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Taxonomic implications from morphological and anatomical studies in the section *Stenodiptera* from the genus *Grammosciadium* (Apiaceae)

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Abstract

Grammosciadium pterocarpum subsp. *bilgilii* and *G. pterocarpum* subsp. *sivasicum* from Turkey are herein described as two new subspecies, and the species *G. schischkinii* is synonymied under *G. pterocarpum* subsp. *pterocarpum*. Quantitative variation of morphological and anatomical characters have been analysed to provide discriminative characters between the taxa of section *Stenodiptera* and to provide a key to the species. The taxonomic status of the taxa has been discussed in light of these morphological and fruit anatomical data using multivariate statistics such as MANOVA and Principal Component Analysis. The results are also used to present a critical discussion of characters used to distinguish and determine different taxa within *Grammosciadium*. MANOVA showed that ten characters, except stylopodium and style length, differed significantly among the taxa, and the results were confirmed by Tukey tests and PCA analysis (except the character of fruit number). However, only ranges of the characters of sepal length, fruit length, fruit width, fruit width/wing width ratio, and width of fruit wing are not overlapped. Qualitative characters of petiolate stipular segments of lower leaves and presence of funicular oil ducts in transvers section of mericarps were found as diagnostic characters.

Keywords

Grammosciadium, MANOVA, PCA, Stenodiptera, taxonomy, Turkey

Introduction

The genus *Grammosciadium* DC. is a taxonomically difficult group of taxa within tribe Scandiceae, subtribe Careae (Apiaceae) (Spalik et al. 2001, Spalik and Downie 2007, Ajani et al. 2008). It falls within the "apioid superclade" (Spalik and Downie 2007) and is closely related with *Fuernrohria* K.Koch, *Carum* L. and other taxonomically critical taxa. As an example, in particular the genus *Carum* has been recently shown to be polyphyletic in its current circumscription, and its various members are even found in different tribes of subfamily Apioideae (Zakharova et al. 2012). The stem group age of Careae is of about 22 million years and has a center of origin in the Irano-Turanian region (Banasiak et al. 2013), and a long-term and spatio-temporarely shared evolutionary history of the various lineages is likely. Accordingly, taxonomy and systematics of these groups of taxa are still unsolved, because morphological characters often display high levels of homoplasy, and phylogenetic inference is scarce (e.g. Downie et al. 2010, Zakharova et al. 2012).

The genus *Grammosciadium* is actually considered to be represented by two subgenera (*Grammosciadium* and *Caropodium* (Stapf & Wettst.) Tamamsch. & V.M.Vinogr.), which are further split into six sections in total (Bani and Koch 2015); however, this has been done with limited available pyhlogenetic evidence so far and applying an extreme taxanomically splitting concept above the species level. Subgenus *Caropodium* has been further splitted into two sections, namely sects. *Caropodium* and *Stenodiptera* (Koso-Pol.) Tamamsch. & V.M.Vinogr. (for a detailed overview refer to Bani and Koch 2015).

The section *Stenodiptera* of the genus *Grammosciadium* DC. has typical mericarps with winged lateral ribs. Additional important characters are the presence of erect stems, white flowers, and 4-6-pinnatisect, narrowly linear-elliptic leaves. The section *Stenodiptera* morphologically resembles section *Caropodium* because of the winged fruits, which are absent in other members of the genus *Grammosciadium* (Tamamschian and Vinogradova 1969a, b, 1970, Vinogradova 1995). However, the section *Caropodium* mainly differs from section *Stenodiptera* by its more branched and distinctly sulcate stems (Hedge and Lamond 1972).

Both sections are also anatomically different from each other: section *Caropodium* has funicular oil ducts in transvers section of mericarps (funicular oil ducts absent in section *Stenodiptera*) (Tamamschian and Vinogradova 1969a, b, 1970, Vinogradova 1995). Also fruit surface ornamentations is different in both sections (Bani et al. 2016). Since both of these sections are included in subgenus *Caropodium* of genus *Grammosciadium* in the actual literature (Tamamschian and Vinogradova 1969a, b, 1970, Vinogradova 1995), we still follow the concepts of sections and subgenera for pragmatic reasons, but being fully aware that this is an artificially splitting concept and is awaiting phylogenetic analysis (work in progress).

The section *Stenodiptera* has three species which are distributed mainly in Turkey, and are additionally found in adjacent areas of Anatolia and Iran (Hedge and Lamond 1972, Vinogradova 1970, Bani and Koch 2015). All members are characteristic plants

of the Irano-Turanian phytogeographic region (Takhtajan 1986, Hedge and Lamond 1972, Tamamschian 1987, Bani and Koch 2015). Among them, *Grammosciadium schischkinii* (V.M.Vinogr. & Tamamsch.) V.M.Vinogr. and *G. haussknechtii* Boiss. are endemic to Turkey and the third species, *G. pterocarpum* Boiss., can be regarded as subendemic plant with smaller distribution ranges outside Turkey (Vinogradova 1970, Pimenov and Leonov 2004, Pimenov and Sutory 2014).

After the first record of the genus *Grammosciadium* has been provided (Candolle 1829) Boissier (1844, 1872) described the three species *G. pterocarpum*, *G. haussknechti* and *G. platycarpum* Boiss. & Hausskn. in addition to the other members of the genus [*G. daucoides* DC., *G. aucheri* Boiss. (currently accepted as synonym of *G. daucoides*), *G. scabridum* Boiss., *G. longilobum* Boiss. & Hausskn. (currently accepted as synonym of *G. scabridum*), and *G. macrodon* Boiss.]. Boissier indicated in his Flora Orientalis, that these three species are different from the other members of the genus by their winged mericarps (Boissier 1872). Later in 1886, *Caropodium* was established as a new genus with a single species (*C. meoides* Stapf and Wettst.) collected by Polak from Iran (Stapf and Wettstein 1886). However Bornmueller (1906) synonymised *C. meoides* under *G. platycarpum*. Freyn (1901) published a subspecies of *G. pterocarpum* from Turkey, namely subsp. *longipes*. The respective type material provides only flowering material and no fruits are available, and, therefore, this taxon is currently accepted as synonym of *G. pterocarpum* (Pimenov and Sutory 2014). Koso-Poliansky established *Stenodiptera* Koso-Pol. with all these three winged species as an independent genus (Koso-Poliansky 1914, 1915). Moreover he divided his genus *Stenodiptera* into two sections with *Euryptera* including *S. pterocarpa* (Boiss.) Koso-Pol. and *Eustenodiptera* including *S. haussknechtii* (Boiss.) Koso-Pol. and *S. platycarpa* (Boiss. & Hausskn.) Koso-Pol., which is mostly based on breadth of wings of mericarps (Koso-Poliansky 1914, 1915). Although a species named *S. armena* Bordz., which was collected from Turkey, was published by Bordzilowski (1915), Koso-Poliansky (1916) synonymised this species under *S. haussknechtii* one year later. According to Schischkin (1923) Koso-Poliansky's idea of establishing a new genus with the winged members was appropriate, but he added and highlighted an important taxonomic aspect: if a new genus has been established with winged fruited species separated from genus *Gramosciadium* sensu Boissier, then this must be with the earlier published name *Caropodium* rather than *Stenodiptera*. Hence, he reduced the genus *Stenodiptera* into synonymy of the genus *Caropodium* and also re-established *C. armenum* (Bordz.) Schischkin on species rank (Schischkin 1923). Vinogradova and Tamamschian (1968) accepted that "*C. armenum* is identical to *C. pterocarpum* (Boiss.) Schischkin" and they also described *C. pterocarpum* var. *schischkinii* V.M.Vinogr. & Tamamsch. as a new taxon based on a specimen collected from Turkey in 1916. This variety was distinguished by its broader and more undulated wings of the fruits (Vinogradova and Tamamschian 1968). Later Tamamschian and Vinogradova (1969b and 1970) reduced *Caropodium* to the rank of a subgenus and recognized section *Stenodiptera* including the taxa *G. pterocarpum*, *G. pterocarpum* var. *schischkinii* and *G. haussknechtii* within this subgenus. In Flora of Turkey, Hedge and Lamond (1972) presented *G. pterocarpum* var.

schischkinii and *G. haussknechtii* as synonyms of *G. pterocarpum*. Finally, Vinogradova (1995) increased *G. schischkinii* to species rank and also *G. haussknectii* was accepted as independent species again.

In summary, there are five taxa in section *Stenodiptera* that have been described so far: *Grammosciadium pterocarpum*, *G. haussknechtii*, *G. pterocarpum* subsp. *longipes* Freyn, *G. armenum* and *G. schisckinii*. However, for more than a whole century botanists are wondering of how to distinguish and how to classify them.

The taxa are morphologically very similar to each other and original descriptions are often based on insufficient material (*Grammosciadium haussknechtii*, *G. schisckinii* and *G. pterocarpum* subsp. *longipes* only known from the types, *G. armenum* is known from the type and some very few additional individuals).

According to the most recent treatments, *Grammosciadium pterocarpum*, *G. haussknechtii* and *G. schischkinii* are currently accepted as distinct species and the other taxa of *G. armenum* and *G. pterocarpum* subsp. *longipes* were synonymised under *G. pterocarpum* (Vinogradova 1995, Pimenov and Sutory 2014, Bani and Koch 2015).

Numerous specimens were collected from the whole distribution areas, which reflect the morphological and presumably also genetic variation limits of the taxa of section *Stenodiptera* in Turkey for the purpose of a phylogenetic-taxonomic revision of the members of the whole genus *Grammosciadium* between the years of 2011 and 2014. We observed a large number of intermediate forms during our field work. Moreover, we encountered many problems during the identification process of the specimens. The previous diagnostic characters mostly overlapped and some of the populations and specimens were not identified unambiguously. Additionally two populations were discovered recently from Turkey (one is from Sivas province, the other one is from Eskişehir province), and although they are very similar to *Grammosciadium pterocarpum* in terms of their habits, these populations do not match with available species descriptions.

The aims of this study were (1) to examine quantitatively pattern of morphological variation of the members of section *Stenodiptera* based on a representative and population-based sampling with 133 individuals from 17 populations in total, (2) to determine diagnostic morphological and anatomical characters for correct discrimination of the putative taxa, and (3) to provide a taxonomic concept for the newly discovered morphotypes.

Materials and methods

133 specimens (individuals) from the members of section *Stenodiptera* were examined and used as operational taxonomic units (OTUs) in the multivariate analyses. *Gramosciadium pterocarpum* (102 individuals from 14 populations), *G. haussknechtii* (11 individuals from one population; because it is known from only one locality), and populations of two new subspecies collected from Eskişehir (*B.Bani* 6983) and Sivas (*B.Bani* 6985) provinces of Turkey (10 individuals from one population, respectively). These specimens, which are

Table 1. Morphological characters and their statistics (mean ± standard deviation (SD), min-max range and range with 95% CI: confidence interval) for the four groups (N: number of individuals used for morphological measurements). Characters that differ significantly (P<0.05) among the taxa as shown by MANOVA are marked with asterisks. Superscript letters indicate the results of Tukey tests, with taxa in the same homogeneous subset (P< 0.05) sharing the same letter.

Characters			*Grammosciadium pterocarpum*			*G. haussknechtii* N=11
			subsp. pterocarpum (incl. the type specimen of *G. schischkinii* and one accession of *G. armenum*) N=102	subsp. *sivasicum* N=10	subsp. *bilgilii* N=10	
1	Ray number*	mean± SD min-max 95% CI	9.9±1.7^{C} 6.0–15.0 9.6–10.2	8.5±1.1^{BC} 7.0–11.0 7.4–9.5	6.8±1.3^{A} 5.0–9.0 5.7–7.8	8.2±1.6^{AB} 6.0–10.0 7.2–9.2
2	Ray length (cm)*	mean± SD min-max 95% CI	4.7±1.34^{B} 1.8–9.4 4.5–5.0	3.2±0.86^{A} 2.0–5.0 2.4–4.0	4.2±0.86^{AB} 3.5–5.0 3.4–5.0	4.8±0.73^{B} 3.8–6.2 4.0–5.5
3	Fruiting pedicel length (mm)*	mean± SD min-max 95% CI	5.2±1.37^{B} 3–10 5.0–5.5	3.9±0.92^{A} 2–5 3.1–4.7	4.2±0.42^{AB} 3.5–5.0 3.4–5.0	3.3±1.05^{A} 2–6 2.5–4.1
4	Fruit number*	mean± SD min-max 95% CI	6.7±2.36^{A} 2–13 6.2–7.1	6.3±2.3^{A} 2–10 4.8–7.7	11.4±2.17^{B} 9–13 9.9–12.8	7.9±1.57^{A} 6–11 6.5–9.2
5	Fruit length (cm)*	mean± SD min-max 95% CI	1.10±0.15^{B} 0.7–1.5 1.10–1.16	1.00±0.05^{A} 0.9–1.0 0.9–1.11	0.8±0.94^{A} 0.7–1.1 0.7–0.97	1.3±.15^{C} 1.2–1.7 1.2–1.4
6	Fruit width (mm)*	mean± SD min-max 95% CI	1.0±0.16^{A} 0.8–1.5 1.0–1.1	1.0±0.03^{A} 1.0–1.1 0.9–1.1	1.0±0.00^{A} 1.0–1.0 0.8–1.1	1.32±0.23^{B} 1.0–1.6 1.2–1.4
7	Fruit width/ length ratio*	mean± SD min-max 95% CI	1.0±0.18^{AB} 0.6–1.4 1.0–1.1	0.9±0.06^{AB} 0.9–1.0 0.8–1.0	0.8±0.09^{A} 0.7–1.1 0.7–0.9	1.07±0.18^{B} 0.8–1.4 0.9–1.1
8	Fruit wing width (mm)*	mean± SD min-max 95% CI	1.7±0.5^{A} 1–3.1 1.6–1.8	0.85±0.19^{B} 0.5–1.1 0.5–1.1	0.6±0.1^{B} 0.5–0.8 0.3–0.9	0.5±0.0^{B} 0.4–0.6 0.2–0.7
9	Fruit width/ wing width ratio*	mean± SD min-max 95% CI	0.6±0.18^{A} 0.3–1.2 0.60–0.61	1.2±0.34^{B} 0.9–2.0 1.0–1.4	1.6±0.31^{C} 1.2–2.0 1.5–1.8	2.6±0.5^{D} 2.0–3.7 2.5–2.8
10	Sepal length (mm)*	mean± SD min-max 95% CI	0.5±0.25^{B} 0.1–1.65 0.5–0.59	0.4±0.12^{AB} 0.1–0.5 0.3–0.67	0.3±0.12^{A} 0.1–0.5 0.1–0.44	0.8±0.20^{C} 0.5–1.0 0.7–1.00
11	Stylopodium length (mm)	mean± SD min-max 95% CI	0.5±0.07^{A} 0.2–0.7 0.51–0.54	0.5±0.03^{A} 0.5–0.6 0.4–0.5	0.5±0.00^{A} 0.5–0.5 0.4–0.5	0.5±0.09^{A} 0.5–0.8 0.50–0.6
12	Style length (mm)	mean± SD min-max 95% CI	0.9±0.15^{A} 0.6–1.50 0.9–0.1	1.0±0.00^{A} 0.9–1.0 1.0–1.0	0.9±0.08^{A} 0.8–1.0 0.8–1.0	1.0±0.03^{A} 1–1.1 1.0–1.0

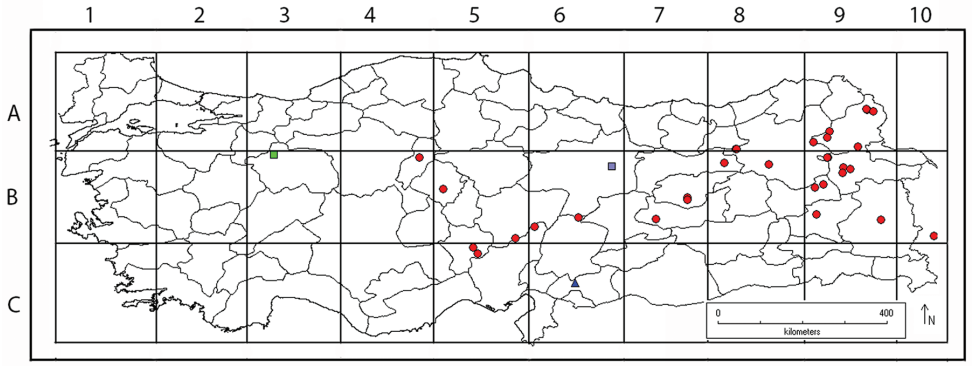

Figure 1. Distribution map of the populations and taxa of section *Stenodiptera* in Turkey analysed herein (*Grammosciadium pterocarpum* subsp. *pterocarpum* ●, *G. pterocarpum* subsp. *bilgilii* ■, *G. pterocarpum* subsp. *sivasicum* ■, *G. haussknechtii* ▲).

listed in the Suppl. material 1 and marked with asteriks, include the types of two taxa (*G. haussknechtii* and *G. schischkinii* see Table 1) and reflected the morphological variability exhibited by the species and populations from throughout its geographic range (Figure 1). Characters used in the multivariate analyses were based on previous taxonomic treatments and our own examination of collected specimens. 12 quantitative characters were selected (Table 1). Characters were scored at the same developmental stage on each plant (fruiting stage). Measurements were taken from the best developed infructescence available on a given specimen. Three data sets were constructed and analyzed: (1) a matrix which included all specimens (133 OTUs and 12 characters), (2) and (3) were created by excluding the OTU's of *G. haussknechtii* and the new subpecies (collected from Eskişehir) from data set 1, respectively. The MANOVA was performed with IBM SPSS Statistics for Windows, Version 20.0. (Armonk, NY), using "Type III sum of squares", and was followed by "Tukey tests" using the harmonic mean sample size to determine patterns of significant differences between the taxa. The F-test was used to determine which, if any, characters differed significantly among the taxa studied. The PCA was conducted also using IBM SPSS Statistics for Windows, Version 20.0. (Armonk, NY). Identical parameters and procedures were used for all analyses on the three different data sets.

Results

Statistical analysis

Descriptive statistics for the 12 morphological characters are presented in Table 1. The MANOVA showed that 10 characters, except stylopodium and style length, differed significantly ($P < 0.05$) among the taxa and newly discovered populations, and this was confirmed by Tukey tests (Table 1). Furthermore, only ranges of the characters of sepal length, fruit length, fruit width, Fruit width/wing width ratio, width of fruit wing are not overlapped. Other six characters are overlapped (Table 1).

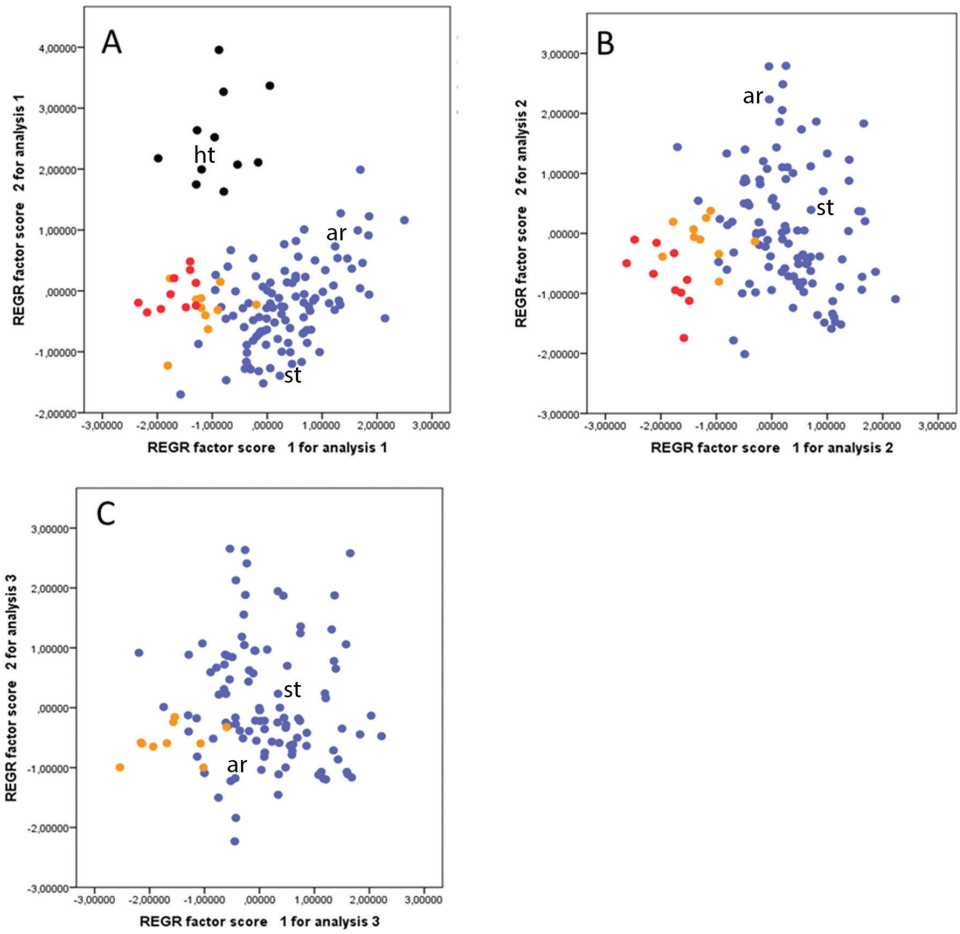

Figure 2. PCA 1-3 with 12 morphological characters. **A** Dataset (1): All the taxa **B** Dataset (2) *Grammosciadium pterocarpum* subsp. *pterocarpum*, subsp. *bilgilii* and subsp. *sivasicum* **C** Dataset (3) subsp. *pterocarpum* and subsp. *sivasicum*. *Grammosciadium haussknechtii* (●), *G. pterocarpum* subsp. *pterocarpum* (●), subsp. *bilgilii* (●) and subsp. *sivasicum* (●) st: type specimen of *G. schiskinii,* ar: *G. armenum*, ht: type specimen of *G. haussknechtii.*

The three Principal Component Analyses of the different datasets, which were performed for OTU's of *Grammosciadium haussknechtii*, *G. pterocarpum*, subsp. *bilgilii* and subsp. *sivasicum* with fruiting characters are given in Figure 2 (the first PCA: 12 characters for 133 plots of all the taxa, the second PCA: 12 characters for 122 plots by excluding the plots of *G. haussknechtii*, the third PCA: 12 characters for 112 plots by excluding the plots of subsp. *bilgilii*). The results of the PCA analyses are as follows: the first two components account for a total of (23.78% and 17.82%) 41.60% (dataset 1), (29.90% and 14.90%) 44.80% (dataset 2) and (27.08% and 15.55%) 42.63% (dataset 3) of the variance, respectively. The factor loadings of the first two components for each PCA are given in Table 2.

Table 2. Factor loadings for the 12 fruiting characters on the first two components for the 84 OTUs of section *Stenodiptera* members. The values with larger magnitudes are shown in bold for each PC.

	1st PCA		2nd PCA		3rd PCA	
	PC1	**PC2**	**PC1**	**PC2**	**PC1**	**PC2**
Sepal length	.286	**.660**	.441	.125	.293	.167
Fruit length	**.550**	.702	**.805**	-.250	**.779**	-.173
Fruit width	.020	.511	.248	**.722**	.129	**.791**
Fruit width/length ratio	**.539**	.206	**.545**	-.766	**.566**	-.768
Fruit width/wing ratio	-.647	**.675**	-.815	-.053	-.747	-.049
Fruits wing width	**.780**	-.367	**.806**	.127	**.752**	.210
Stylopodium length	.182	.028	.213	.021	.148	.058
Style length	.062	-.046	.079	.021	.035	-.002
Fruiting pedicel length	**.634**	-.152	**.580**	.121	**.553**	.285
Ray length	**.710**	.394	**.707**	-.202	**.814**	.060
Fruit number	-.145	.222	-.166	-.414	.308	-.187
Ray number	.433	-292	.396	**.597**	.103	**.650**

Description of two new subspecies

Based on the morphometric results we can significantly distinguish and characterize the following new subspecies of *Grammosciadium pterocarpum*:

***Grammosciadium pterocarpum* Boiss. subsp. *bilgilii* B.Bani, subsp. n.**
urn:lsid:ipni.org:names:60472798-2
Figs 3–6

Diagnosis. The new subspecies is similar to *Grammosciadium pterocarpum* subsp. *pterocarpum,* but mainly differs from it by the fruits with the narrower wings of lateral ribs (0.5–0.8 mm, not 1–3.1 mm).

Type. Turkey. B3 Eskişehir: around of Yarımca village, clearings of oak woodland, 1250 m, 20.06.2014, *B.Bani 6983, E.D.Güner* (holotype GAZI!).

Perennial, erect, branched (at third node or above) herbs. Rootstock with remaining of elder leaf bases. Stem 35–50 cm long and 0.15–0.40 mm broad (just below the first node), angular, prominently or slightly striate, always smooth, white, green or purplish at base. Basal leaves petiolate; petioles 2.5-8 cm long, broadly sheathed towards base, always smooth, prominently ribbed, canaliculate or flat, angular or triangular. Lamina 5–pinnatisect, 5.5–12 cm long, glabrous, linear-elliptic in outline; primary segments 0.5-1.3 cm long, distance between primary segments 0.4–1.5 cm long; ultimate segments 2–4 mm long, mucronate at apex. Lower leaf sheaths mostly connate at base, with stipular segments at margins; stipular segments sessile or shortly petiolate. Upper leaves similar but decreasing in size upwards. Bracts 3-6, trisect or up to 1–3–pinnatisect, 0.6–1.6 cm long; rarely narrowly sheathed; segments 0.3-0.7 cm,

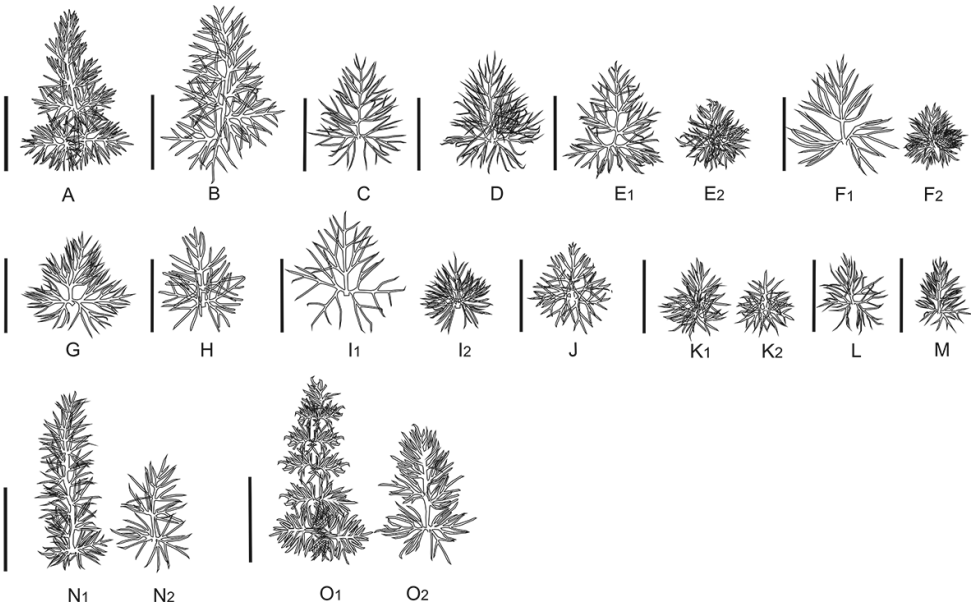

Figure 3. Primer segments of basal leaves in the section *Stenodiptera*. **A–M** *Grammosciadium pterocarpum* subsp. *pterocarpum* (**A** *B.Bani* 6966 **D** *B.Bani* 6825 **E** *B.Bani* 6820 **F** *B.Bani* 6997 **G** *B.Bani* 6999 **H** *B.Bani* 6994 **I** *B.Bani* 6931 **J** *B.Bani* 6977 **K** *B.Bani* 6976 **L** *B.Bani* 6932 **M** *B.Bani* 6926) **B** subsp. *bilgilii* (*B.Bani* 6983) **C** susbp. *sivasicum* (*B.Bani* 6985) **N** *G. haussknechtii* (*B.Bani* 6903) **O** *G. platycarpum* (*B.Bani* 6810). Scale bar represents 5 mm.

always smooth, mucronate at apex. Rays 5–9, unequal, 2.5–5.5 cm. Bracteoles 5-7, trisect to 1–pinnatisect, 0.35-0.65 cm long, always smooth. Flowers male only or hermaphrodite, 8-18, slightly radiate. Pedicels of male flowers 0.15–0.6 cm long. Sepals 0.14–0.5 mm long, smooth, patent or erect. Petals cordate, with long central oil duct, largest petal 2.8–3.5 mm long. Stamens 5; longest filament 1.3–2 mm long. Fruiting pedicels 3.5–5 mm long. Fruits, 9–16 per umbellule, oblong or narrowly lanceolate, 0.7–1.1 × 0.1 cm; each mericarp has 5 primary ribs and four secondary ribs alternating with the primary ribs; lateral ribs winged; wings 0.5–0.8 mm. Stylopodium minute up to 0.5 mm long. Styles divergent, 0.8–1 mm, uninerved on outer side. Flowering May–June; fruiting June–July.

Etymology. We dedicate this new subspecies in memory of our dear colleague Dr. Bilgehan Bilgili who passed away in 2015.

***Grammosciadium pterocarpum* Boiss. subsp. *sivasicum* B.Bani, subsp. n.**
urn:lsid:ipni.org:names:60472799-2
Figs 3–6

Diagnosis. The new subspecies is similar to *Grammosciadium pterocarpum* subsp. *pterocarpum* and *G. platycarpum,* but mainly differs from *G. pterocarpum* subsp. *pterocar-*

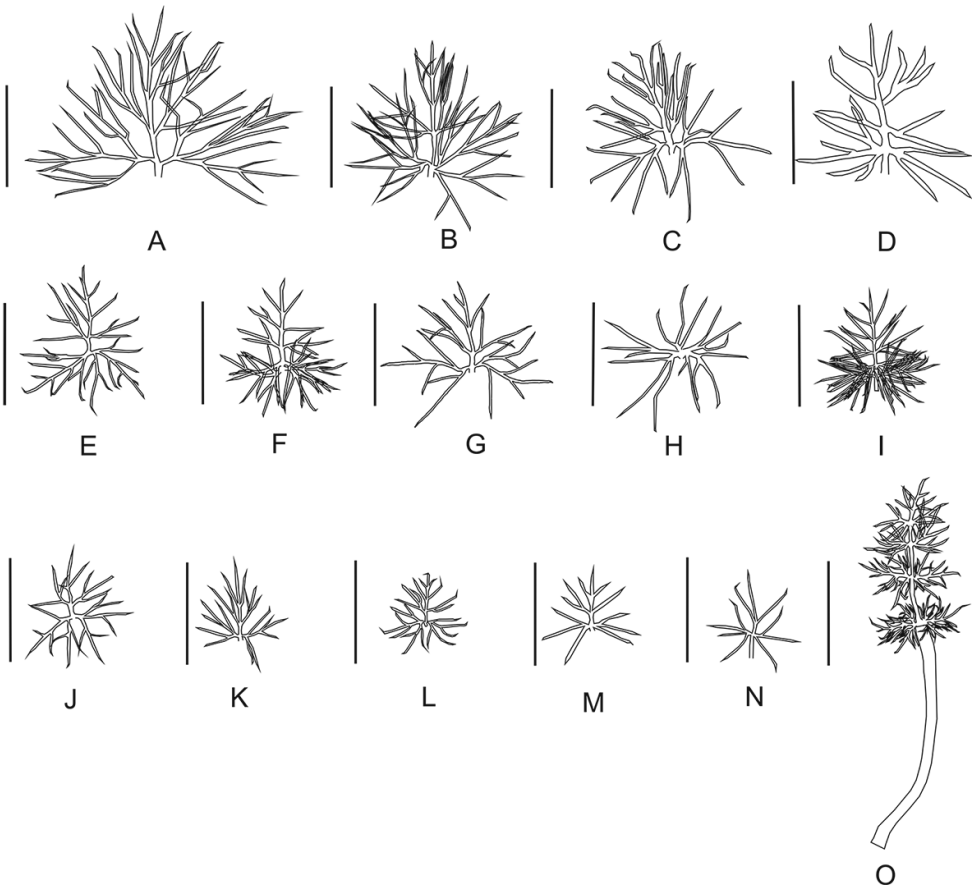

Figure 4. Stipular segments of lower leaf sheaths in the section *Stenodiptera*. **A–M** *Grammosciadium pterocarpum* subsp. *pterocarpum* (**A** *B.Bani* 6969 **B** *B.Bani* 6932 **D** *B.Bani* 6966 **E** *B.Bani* 6825 **F** *B.Bani* 6820 **G** *B.Bani* 6977 **H** *B.Bani* 6994 **J** *B.Bani* 6912 **K** *B.Bani* 6926 **L** *B.Bani* 6931 **M** *B.Bani* 6997) **C** subsp. *bilgilii* (*B.Bani* 6983) **I** subsp. *sivasicum* (B.B.6985) **N** *G. haussknechtii* (*B.Bani* 6903), O: *G. platycarpum* (*B.Bani* 6810). Scale bar represents 5 mm.

pum by the fruits with two oil ducts in funiculus, and it differs from *Grammosciadium platycarpum* by its shorter fruits (0.9–1.1 cm, not 1.2–1.8 cm) and lower leaf sheaths without distinctly stalked stipular segments.

Type. Turkey. B6 Sivas: Zara, around of Taşgöze village, steppe, 1920 m, 07.07.2014, *B.Bani 6985*, *M.A.Karakaya* (holotype GAZI!).

Perennial, erect, branched (at third node or above) or unbranched herbs. Rootstock with remaining of elder leaf bases. Stem 23–46 cm long and 0.2–0.4 mm broad (just below the first node), angular, prominently or slightly striate, scabrid or smooth, white, green or purplish at base. Basal leaves petiolate; petioles 6.5–11.5 cm long, broadly sheathed towards base; always smooth, prominently ribbed, canaliculate or flat, angular or triangular. Lamina 4-5–pinnatisect, 5.5–12 cm long, glabrous, gla-

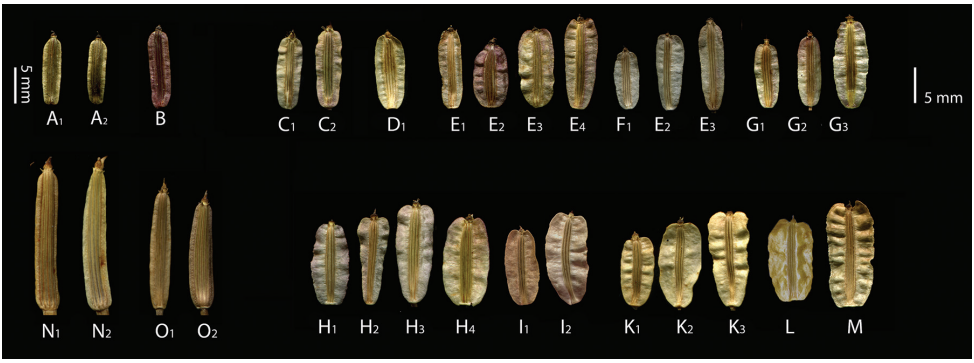

Figure 5. Fruit variations in the section *Stenodiptera* members. **A** *Grammosciadium pterocarpum* subsp. *bilgilii* (*B.Bani* 6983) **B** *G. pterocarpum* subsp. *sivasicum* (*B.Bani* 6985) **C–M** subsp. *pterocarpum* (**C** *B. Bani* 6969 **D** *B.Bani* 6926 **E** *B.Bani* 6932 **F** *B.Bani* 6999 **G** *B.Bani* 6994 **H** *B.Bani* 6977 **I** *B.Bani* 6885 **K** *B.Bani* 6931 **L** Type of *G. schischkinii* **M** *B.Bani* 6872) **N** *G. platycarpum* (*B.Bani* 6850) **O** *G. haussknechtii* (*B.Bani* 6903).

brous, linear-elliptic in outline; primary segments 0.4–1 cm long, distance between primary segments 0.7–1.3 cm long; ultimate segments 3–5 mm long, mucronate at apex. Upper leaves similar but decreasing in size upwards. Bracts 3–6, trisect or up to 1–2 pinnatisect, (0.7–2.3 cm long; never with hyaline margin; segments 0.3–0.75 cm, always glabrous, mucronate at apex. Rays 7–11, unequal, 2–5 cm. Bracteoles 5–8, mostly simple and rarely trisect or 1-pinnatisect, 0.3–1 cm long, always glabrous. Flowers male only or hermaphrodite, 8–14, slightly radiate. Pedicels of male flowers 0.3–0.5 cm long. Sepals 0.1–0.5 mm long, smooth, patent or erect. Petals cordate, with long central oil duct, largest petal to 3 mm long. Stamens 5; longest filament to 1.5 mm long. Fruiting pedicels 2–5 mm long. Fruits, 2–10 per umbellule, linear-oblong, 0.9–1.1×0.1–0.11 cm long; each mericarp has 5 primary ribs and four secondary ribs alternating with the primary ribs; lateral ribs winged; wings 0.5-1.1 mm. Stylopodium minute up to 0.6 mm long. Styles divergent, ca. 1 mm, uninerved on outer side. Flowering May–June; fruiting June–July.

Etymology. The epithet of this new subspecies derived from Sivas province of Turkey where this taxon is distributed.

Primary leaf segments of basal leaves are shown in Figure 3. *Grammosciadium haussknechtii* is distinctly different with the linear oblong leaf segments. *G. platycarpum*, *G. pterocarpum* subsp. *bilgilii* and one population of *G. pterocarpum* subsp. *pterocarpum* (*B.Bani* 6966) have lanceolate primary segments. The others do have ovate-lanceolate to orbicular leaf shapes. Stipular segments which are shown in Figure 4 are quite similar each other except stipular segments of *G. platycarpum* which are long pedicellate. As shown in Figure 5, the fruits are ordered from narrowly winged to broadly winged one. The width of fruit wings is very highly variable character. It is impossible to distinguish *G. schischkinii* with wider fruit wings which was previously used as diagnostic character. This species has clearly similar fruits with fruits of subsp. *ptero-*

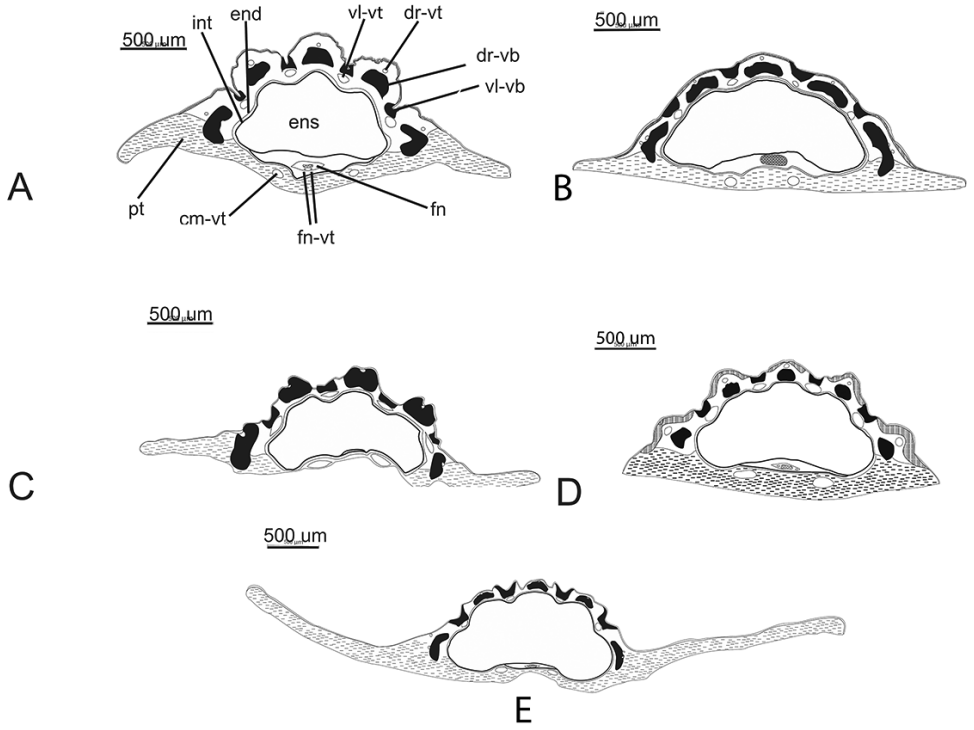

Figure 6. Transvers section of mericarps. **A** *Grammosciadium pterocarpum* subsp. *sivasicum* (*B.Bani* 6985) **B** *G. haussknechtii* (*B.Bani* 6903) **C** *G. pterocarpum* subsp. *bilgilii* (*B.Bani* 6983) **D** *G. platycarpum* (*B.Bani* 6810) **E** *G. pterocarpum* subsp. *pterocarpum* (*B.Bani* 6932). cm-vt: commissural vittae. dr-vb: dorsal vascular bundle. dr-vt: dorsal vittae. end: endepidermis. ens: endosperm. fn: funiculus. fn-vt: funicular vittae. int: integument. pt: pterenchyma. vl-vb: vallecular vascular bundle. vl-vt: vallecular vittae.

carpum. *G. haussknechtii*, *G. platycarpum* and *G. pterocarpum* subsp. *bilgilii* and subsp. *sivasicum* have relatively narrow winged fruits than the fruits of subsp. *pterocarpum*. Figure 4 present the fruit anatomical structure of all taxa in the section *Stenodiptera*. *G. platycarpum* and *G. pterocarpum* subsp. *sivasicum* share similar character of presence of two funicular oil ducts in transverse section of mericarps (Figure 6).

Discussion

Historically the species have been distinguished by a combination of quantitative and qualitative characters (Boissier 1844, 1872, Freyn 1901, Bordzilowski 1915, Vinogradova and Tamamschian 1968, Tamamschian and Vinogradova 1969, 1969a, 1970, Vinogradova 1995, Bani and Koch 2015, Bani et al. 2016).

Boissier (1844) described *Grammosciadium pterocarpum* with the following diagnosis based on Aucher's specimen (with immature fruits) collected from Turkey: stem

8-13 cm, fibrous collar present at base, leaves 4.5×0.6 cm and resembling the leaves of *Carum verticillatum* W.D.J.Koch. Fruits are nearly 1 cm long, and fruit wings are 1.5 mm broad. *G. haussknechtii*: stems are 30 cm long, leaves are 8 cm long and less than 0.4 cm broad, fruits are 1–1,2 cm long. *G. haussknechtii* is close to *G. pterocarpum*, but it differs by its narrower leaves, narrower wings of fruits and shorter calyx teeth (Boissier 1872). This species known only from type material located with various herbaria (WU, E, K, LE). *G. pterocarpum* subsp. *longipes* was described by Frey in 1901 based on the specimens which were collected by Kronenburg from Van province in Turkey in 1889 (Freyn 1901). The lectotype was designated by Pimenov and Sutory (2014) from the herbaria of BRNM (lectotype) and WU (isolectotype). The diagnostic characters are as follows: large pointed calyx teeth and longer pedicels (these specimens have longer pedicels in contrast to the other specimens of *G. pterocarpum*) (Freyn 1901). This subspecies is currently under synonymy of *G. pterocarpum* (Pimenov and Sutory 2014). According to Bordzilowski (1915) in its original diagnosis *G. armenum* is close to *G. pterocarpum* and *G. haussknechtii*. It differs from both, by its broader leaves, shorter fruits and marginate stylopodium. It slightly differs from *G. pterocarpum* by larger stature, rotundate fruit apex (not truncate) and narrower wings of mericarps, and it differs from *G. haussknechtii* in having broader wings of fruits. The type of this species is deposited in KW and few vouchers are fund in LE herbarium. *G. schischkinii* is close to *G. pterocarpum* but differs from it in having more undulated and broader fruit wings (2.5–3.5 mm not 1.5–2 mm), fewer number of fruits (1–4 compared to 4–9), and a more branched stem (Vinogadova 1995). This species has been described based on one specimen only and is kept in LE herbarium. There is no any other collection.

Although the characters of fruit number, width of fruit wings and undulation of wings have been used previously to distinguish *Grammosciadium schischkinii* from the other species (Vinogradova 1995), our data demonstrates that the measurements obtained from the type specimen of *G. schischkinii* clearly overlapped with characters of *G. pterocarpum* subsp. *pterocarpum* (Table 1). Also undulation of fruit wings is common in nearly all populations. We also achieved similar results for *G. armenum*, which has been previously recognized as synonym of *G. pterocarpum*. We did not find any qualitative or quantitative character to distinguish these species. The type of *G. pterocarpum* subsp. *longipes* is also identical with subsp. *pterocarpum*. Length of calyx teeth and length of pedicels, which has been used as diagnostic characters (Freyn 1901) are overlapping with the other taxa and do not allow reliable differentiation. It is obvious from this study that sufficient fruiting and flowering material is needed for its proper taxonomic treatment.

MANOVA demonstrated that most of the characters differ statistically among the groups (Table 1), and the range values of the various characters (sepal length, fruit length, fruit width, fruit width/wing ratio and width of fruit wings) can be used to distinguish the various taxa significantly. Fruit length and sepal length separate *Grammosciadium haussknechtii* from subsp. *sivasicum* and subsp. *bilgilii*. Fruit width is distinguishing between *G. haussknechtii* and subsp. *bilgilii*. *G. haussknechtii* is clearly different from the all others by its higher Fruit width/wing width ratio also separates

subsp. *bilgilii* from subsp. *pterocarpum*. Another diagnostic character is width of fruit wings, which discriminates subsp. *pterocarpum* from all other taxa.

According to PCA on dataset 1 (complete dataset), individuals of *G. haussknechtii* are clearly distinguished from all other taxa as a distinct group mostly because of their larger ratio of fruit width/wing width (2-3,7 mm not 0,3-2 mm). Fruit length, fruit width/length ratio, fruit width/wing ratio, fruiting pedicel and ray length are the most discriminative characters with the largest eigenvalues (Figure 2A, Table 2). With PCA on dataset 2 (subsp. *pterocarpum*, subsp. *sivasicum* and subsp. *bilgilii*) individuals of subsp. *bilgilii*, are clearly distinguished from subsp. *pterocarpum* by the narrower wings of fruit (0.5-0.8 mm, not 1-3.1 mm). However, individuals of subsp. *sivasicum* are placed with an intermediate position between these two groups (Figure 2B). Fruit length, fruit width/length ratio, width of fruit wing, fruiting pedicel, ray length, fruit number and ray number are the characters with highest eigenvalues (Table 2). Similarly, the PCA on the third dataset (subsp. *pterocarpum* and subsp. *sivasicum*) separates both taxa from each other, but few individuals of both groups are overlapping (Figure 2C). PCA on dataset 2 and 3 show the same discriminative characters (except fruit number) (Table 2). But as indicated above, subspecies *sivasicum* has two funicular oil ducts in the funiculus in transverse section of mericarps resembling a unique character within the section *Stenodiptera*.

Currently accepted taxa with the synonyms and a key to the members of section *Stenodiptera*

1 Funicular oil duct present in transverse section of mericarps ..... ***Grammosciadium pterocarpum* subsp. *sivasicum***

– Funicular oil duct absent in transverse section of mericarps **2**

2 Fruit wings more than 1 mm ..... ***Grammosciadium pterocarpum* subsp. *pterocarpum***

– Fruit wings less than 1 mm **3**

3 Fertile part of fruits 0.7–1.1×1 mm ..... ***Grammosciadium pterocarpum* subsp. *bilgilii***

– Fertile part of fruits 1.2–1.7×1–1.6 mm ... ***Grammosciadium haussknechtii***

1. *Grammosciadium pterocarpum* Boiss. subsp. *pterocarpum* in Ann. Sci. Nat. ser. 3, 2: 68 (1844).

Syn: *Stenodiptera pterocarpa* (Boiss.) Koso-Pol. in Bot. Zhurn. 1–2: 13 (1915)
Caropodium pterocarpum (Boiss.) Schischkin in Not. Syst. (Leningrad) 4: 30 (1923) *Grammosciadium pterocarpum* (Boiss.) subsp. *longipes* Freyn in Bull. Herb. Boiss. 2(1): 245–289 (1901)
Stenodiptera armena Bordz. in Mem. Soc. Nat. Kiev 25(1): 96 (1915)
Caropodium armenum (Bordz.) Schischkin in Not. Syst. (Leningrad) 4: 30 (1923)

Grammosciadium schischkinii (Vinogr. & Tamamsch) Vinogr. in Bot. Zhurn. (1995) **syn. n.**
Caropodium pterocarpum (Boiss.) Schischkin var. *schischkinii* Vinogr. & Tamamsch. in Notes R.B.G. Edinb. 28: 203 (1968)

2. *Grammosciadium pterocarpum* subsp. *bilgilii* subsp. n.

3. *Grammosciadium pterocarpum* subsp. *sivasicum* subsp. n.

4. *Grammosciadium haussknechtii* Boiss. in FI. Or. 2:901 (1872)
Syn: *Stenodiptera haussknechtii* (Boiss.) Koso-Pol., in Bot. Zhurn. (1-2): 13 (1915)
Caropodium haussknechtii (Boiss.) Schischkin in Not. Syst. (Leningrad) 4: 30 (1923)

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References

Ajani Y, Ajani A, Cordes JM, Watson MF, Downie SR (2008) Phylogenetic analysis of nrDNA ITS sequences reveals relationships within five groups of Iranian Apiaceae subfamily Apioideae. Taxon 57: 383–401.

Banasiak L, Piwczyński M, Uliński T, Downie SR, Watson MF, Shakya B, Spalik K (2013) Dispersal patterns in space and time: a case study of Apiaceae subfamily Apioideae. Journal of Biogeography 40(7): 1324–1335. doi: 10.1111/jbi.12071

Bani B, Koch MA (2015) A new subspecies of *Grammosciadium macrodon* Boiss. (Apiaceae) from Turkey. Phytotaxa 224(3): 267–275. doi: 10.11646/phytotaxa.224.3.5

Bani B, Karakaya MA, Çeter T (2016) Fruit micromorphological characters of the genus *Grammosciadium* DC. (Apiaceae) in Turkey. Phytotaxa 246(2): 184–191. doi: 10.11646/phytotaxa.246.3.2

Bornmüller JFN (1906) Plantae Straussianae sive enumeratio plantarum a Th. Strauss annis in Persia occidentali collectarum. Beihefte zum Botanischen Centralblatt 19: 1–260.

Boissier PE (1872) Flora Orientalis (vol. 2). Geneva, 890–901.

Boissier PE (1844) Plantae Aucherianae adjunctis nonnullis e regionibus Mediterraneis et Orientalibus aliis cum novarum specierum descriptione; Umbelliferae. Annales des Sciences naturelles, Botanique 3: 66–68.

Bordzilowski EI (1915) Contribution to the flora of Caucasus. Mémoires de la Société des Naturalistes de Kiew 25: 96. [In Russian]

Candolle AP (1829) Mémoire sur la famille des Ombellifères. In: Candolle AP (Ed.) Collection de mémoires pour servir à l'histoire du régne vegetal 5. Paris, 1–84.

Downie SR, Spalik K, Katz-Downie DS, Reduron JP (2010) Major clades within Apiaceae subfamily Apioideae as inferred by phylogenetic analysis of nrDNA ITS sequences. Plant Diversity and Evolution 128(1-2): 111–136. doi: 10.1127/1869-6155/2010/0128-0005

Freyn J (1901) Ueber neue und bemerkenswerte orientalische Pflanzenarten, 5. Bulletin de l'Herbier Boissier, Sér. 2, 1: 245–289.

Hedge IC, Lamond JM (1972) *Grammosciadium* DC. In: Davis PH (Ed.) Flora of Turkey and East Aegean islands. vol 4. Edinburgh University Press, Edinburgh, 318–321.

Koso-Poliansky BM (1914) Preliminary review of the genera Umbelliferae Crimea and the Caucasus. Trudy Bot. Sada Imp. Jurevsk. Univ. 15: 21.

Koso-Poliansky BM (1915) A revision of The Oriental Genus *Grammosciadium* DC. Journal Russe de Botanique 1/2: 1–22.

Koso-Poliansky BM (1916) Acta Florae Rossicae 2(2): 97.

Pimenov MG, Sutory K (2014) Name typification of Umbelliferae taxa described by Joseph Franz Freyn. Plant Biosystems 148(6): 1102–1111. doi: 10.1080/11263504.2014.980363

Pimenov MG, Leonov MV (2004) The Asian Umbelliferae biodiversity database (ASIUM) with particular reference to South-West Asian taxa. Turkish Journal of Botany 28: 139–145.

Schischkin BA (1923) On the genus *Stenodiptera* Kos.-Pol. Notulae Systematicae ex Herbario Horti Botanici Petropolitani 4(4): 29–30.

Spalik K, Wojewódzka A, Downie SR (2001) The evolution of fruit in Scandiceae subtribe Scandicinae (Apiaceae). Canadian Journal of Botany 79: 1358–1374. doi: 10.1139/b01-116

Spalik K, Downie SR (2007) Intercontinental disjunctions in Cryptotaenia (Apiaceae, Oenantheae): an appraisal using molecular data. Journal of Biogeography 34: 2039–2054. doi: 10.1111/j.1365-2699.2007.01752.x

Stapf O, Wettstein R (1886) *Caropodium*. In: Stapf O (Ed.) Denkschriften der Kaiserlichen Akademie der Wissenschaften/Mathematisch-Naturwissenschaftliche Klasse 51, 2. Wien, 317–318.

Takhtajan AL (1986) Floristic regions of the World. University of California Press, London, 544.

Tamamschian SG (1968) On some relationships in the floras of Transcaucasica, Anatolia and Iran-I. Notes from the Royal Botanic Garden, Edinburgh 28(2): 203.

Tamamschian SG, Vinogradova VM (1969a) A contribution to the taxonomy of the genus *Grammosciadium* DC. Umbelliferae. Botanicheskii Zhurnal (Leningrad) 54: 1197–1212.

Tamamschian SG, Vinogradova VM (1969b) *Grammosciadium* and *Caropodium* (Umbelliferae-Apioideae). Taxon 18: 546–548. doi: 10.2307/1218383

Tamamschian SG, Vinogradova VM (1970) *Grammosciadium* and *Caropodium*. Taxon 19: 652. doi: 10.2307/1218982

Tamamschian SG (1987) *Grammosciadium* DC. In: Rechinger K (Ed.) Flora Iranica 162. Akademische Druck- und Verlagsanstalt, Graz, 96–100.

Vinogradova VM (1970) *Grammosciadium* DC. (Umbelliferae) an endemic Antasitan genus. Botanicheskii Zhurnal 55: 54–60.

Vinogradova VM (1995) The new data on the genus *Grammosciadium* and the systematic position of *Fuernrohria setifolia* (Apiaceae). Botanicheskii Zhurnal 80: 91–99.

Zakharova EA, Galina VD, Michael GP (2012) Redefined generic limits of *Carum* (Umbelliferae, Apioideae) and new systematic placement of some of its taxa. Willdenowia 42(2): 149–168. doi: 10.3372/wi.42.42201

Supplementary material 1

Herbarium specimens of members of section *Stenodiptera* distributed in Turkey

Authors: Barış Bani, Fatma Ulusoy, Muhammet Ali Karakaya, Marcus A. Koch

Data type: Specimens data (doc file)