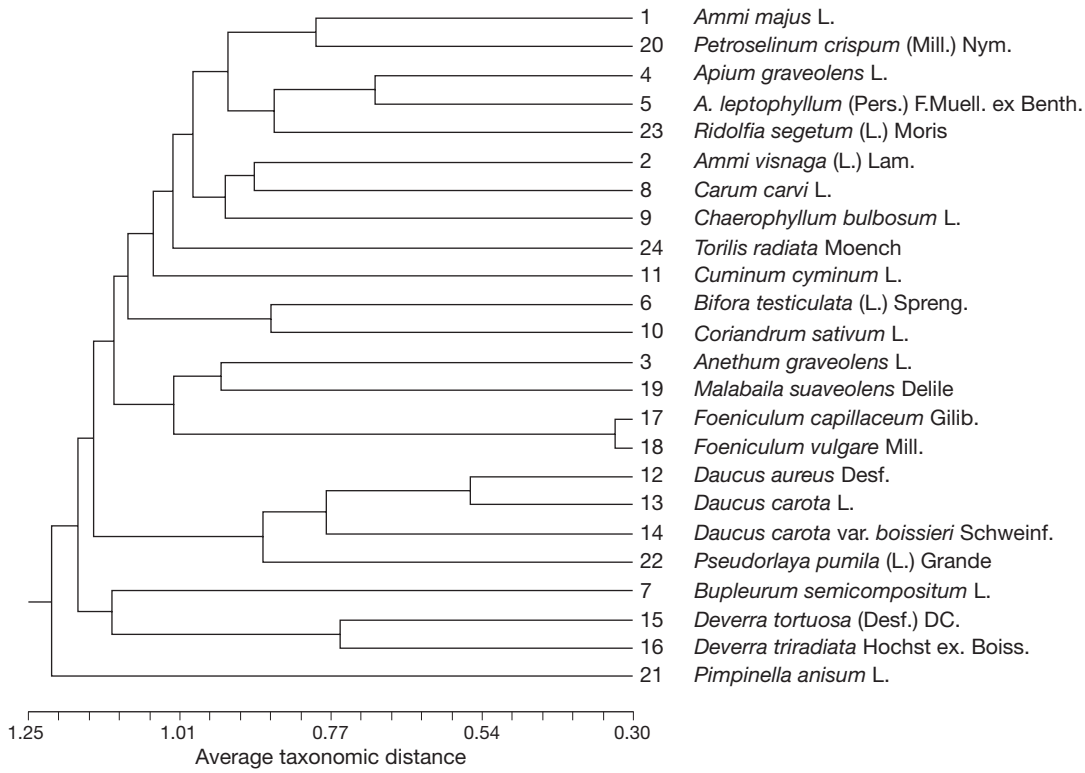

FIG. 4. — UPGMA phenogram based on 79 characters (gross morphology and fruit morphology and anatomy), illustrating the average taxonomic distance (dissimilarity) between the studied taxa of Apioideae.

many workers. Some of the genera of Drude's Ammineae tribe, Carinae subtribe namely *Ammi*, *Apium*, *Petroselinum*, *Ridolfia, Cuminum* and *Carum* are agglomerated in subgroup I of group I. *Chaerophyllum* of tribe Scandicinieae subtribe Scandicinae, *Torilis* of tribe Scandicinieae subtribe Caucalinae and *Cuminum* of tribe Ammineae are separated in the form of separate branches from Subgroup I of group I and maintained as monophyletic, sister to Daucinae plus Torilidinae. *Bifora* and *Coriandrum* of tribe Coriandreae are also separated together in subgroup II of group I. *Anethum* of tribe Ammineae and *Malabaila* of tribe Peucedaneae subtribe Tordyliinae are clustered with *Foeniculum* of tribe Ammineae in subgroup III of group I. *Daucus* of tribe Dauceae and *Pseudorlaya* of tribe Scandicineae subtribe Caucalinae are clustered together in group II. *Deverra* species and *Bupleurum semicompositum* of tribe Ammineae are clustered together in group III.

Our study is one of only a few studies incorporating such data, adds to the existing and growing database of information on Apioideae. While these data, like others, are singularly insufficient to resolve relationships among closely related taxa. Results based on the morphological, carpological studies and phylogenetic analyses recognize seven tribes in subfamily Apioideae. Further sampling and study are necessary before they can be treated formally. These results, and those presented in phylogenetic analysis, provide the necessary framework and explicit phylogenetic hypotheses from which future revisionary and other systematic studies can proceed.

Acknowledgements
We would thank J.-P. Reduron and Valéry Malécot, who read a first version of the manuscript.

REFERENCES

BENTHAM G. 1867. — *Umbelliferae*, *in* BENTHAM G. & HOOKER J. D. (eds), *Genera Plantarum* v.1: pt 3 (859-931).

BOULOS L. 2000. — *Flora of Egypt*, Geraniaceae-Boraginaceae 2. Al Hadara Publishing, Cairo: 153-188.

CRONQUIST A. 1982. — Reduction of *Pseudotaenidia* to *Taenidia* (Apiaceae). *Brittonia* 34: 365-367. http://dx.doi.org/10.2307/2806490

DANDERSON C. A. & DOWNIE S. R. 2007. — Resolving phylogenetic relationships within the apioid superclade (Apiaceae subfamily Apioideae) using cpDNA sequence data, with emphasis on tribe Apieae. *Botany and Plant Biology* 2007 Joint Congress, Chicago IL., abstract 1396.

DE CANDOLLE A. P. 1830. — *Prodromus systematis naturalis regni vegetabilis* IV. Treuttel and Würtz, Paris, Strasbourg, London: 55-250.

DOWNIE S. R. & KATZ-DOWNIE D. S. 1996. — A molecular phylogeny of Apiaceae subfamily Apioideae: evidence from nuclear ribosomal DNA internal transcribed spacer sequences. *American Journal of Botany.* 83 (2): 234-251. http://dx.doi.org/10.2307/2445943

DOWNIE S. R., KATZ-DOWNIE D. S. & CHO K.-J. 1996. — Phylogenetic analysis of Apiaceae subfamily Apioideae using nucleotide sequences from the chloroplast *rpoC1* intron. *Molecular Phylogenetics and Evolution* 6: 1-18. http://dx.doi.org/10.1006/mpev.1996.0053

DOWNIE S. R., KATZ-DOWNIE D. S. & WATSON M. F. 2000a. — A phylogeny of the flowering plant family Apiaceae based on chloroplast DNA rpl16 and rpoC1 intron sequences: towards a suprageneric classification of subfamily Apioideae. *American Journal of Botany* 87: 273-292.

DOWNIE S. R., WATSON M. F., SPALIK K. & KATZ-DOWNIE D. S. 2000b. — Molecular systematics of Old World Apioideae (Apiaceae): relationships among some members of tribe Peucedaneae sensu lato, the placement of several island-endemic species, and resolution within the apioid superclade. *Canadian Journal of Botany* 78: 506-528. http://dx.doi.org/10.1139/cjb-78-4-506

DOWNIE S. R., SPALIK K., KATZ-DOWNIE D. S. & REDURON J. P. 2008. — An ITS-based classification of Apiaceae subfamily Apioideae. *The 6th International Symposium on the Apiales*. Moscow State University, Moscow: 1-44.

DOWNIE S. R., SPALIK K., KATZ-DOWNIE D. S. & REDURON J.-P. 2010. — Major clades within Apiaceae subfamily Apioideae as inferred by phylogenetic analysis of nrDNA ITS sequences. *Plant Diversity and Evolution* (formerly *Botanische Jahrbücher*) 128: 111-136. http://dx.doi.org/10.1127/1869-6155/2010/0128-0005

DRUDE C. G. O. 1898. — Umbelliferae, *in* ENGLER A. & K. PRANTL (eds), *Die natürlichen Pflanzenfamilien* 3. Wilhelm Engelmann, Leipzig: 63-250.

HEYWOOD V. H. 1971. — Systematic survey of Old World Umbelliferae, *in* HEYWOOD V. H. (ed.), *The Biology and Chemistry of the Umbelliferae*. Academic Press, London: 31-41.

JOHANSEN J. 1940. — *Plant Microtechnique*. New York Book Company: 1-523.

KATZ-DOWNIE D. S., VALIEJO-ROMAN C. M., TERENTIEVA E. I., TROITSKY A. V., PIMENOV M. G., LEE B.-Y. & DOWNIE S. R. 1999. — Towards a molecular phylogeny of Apiaceae subfamily Apioideae: additional information from nuclear ribosomal DNA ITS sequences. *Plant Systematic and Evolution* 216: 167-195. http://dx.doi.org/10.1007/BF01084397

KOSO-POLJANSKY B. M. 1916. — Sciadophytorum systematis lineamenta: Mantissa prior. *Bulletin de la Société impériale des Naturalistes* (Moscou) 30: 277-290.

LEE B.-Y. & DOWNIE S. R. 1999. — A molecular phylogeny of Apiaceae tribe Caucalideae and related taxa: inferences based on ITS sequence data. *Systematic Botany* 24: 461-479. http://dx.doi.org/10.2307/2419700

LEE B.-Y., LEVIN G. A. & DOWNIE S. R. 2001. — Relationships within the spiny-fruited umbellifers (Scandiceae subtribes Daucinae and Torilidinae) as assessed by phylogenetic analysis of morphological characters. *Systematic Botany* 26: 622-642. http://dx.doi.org/10.2307/2419700

LIU M. R. 2004. — *A Taxonomic Evaluation of Fruit Structure in the Family Apiaceae*. PhD dissertation, Rand Afrikaans University, Auckland Park: 1-269.

LIU M. R., PLUNKETT G. M., LOWRY II P. P., VAN WYK B. E. & TILNEY P. M. 2006. — The taxonomic value of fruit wing types in the order Apiales. *American Journal of Botany* 93: 1357-1368. http://dx.doi.org/10.3732/ajb.93.9.1357

MAGEE A. R., CALVIÑO C. I., LIU M., DOWNIE S. R., TILNEY P. M. & VAN WYK B.-E. 2010. — New tribal delimitations for the early diverging lineages of Apiaceae subfamily Apioideae. *Taxon* 59: 567-580.

NEVES S. S. & WATSON M. F. 2004. — Phylogenetic relationships in *Bupleurum* (Apiaceae) based on Nuclear Ribosomal DNA ITS Sequence Data. *Annals of Botany* 93: 379-398. http://dx.doi.org/10.1093/aob/mch052

PIMENOV M. G. & LEONOV M. V. 1993. — *The Genera of the Umbelliferae: a Nomenclator*. Royal Botanic Gardens, Kew, 1-164.

PLUNKETT G. M. & DOWNIE S. R. 1999. — Major lineages within Apiaceae subfamily Apioideae: a comparison of

chloroplast restriction site and DNA sequence data. *American Journal of Botany* 86: 1014-1026.

ROHLF F. J. 2005. — Geometric morphometrics simplified. Review of "Geometric Morphometrics for Biologists: a primer". *Trends in Ecology and Evolution* 20: 13, 14.

SPALIK K., WOJEWÓDZKA A. & DOWNIE S. R. 2001. — The evolution of fruit in Scandiceae subtribe Scandicinae (Apiaceae). *Canadian Journal of Botany.* 79: 1358-1374. http://dx.doi.org/10.1139/cjb-79-11-1358

SHIHA A. M., SHEHATA A. A. & LOUTFY M. H. A. 2008. — Taxonomic utility of fruit features of some taxa of Apiaceae in Egypt. *Taeckholmia* 28: 101-130.

SNEATH P. H. A. & SOKAL R. R. 1973. — *Numerical taxonomy* – The principles and practice of numerical classification. W. H. Freeman, San Francisco: 1-573.

SOKAL R. R. & ROHLF J. F. 1981. — *Biometry: The Principles and Practice of Statistics in Biological Research*. 2nd ed., W. H. Freeman and Company, San Francisco, 859 p.

SOLTIS P. S. & NOVAK S. J. 1997. — Polyphyly of the tuberous Lomatiums (Apiaceae): cp DNA evidence for morphological convergence. *Systematic Botany* 22: 99-112.

TÄCKHOLM V. 1974. — '*Students*' *Flora of Egypt*. Cairo University, ed. 2: 382-397.

THEOBALD W. L. 1971. — Comparative anatomical and developmental studies in the Umbelliferae, *in* HEYWOOD V. H. (ed.), *The Biology and Chemistry of the Umbelliferae*, Supplement 1. *Botanical Journal of the Linnanean Society* 64: 177-197.

Submitted on 13 March 2012;
accepted on 28 December 2012;
published on 27 December 2013.

APPENDICES

TABLE 1. — Classification of the studied taxa of Apioideae according to Drude (1898) and its collection data. Abbreviations: *, Taxa introduced from seed bank exchange; **Alex**, Alexandria; **APNI**, Australian Plant Name Index; **ASUH**, Ain Sham University herbarium; **CAIM**, Seed bank of flora and cytotaxonomy department (Cairo Museum); **GRIN**, Germplasm Resources Information Network; **IK**, Index Kewensis.

Tribe	Subtribe	Genus	Species	Locality
Ammineae (Apieae)	Carinae	*Ammi* L.	*A. majus* L. – *Sp. Pl.* 2 1753 (APNI)	East. Med. Coast. region
			A. visnaga (L.) Lam. – Flore Françoise 3 1778 (APNI).	East. Med. Coast. region
		Apium L.	*A. graveolens* L. – *Sp. Pl.* 2 1753 (APNI).	Med. Coast. Strip (Alex-Matouh)
			A. leptophyllum (Pers.) F. Muell. ex Benth. – Fragmenta Phytographiae Australiae 4 1864 (APNI).	Cult. Botanical garden ASUH
		Bupleurum L.	*B. semicompositum* L. – *Demonstr. Pl.* 7. 1753 (IK)	Alalmin-Wadi Natron road sides
		Carum L.	*C. carvi* L. – *Sp. Pl.* 1: 263. 1753 (IK)	Cult. Seed Bank (ASUH)
		Cuminum L.	*C. cyminum* L. – *Sp. Pl.* 1: 254. 1753 (IK).	Cult. Seed Bank (ASUH)
		Deverra DC.	*D. tortuosa* (Desf.) DC. – *Prodr.* [A. P. de Candolle] 4: 143. 1830 (IK).	Wadi Talaa St. Kathreen Sinai
			D. triradiata Hochst. ex. Boiss. – *Fl. Orient.* [Boissier] 2: 861. [Dec. 1872 or Jan. 1873] (IK).	Wadi Talaa St. Kathreen Sinai
	Seselinae	*Petroselinum* Hill	*P. crispum* (Mill.) Nym. – *Conspectus Florae Europae* 1882 in obs. (APNI).	Cult. Botanical garden ASU
		Pimpinella L.	*P. anisum* L. – *Sp. Pl.* 1: 264. 1753 (IK).	Cult. Seed Bank (ASUH)
		Ridolfia Moris	*R. segetum* (L.) Moris – *Ind. Sem. Hort. Taur.* (1841); *Fl. Sard.* ii. 212. t. 75 (1842). (IK).	CAIM
		Anethum L.	*A. graveolens* L. – *Sp. Pl.* 2 1753 (APNI).	Cult. Seed Bank (ASUH)
		Foeniculum Mill.	*F. vulgare* Mill. – *Gard. Dict.*, ed. 8. n. 1. 1768 (IK).	Cult. Seed Bank (ASUH)
			F. capillaceum Gilib. – *Fl. Lit. Inch.* ii. 40. 1782 (IK).	CAIM
Coriandreae		*Bifora** Hoffm.	*B. testiculata** (L.) Spreng. – *Systema Vegetabilium* 6 1820 (APNI)	CAIM
		Coriandrum L.	*C. sativum* L. – *Sp. Pl.* 1: 256. 1753 (IK).	Cult. Seed Bank (ASUH)
Dauceae		*Daucus* L.	*D. aureus Desf. Fl. Atlant.* – 1: 242, t. 61. 1798 (IK).	Burg El-arab (Alex)
			D. carota L. – *Sp. Pl.* 2 1753 (APNI)	Cult. Seed Bank (ASUH)
			D. carota var. *boissieri* Schweinf. – *D. carota* L. subsp. *sativus* (Hoffm.) Schübl. & G. Martens var. *boissieri* Schweinf. Synonym of *Daucus carota* L. subsp. *sativus* (Hoffm.) Schübl. & G.Martens var. *atrorubens* Alef. (GRIN) *Gartenflora* 53: t. 1527.	Cult. Seed Bank (ASUH)
Peucedaneae	Tordyliinae	*Malabaila* Hoffm.	*M. suaveolens* Delile - *Bull. Soc. Bot. France* 19:82. 1873 (IK).	CAIM
Scandicineae	Caucalidinae	*Pseudorlaya* (Murb.) Murb.	*P. pumila* (L.) Grande – *Nuovo Giorn. Bot. Ital.* 1925, n. s. xxxii. 86. (IK).	CAIM
	Scandicinae	*Torilis* Adans.	*T. radiata* Moench – *Methodus (Moench)* 103. 1794 (IK).	CAIM
		Chaerophyllum L.	*C. bulbosum* L. – *Sp. Pl.* 1: 258. 1753 (IK).	CAIM

TABLE 2. — Data matrix of the gross morphology (1-28) and fruit morphological and anatomical characters (29-79) of the studied taxa of Apioideae with their coded numbers. Taxa studied: **1**, *Ammi majus* L.; **2**, *A. visnaga* (L.) Lam.; **3**, *Anethum graveolens* L.; **4**, *Apium graveolens* L.; **5**, *A. leptophyllum* (Pers.) F. Muell. ex Benth.; **6**, *Bifora testiculata* (L.) Spreng.; **7**, *Bupleurum semicompositum* L.; **8**, *Carum carvi* L.; **9**, *Chaerophyllum bulbosum* L.; **10**, *Coriandrum sativum* L.; **11**, *Cuminum cyminum* L.; **12**, *Daucus aureus* Desf.; **13**, *D. carota* L.; **14**, *D. carota* var. *boissieri* Schweinf.; **15**, *Deverra tortuosa* (Desf.) DC.; **16**, *D. triradiata* Hochst. ex Boiss.; **17**, *Foeniculum capillaceum* Gilib.; **18**, *F. vulgare* Mill.; **19**, *Malabaila suaveolens* Delile; **20**, *Petroselinum crispum* (Mill.) Nym.; **21**, *Pimpinella anisum* L.; **22**, *Pseudorlaya pumila* (L.) Grande; **23**, *Ridolfia segetum* (L.) Moris; **24**, *Torilis radiata* Moench.

	Taxa																							
Attributes	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Gross morphology																								
Habit																								
1 – Herb (1), Shrub (0)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1
Duration																								
2 – Annual	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0	0	0	0	0	0	1	1	1	1
3 – Biennial	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
4 – Perennial	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
Tap root																								
5 – Normal (1), Tuberous (0)	1	1	1	1	1	1	1	0	0	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1
Stem texture																								
6 – Smooth (1), Hairy (0)	1	1	1	1	1	1	1	1	0	1	1	0	0	0	1	1	1	1	0	1	0	0	1	0
Leaf Composition																								
7 – Once pinnate	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1
8 – 2-3 pinnate	1	1	0	0	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	1	0	1	1	0
9 – 3-4 lobed or parted	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
10 – Simple linear	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 – Filiform with tipped division	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
12 – Capillary (reduced)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Leaf segments shape																								
13 – Narrowly lanceolate	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
14 – Linear	0	1	1	0	0	1	0	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0
15 – Obovate	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
16 – Long filiform	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0
17 – Ovate-lanceolate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0
Leaf margin																								
18 – Serrate (1), Entire (0)	1	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0
Leaf Sheath																								
19 – Membranous margin	0	0	0	0	0	1	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
20 – Narrow	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1
21 – Scarious margin	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
22 – Petiole-sheathing throughout	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
23 – Leaves reduced to sheath	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Petiole																								
24 – Present (1), Absent (0)	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1
Bracts																								
25 – Present (1), Absent (0)	1	1	0	0	0	0	1	0	0	0	1	1	1	1	1	1	0	0	0	1	0	1	0	0
Bracteoles																								
26 – Present (1), Absent (0)	1	1	0	0	0	1	1	0	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	1
Inflorescence (Flower unit) – Umbel	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27 – Compound (1), Simple (0)																								

TABLE 2. — Continuation.

Attributes	Taxa																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Flower color																								
28 – White (1), Coloured (0)	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	1
Stylopodium base																								
29 – Conic (1), Slender (0)	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fruit shape																								
30 – Ovoid, laterally compressed	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
31 – Ellipsoid, dorsally flattened	0	0	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
32 – Ellipsoid, lat. compressed	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
33 – Globose	0	0	0	1	1	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
34 – Ovoid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
35 – Oblong-cylindrical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
36 – Flattened-lens shaped	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
37 – Oblong-linear, laterally compressed	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Fruit texture																								
38 – Glabrous	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	0
39 – Hairy	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	1	1	0	0
40 – Prickly	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0	1
41 – Setulose	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
42 – Tuberculate	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpophore																								
43 – 2-cleft (2-parted) (1), Entire (0)	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	1	1
Mericarp symmetry																								
44 – Homomorphic (1), Hetero. (0)	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
Fruit ribs																								
45 – 1ry ribs more or less equal	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
46 – Median ribs more projecting	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
47 – Marginal ribs more projecting	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
48 – 2ry ribs present (1), Absent (0)	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	0	0	0	0	0	1	0	1
49 – 2ry ribs more proj. than 1ry (1), as long as 1ry ribs (0)	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0
Fruit wings																								
50 – Present (1), Absent (0)	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1	0	0
Wings origin																								
51 – From ribs (1), Absent (0)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
52 – From furrows (1), Absent (0)	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0
Mesocarp																								
53 – Thin walled (1), thick lignified (0)	1	0	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1
Endocarp																								
54 – One cell layer (1), more (0)	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
55 – Lignified (1), not lignified (0)	0	1	1	1	0	1	0	1	1	1	0	1	1	1	0	1	1	1	1	0	0	1	0	1
56 – Continuous lignified (1), discontinuous (0)	0	1	1	0	0	1	0	1	1	0	0	1	1	1	0	0	1	1	1	0	0	1	0	1
Vascular bundles/mericarp																								
57 – Five (1), more than 5 (0)	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

TABLE 2. — Continuation.

Attributes	Taxa																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Vittae/mericarp																								
58 – Regular (1), irregular (0)	1	1	1	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1
Occurrence																								
59 – Vallecular and commissural vittae (1), Dispersed continuously (0)	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
Number of vittae																								
60 – One/furrow	1	1	1	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1
61 – Two/furrow	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62 – More than two/furrow	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
63 – Two/commissure (1), Four/commissure (0)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
Rib oil ducts (intrajugal ducts)																								
64 – Present (1), Absent(0)	1	0	1	0	0	0	0	1	0	1	1	0	0	1	0	0	1	1	0	1	1	1	0	1
Occurrence																								
65 – Outside vascular bundles	0	0	0	0	0	0	0	1	0	1	1	0	0	1	0	0	0	0	0	1	0	1	0	1
66 – Inside vascular bundles	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
67 – Both sides of the v.b.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Endosperm shape along the commissural face of each mericarp																								
68 – Flat	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0
69 – Shallowly convex	0	1	1	0	0	0	0	1	0	0	0	1	0	1	0	1	1	1	0	0	1	1	0	0
70 – Shallowly concave	0	0	0	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0
71 – Deep commissural groove	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Commissure																								
72 – Occupies roughly the entire width of the fruit	1	0	1	0	0	0	0	0	0	1	1	0	0	0	1	0	1	1	0	0	0	0	1	0
73 – Greater than 50% (less than 100%) of the fruit width	0	1	0	0	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	1	1	0	1
74 – Less than 50% of the fruit width	0	0	0	1	0	1	1	1	0	0	0	0	0	1	0	1	0	0	1	1	0	0	0	0
Ventral bundles																								
75 – Present (1), Absent (0)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpophore bundle(s)																								
76 – One	0	0	0	1	1	1	0	0	1	1	0	0	0	0	0	0	0	1	0	1	1	0	0	1
77 – Two fused	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
78 – Two opposite one another	0	1	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	0	1	0	0	1	1	0
Druses Crystals																								
79 – Present (1), Absent (0)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1