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Morphological character analysis in Turkish *Micromeria* Benth. (Lamiaceae) species with a numerical taxonomic study

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Abstract: As an initial part of a revisional study based on the genus *Micromeria* Benth. (Lamiaceae), extensive field studies, herbarium and literature surveys, and multivariate analysis have been conducted. Recently, many morphological and molecular studies have been conducted on the genus *Micromeria* and related genera. Consequently, the generic boundaries of *Micromeria* have dramatically changed. Therefore, a morphometric analysis was carried out on Turkish *Micromeria* s.l. species, belonging to sect. *Micromeria*, sect. *Cymularia* Boiss., and sect. *Pseudomelissa* Benth., 2 *Clinopodium* L. species, and 2 *Mentha* L. species in order to understand their taxonomic relationship. For morphometric analysis, 27 morphological characters and their states were investigated by means of MVSP software. Our results supported previous molecular studies. The members of the sect. *Pseudomelissa* should be transferred to the genus *Clinopodium*. Turkish *Micromeria* species are now represented by 8 species belonging to sect. *Micromeria* and sect. *Cymularia.* In addition, the taxonomic position of *Micromeria cymuligera* Boiss. & Hausskn. (sect. *Cymularia*) is discussed. The most important diagnostic characters of the *Micromeria* species such as leaf and calyx are illustrated.

Key words: *Clinopodium*, *Cymularia,* Labiatae, *Micromeria*, morphology, *Pseudomelissa*, taxonomy

Türkiye *Micromeria* Benth. (Lamiaceae) türleri üzerinde morfolojik karakter analizi ve sayısal taksonomik çalışmalar

Özet: *Micromeria* Benth. (Lamiaceae) cinsi üzerine temel alınan revizyon çalışmasının ilk bölümü olarak, kapsamlı arazi çalışmaları, herbaryum ve literatür taramaları ile çoklu değişken analizleri yapılmıştır. Son zamanlarda, *Micromeria* ve akraba cinsleri ile ilgili birçok morfolojik ve moleküler çalışma yapılmıştır. Dolayısıyla, *Micromeria* cinsinin sınırları önemli ölçüde değişmiştir. Bu nedenle, Türkiye *Micromeria* s.l. cinsinin *Micromeria*, *Cymularia* Boiss. ve *Pseudomelissa* Benth. seksiyonlarına ait türleri ile 2 *Clinopodium* L. ve 2 *Mentha* L. türünün taksonomik ilişkilerinin anlaşılabilmesi için morfometrik analizleri yapılmıştır. Morfometrik analizler için 27 morfolojik karakter ve bunların karakter durumları MVSP yazılımı kullanılarak çalışılmıştır. Sonuçlarımız önceki moleküler çalışmaları desteklemiştir. *Pseudomelissa* seksiyonu üyeleri *Clinopodium* cinsine aktarılmalıdır. Türkiye *Micromeria* türleri günümüzde *Micromeria* ve *Cymularia* seksiyonuna ait 8 türle temsil edilmektedir. Bununla birlikte, *Micromeria cymuligera* Boiss. & Hausskn. (sect. *Cymularia*)'nın taksonomik durumu tartışılmıştır. *Micromeria* türlerinin en önemli tanımlayıcı karakterleri olan yaprak ve kaliksleri de çizilmiştir.

Anahtar sözcükler: *Clinopodium*, *Cymularia,* Labiatae, *Micromeria*, morfoloji, *Pseudomelissa*, taksonomi

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Introduction

The genus *Micromeria* Benth. (Lamiaceae, Nepetoideae) is a taxonomically difficult and complex genus in the tribe Mentheae. It represents nearly 54 species with 32 subspecies and 13 varieties. The genus is distributed from the Macaronesian-Mediterranean region to southern Africa, India, and China (Bräuchler et al., 2008).

The genus was first described by Bentham (1829). Subsequently, it is considered part of *Satureja* L. s.l. Taxonomists have split this complex into several genera such as *Satureja*, *Clinopodium* L., *Calamintha* Mill., *Acinos* Mill., and *Micromeria* (Bentham, 1848; Boissier, 1879; Ball & Getliffe, 1972; Davis, 1982). On the other hand, others gathered the group to a single genus *Satureja* s.l. (Briquet, 1896; Brenan, 1954; Greuter et al., 1986).

Harley et al. (2004) placed the species of *Micromeria* under 4 sections. These sections are *Micromeria*, *Pineolentia* P.Pérez, *Cymularia* Boiss. and *Pseudomelissa* Benth. A recent molecular analysis has been revealed that *Micromeria* is polyphyletic and members of sect. *Pseudomelissa* are closely related to *Clinopodium* (Bräuchler et al., 2005). In 2006, the species of *Micromeria* sect. *Pseudomelissa* were transferred to *Clinopodium* (Bräuchler et al., 2006).

Bräuchler et al. (2005, 2006, 2008) stated that *Micromeria cymuligera* Boiss. & Hausskn. is an isolated species within the genus with respect to its annual habit, resupinate flowers, special anther structure, and different other characters. According to Bräuchler et al. (2010), *M. cymuligera* is more closely related to the genus *Mentha* L. (especially *M. pulegium* L.) rather than *Micromeria* s.str. Bräuchler et al. (2008) also suggested that the species could be evaluated as a monotypic genus.

The first revision of *Micromeria* species in Turkey was made by Davis (1982), who recognised 14 species (22 taxa). In the *Flora of Turkey*, the species were placed in 3 sections, namely sect. *Micromeria* with 7 species (12 taxa), sect. *Cymularia* with 1 species, and sect. *Pseudomelissa* with 6 species (9 taxa). After the transfer of *Micromeria* section *Pseudomelissa* to *Clinopodium* by Bräuchler et al. (2006), the genus is now represented by 8 species in Turkey.

The objectives of this study were to determine generic boundaries of *Micromeria* against *Clinopodium* on the basis of morphometric analysis, to update the current taxonomic position of Turkish *Micromeria*, and to illustrate leaf and calyx shapes for taxonomy of the genus.

Materials and methods

Between 2004 and 2008, as a part of a taxonomic revision of the genus *Micromeria* in Turkey, Dr. Dirmenci and Dr. Arabacı carried out extensive field works and collected a large number of specimens. In addition, they examined many herbarium specimens at AEF, ANK, BM, E, EGE, ESSE, G, GAZI, HUB, ISTE, JE, K, and W. In this study, 128 localities belonging to 109 populations were examined. Twenty-seven morphological characters (13 quantitative and 14 qualitative) were selected and measured for morphometric analysis. Mean and standard deviation of the quantitative characters were calculated and are given in Table 1. A data matrix is given in Table 2. All Turkish *Micromeria* species are represented in the phenogram (Figure 1). In this study, 2 *Clinopodium* species (3 taxa) and 2 *Mentha* species were sampled as a sister group. The voucher specimens are kept in INU, GAZI, and the Herbarium of Balıkesir University, Turkey. During field studies, *Micromeria cymuligera* was not found in spite of many field expeditions. Its measurements were obtained from herbarium specimens in G herbarium by Dr. Dirmenci.

Selection of specimens was undertaken according to the following criteria: well-preserved and dried specimens, and well-developed leaves and flowers. In addition, some morphological characters such as length of corolla and calyx hard to infer from dried specimens were noted in the field.

Leaf and calyx structures of *Micromeria* and *Clinopodium* species, which are the most useful and constant characters for distinguishing the species, were illustrated by the first author (only *Micromeria cymuligera* could not be illustrated from herbarium specimens) (Figures 2-4).

Table 1. The mean and standard deviation of quantitative measurements in the genera *Micromeria, Clinopodium,* and *Mentha.*

Taxa	subsp.	Leaf length (mm)	Leaf width (mm)	Petiole (mm)	Inf. length (cm)	Inf. width (cm)	Flower in verticillaster	Pedicel (mm)	Bracteole length (mm)	Calyx length (mm)	Calyx width (mm)	Length of Low. teeth (mm)	Length of Upp. teeth (mm)	Corolla length (mm)
Micromeria cristata	*cristata*	4.99	2.23	0.42	6.03	0.64	3.07	0.58	1.64	3.49	1.01	1.34	1.09	5.29
		*0.77	0.16	0.28	2.16	0.04	1.03	0.11	0.10	0.29	0.14	0.12	0.09	0.50
	xylorrhiza	5.78	2.04	0.31	3.21	0.52	3.00	0.58	2.22	4.34	0.89	1.89	1.59	5.48
		*1.24	0.55	0.29	1.29	0.12	1.03	0.23	0.25	0.25	0.08	0.09	0.08	0.38
	orientalis	5.31	2.01	0.09	1.40	0.98	3.23	0.98	0.92	4.04	1.08	1.50	1.01	6.54
		*1.03	0.51	0.09	0.31	0.20	1.30	0.21	0.08	0.33	0.07	0.06	0.06	0.52
	carminea	6.76	2.43	0.41	1.14	2.12	4.75	1.98	1.52	5.56	0.90	1.75	1.01	8.59
		*0.83	0.64	0.29	0.47	0.47	1.91	0.28	0.19	0.31	0.08	0.20	0.08	1.52
	phrygia	5.21	1.25	0.06	1.85	0.91	3.71	2.09	1.64	3.97	0.91	1.11	0.91	6.50
		*0.97	0.17	0.08	0.75	0.06	1.33	0.68	0.12	0.37	0.08	0.08	0.08	0.52
M. elliptica		7.31	3.19	0.18	5.54	1.15	4.31	1.15	0.73	4.32	0.71	1.08	0.92	8.23
		*1.32	1.16	0.16	1.39	0.21	1.11	0.19	0.14	0.43	0.08	0.08	0.08	0.93
M. cremnophila	*anatolica*	5.36	2.52	0.49	5.46	0.40	6.31	0.92	0.92	3.72	0.71	0.48	0.48	3.57
		*0.88	0.65	0.22	1.94	0.06	2.14	0.28	0.13	0.93	0.08	0.09	0.09	0.31
	amana	5.06	2.15	0.45	6.73	0.41	4.18	0.51	0.85	2.48	0.70	0.44	0.44	3.56
		*0.77	0.50	0.28	2.10	0.08	2.75	0.27	0.29	0.37	0.08	0.09	0.09	0.30
M. myrtifolia		8.79	3.17	0.52	10.17	1.00	15.00	0.16	2.48	3.17	1.01	0.55	0.47	4.83
		*2.55	1.17	0.34	4.45	0.13	7.69	0.14	0.40	0.31	0.11	0.05	0.06	0.72
M. juliana		6.50	1.39	0.57	8.92	0.87	12.33	0.12	1.84	3.34	0.90	0.93	1.11	4.21
		*1.62	0.49	0.28	4.08	0.08	4.08	0.07	0.20	0.41	0.09	0.08	0.11	0.86
M. graeca	*graeca*	8.96	2.96	0.53	13.42	1.06	12.50	0.76	1.77	3.97	0.92	1.72	1.25	7.17
		*2.50	0.69	0.26	5.79	0.24	4.83	0.14	0.57	0.62	0.11	0.16	0.14	1.15
M. nervosa		7.43	3.91	0.52	6.88	0.95	13.00	0.91	0.44	3.51	0.88	1.44	1.09	5.07
		*1.28	0.62	0.30	2.19	0.18	5.08	0.12	0.04	0.31	0.09	0.09	0.09	0.63
M. cymuligera		9.00	4.25	2.44	13.67	1.52	14.73	1.01	7.00	3.53	1.01	1.54	1.54	2.55
		*1.30	1.14	0.81	4.76	0.36	3.77	0.14	3.24	0.30	0.14	0.30	0.30	0.29

Table 1. (Continued).

Taxa	subsp.	Leaf length (mm)	Leaf width (mm)	Petiole (mm)	Inf. length (cm)	Inf. width (cm)	Flower in verticillaster	Pedicel (mm)	Bracteole length (mm)	Calyx length (mm)	Calyx width (mm)	Length of Low. teeth (mm)	Length of Upp. teeth (mm)	Corolla length (mm)
Clinopodium molle		6.38	5.76	4.47	8.12	1.94	3.62	1.33	1.14	3.67	1.44	0.83	0.83	7.62
		*1.36	1.04	1.55	3.20	0.26	1.50	0.53	0.29	0.37	0.17	0.13	0.13	1.24
C. caricum		9.29	6.71	1.71	13.43	1.50	6.43	3.30	0.76	2.72	1.12	0.48	0.48	5.91
		*4.43	2.67	0.51	4.62	0.37	2.10	1.20	0.15	0.18	0.10	0.07	0.07	0.59
C. dolichodontum		15.17	11.17	1.50	13.67	1.51	19.50	0.17	0.95	2.41	0.78	1.09	0.57	4.92
		*3.81	3.33	0.52	5.33	0.36	6.16	0.27	0.12	0.32	0.14	0.09	0.05	0.79
C. cilicicum		11.87	5.41	2.57	11.93	0.88	12.27	0.79	0.87	1.82	0.89	0.58	0.58	5.83
		*4.05	1.76	0.98	4.65	0.23	5.20	0.29	0.07	0.22	0.09	0.08	0.08	0.62
C. congestum		12.07	8.29	2.60	7.64	0.89	32.93	0.12	0.83	2.26	0.91	0.45	0.45	4.50
		*2.92	2.02	0.81	1.78	0.20	16.60	0.08	0.11	0.19	0.09	0.05	0.05	0.94
C. serpyllifolium	*serpyllifolium*	13.33	7.93	3.80	12.40	1.41	31.00	0.50	0.75	2.21	1.02	0.53	0.53	4.27
		*3.42	1.53	0.86	4.47	0.40	12.98	0.21	0.17	0.19	0.08	0.05	0.05	1.10
	giresunicum	18.20	10.80	4.47	5.87	2.92	38.33	0.67	1.01	2.22	1.03	0.50	0.50	5.00
		*7.29	2.24	1.30	2.53	1.21	6.73	0.22	0.10	0.23	0.09	0.05	0.05	1.25
	barbatum	15.83	6.67	5.08	17.83	3.52	42.50	0.40	0.49	2.03	1.23	0.46	0.46	5.08
		*9.93	3.52	2.35	7.88	0.78	17.65	0.11	0.08	0.31	0.14	0.05	0.05	1.16
	brachycalyx	7.58	5.65	1.94	12.65	2.42	34.12	0.06	0.52	1.66	1.11	0.30	0.30	3.52
		*2.2	2.26	0.65	1.66	0.36	11.49	0.08	0.06	0.17	0.07	0.03	0.03	0.43
C. umbrosum		24.08	16.67	5.67	4.38	1.84	19.58	3.08	2.62	6.28	1.27	2.39	0.84	8.61
		*9.96	5.79	1.87	1.81	0.60	5.11	0.62	0.47	0.70	0.17	0.12	0.11	0.89
C. vulgare	*vulgare*	28.75	16.58	4.75	12.75	4.46	26.08	1.81	8.21	8.19	1.76	3.00	2.05	15.50
		*8.59	4.42	0.96	4.69	1.43	8.96	0.41	0.58	0.73	0.17	0.67	0.30	2.15
	arundanum	31.14	14.36	4.43	7.67	2.95	34.86	2.18	9.33	10.83	1.98	4.91	3.41	15.71
		*12.51	6.61	1.55	1.32	0.77	12.59	0.99	2.49	0.70	0.13	0.85	0.49	2.70
Mentha pulegium		11.69	6.12	1.11	13.5	1.50	22.00	2.32	2.41	2.81	1.03	1.10	0.85	6.70
		*3.76	2.43	0.25	5.50	0.25	5.00	0.20	0.32	0.31	0.21	0.30	0.10	0.52
M. aquatica		30.14	21.16	10.10	6.59	1.80	35.00	2.20	3.40	3.50	1.20	0.92	0.80	6.78
		*8.56	4.29	3.57	1.68	0.30	5.00	0.30	0.60	0.70	0.31	0.20	0.10	0.60

*Standard deviation

Table 2. Character states and their distribution in the genera *Micromeria, Clinopodium,* and *Mentha.*

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	25	26	27
Micromeria cristata subsp. *cristata*	8	0	0	2	6	1	3	0	1	2	1	0	2	0	0	0	1	1	1	1	1	5	1	1	3	0	0
M. cristata subsp. *xylorrhiza*	3	0	0	2	6	1	4	0	10	2	0	0	2	0	0	1	2	0	1	0	1	1	1	1	3	0	0
M. cristata subsp. *orientalis*	8	0	0	2	6	1	1	0	10	3	0	0	2	0	0	0	0	0	1	1	1	5	1	1	3	0	1
M. cristata subsp. *carminea*	0	0	0	2	7	1	1	0	1	3	0	2	2	0	1	1	1	0	1	0	1	5	0	1	3	0	1
M. cristata subsp. *phrygia*	3	0	0	2	6	1	4	0	1	3	0	0	2	0	2	1	1	0	1	0	1	1	0	1	3	0	1
M. elliptica	1	0	0	1	6	1	3	0	4	1	1	1	1	0	1	4	0	1	1	0	1	1	0	1	2	0	1
M. cremnophila subsp. *anatolica*	7	0	0	1	6	1	0	0	4	1	1	0	0	0	0	4	0	1	1	0	0	3	0	0	1	0	0
M. cremnophila subsp.*amana*	7	0	0	1	6	1	2	0	0	1	1	0	0	0	0	4	0	1	0	0	0	3	0	0	1	0	0
M. myrtifolia	6	0	0	3	4	1	0	0	0	1	2	1	0	1	0	1	2	5	1	0	1	2	0	0	1	0	0
M. juliana	2	0	0	2	5	1	1	0	3	1	1	0	0	1	0	1	1	5	1	0	0	0	0	1	2	1	0
M. graeca subsp. *graeca*	8	0	0	2	5	1	4	0	5	1	2	1	0	1	0	0	1	5	1	0	1	0	1	1	3	0	1
M. nervosa	6	0	0	2	4	1	2	0	5	1	1	0	1	1	0	0	0	5	1	0	1	0	1	1	3	0	0
M. cymuligera	4	0	0	3	0	0	4	1	0	1	2	1	0	1	1	5	2	6	1	1	1	0	1	1	3	1	0
Clinopodium molle	9	0	1	0	0	0	0	1	9	0	1	1	0	0	1	3	0	3	1	1	0	5	0	1	2	1	1
C. caricum	10	0	1	1	0	0	1	1	1	0	2	1	0	0	2	3	0	3	1	1	0	5	0	0	3	1	0
C. dolichodontum	9	1	2	0	1	0	0	1	8	0	2	1	0	1	0	4	0	3	0	0	1	0	0	0	3	1	0
C. cilicicum	6	1	1	0	1	0	2	1	9	1	2	0	0	1	0	4	0	1	0	0	0	4	0	0	1	1	0
C. congestum	9	1	1	0	1	0	2	1	6	1	1	0	1	1	0	4	0	6	0	0	0	5	0	0	0	1	0
C. serpyllifolium subsp. *serpyllifolium*	4	1	1	0	1	0	1	1	7	0	2	1	0	1	0	4	0	6	0	1	0	5	0	0	0	1	0
C. serpyllifolium subsp. *giresunicum*	9	1	2	0	1	0	2	1	7	0	1	2	0	1	0	4	0	6	0	1	0	5	0	0	0	0	0
C. serpyllifolium subsp. *barbatum*	4	1	1	0	1	0	1	1	7	0	2	2	2	1	0	4	0	6	0	1	0	5	0	0	0	0	0
C. serpyllifolium subsp. *brachycalyx*	5	0	1	0	2	0	1	1	7	0	2	2	0	1	0	4	0	4	0	1	0	5	0	0	0	0	0
C. umbrosum	4	2	2	0	3	0	1	1	11	1	0	1	1	1	2	0	2	2	1	1	2	1	1	1	3	1	1
C. vulgare subsp. *vulgare*	4	2	2	0	2	0	0	1	2	1	2	2	0	1	1	2	2	2	2	1	2	1	1	1	3	1	1
C. vulgare subsp. *arundanum*	5	2	2	1	3	0	3	1	2	1	1	2	0	1	2	2	2	2	2	1	2	1	1	1	3	1	1
Mentha pulegium	6	1	1	0	1	0	3	1	12	1	2	1	0	1	2	5	2	1	1	1	1	4	0	1	3	0	1
M. aquatica	4	2	2	2	2	0	3	1	10	1	1	1	1	1	2	3	2	1	1	1	1	4	0	1	3	1	1

For the multivariate analysis, a similarity matrix was created first by using Gower's (1971) general coefficient similarity (Sneath & Sokal, 1973), which can be used directly with a mixture of character types (binary, qualitative, and quantitative characters) as well as taking into account missing values (St-Laurent et al., 2000). This similarity matrix was then clustered by using UPGMA (the unweighted pair-group method using arithmetic averages) and the results are shown in the phenogram (Figure 1). UPGMA is the most frequently used method (Romesburg, 1984) and also appears to produce the best results (Radford, 1986) in terms of the following criteria: accurate reflection of the similarity matrix, symmetrical hierarchical structure, and congruence with classification derived by traditional methods (Ward, 1993). The characters used in the analysis were assumed to be as important as each other and were unweighted. For this analysis, MVSP for Windows v. 3. 13d (a multivariate statistics package for IBM PC and compatibles) was applied (Kovach, 1999).

Results and discussion

The phenogram obtained from UPGMA clustering of the similarity matrix is presented in Figure 1. A line across the phenogram at 0.60 similarity level empirically distinguishes 3 phenon lines. The first phenon line represents *Micromeria* sect. *Micromeria*. The second phenon line represents 6 *Clinopodium* species (9 taxa) previously treated as *Micromeria* sect. *Pseudomelissa*. The section was transferred to *Clinopodium* by Bräuchler (2006). The third phenon consists of 3 subgroups. The first subgroup represents *Micromeria* sect. *Cymularia*, which has only 1 species, namely *M. cymuligera*. The second subgroup represents 2 *Mentha* species and the third subgroup represents 2 traditional *Clinopodium* species (3 taxa).

While sect. *Micromeria* has a subequal or actinomorphic calyx, and revolute and shortly petiolate leaf (up to 1 mm), *Clinopodium* has a mainly bilabiate calyx, and entire or crenate and clearly

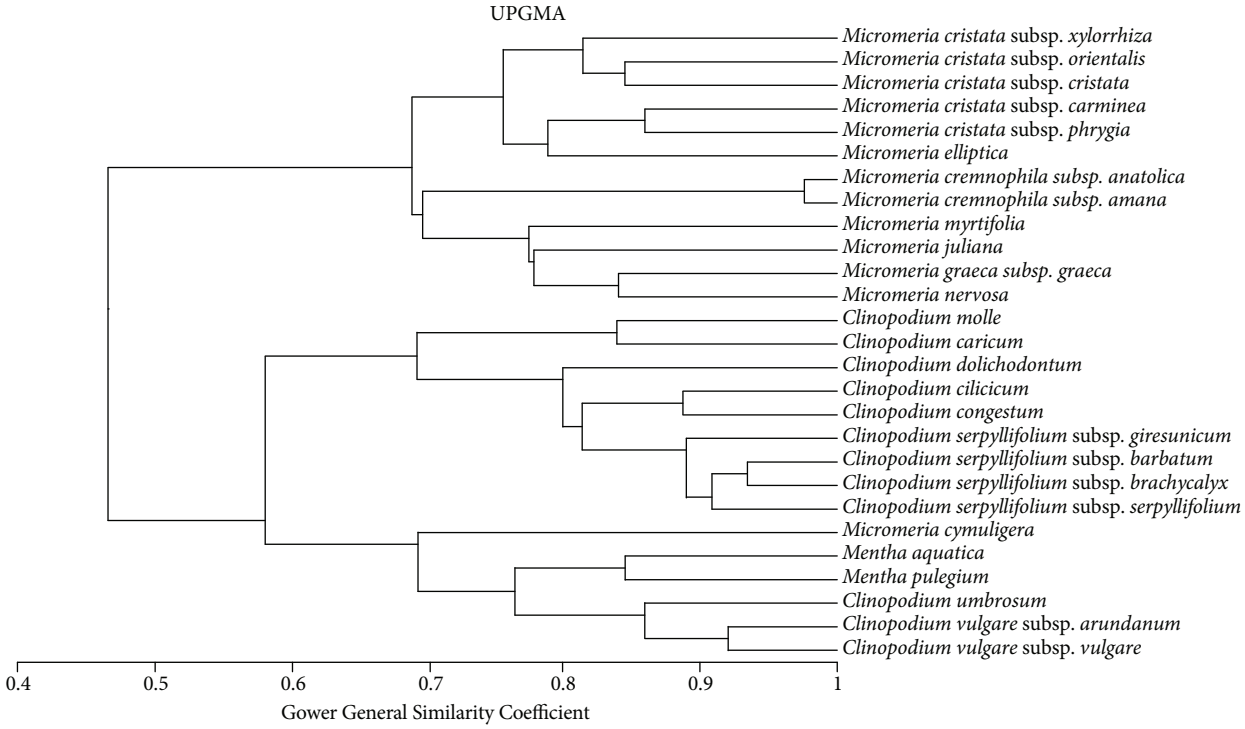

Figure 1. UPGMA phenogram showing the relationships within the genera *Micromeria, Clinopodium,* and *Mentha*.

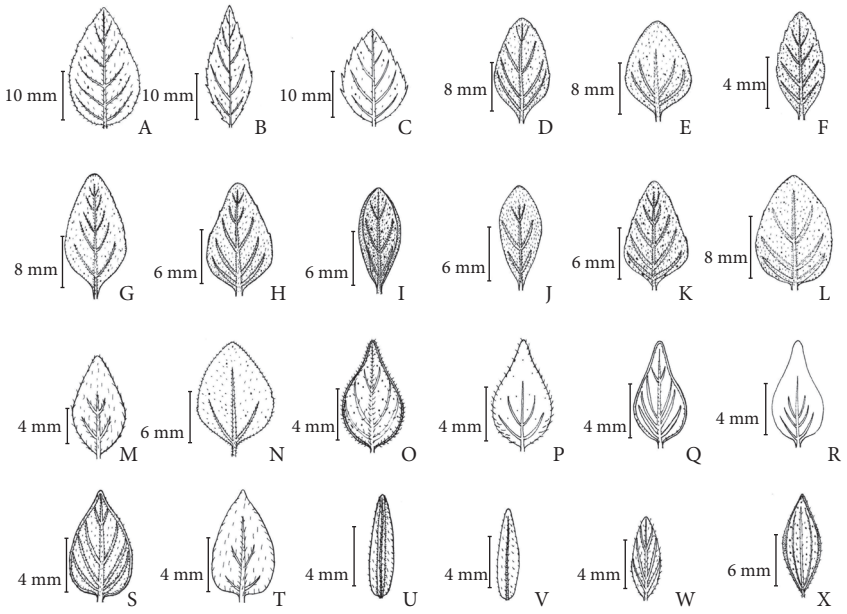

Figure 2. Leaves: a) *Clinopodium vulgare* subsp. *vulgare* (Dirmenci 3677); b) *C. vulgare* subsp. *arundanum* (Dirmenci 3453); c) *C. umbrosum* (Yıldız 16679); d) *C. serpyllifolium* subsp. *serpyllifolium* (Yıldız 16282); e) *C. serpyllifolium* subsp. *giresunicum* (Yıldız 16393-a); f) *C. serpyllifolium* subsp. *brachycalyx* (Dirmenci 3099); g) *C. serpyllifolium* subsp. *barbatum* (Dirmenci 3085); h) *C. congestum* (Satıl 1502); i) *C. cilicicum* (Dirmenci 3088) (revolute leaf); j) *C. cilicicum* (Dirmenci 3088) (revolute leaf, upper surface); k) *C. cilicicum* (Dirmenci 3088) (flat leaf); l) *C. dolichodontum* (Dirmenci 3089); m) *C. caricum* (Dirmenci 3477); n) *C. molle* (Dirmenci 3461); o) *Micromeria nervosa* (Dirmenci 3112); p) *M. nervosa* (Dirmenci 3112) (upper surface); q) *M. myrtifolia* (Dirmenci 3065); r) *M. myrtifolia* (Dirmenci 3065) (upper surface); s) *M. myrtifolia* (Dirmenci 1759); t) *M. myrtifolia* (Dirmenci 1759) (upper surface); u) *M. juliana* (Dirmenci 3153); v) *M. juliana* (Dirmenci 3153) (upper surface); w) *M. juliana* (Dirmenci 3153); x) *M. graeca* subsp. *graeca* (Dirmenci 3681).

petiolate leaf (2-9 mm) (Bentham, 1848; Boissier, 1879; Leblebici 1982). In terms of these characters, sect. *Pseudomelissa* is clearly similar to *Clinopodium*. In addition, chromosome numbers of sect. *Pseudomelissa* are more similar to those found in *Clinopodium* (Morales, 1993). Recently, Bräuchler et al. (2006, 2010) transferred *Micromeria* sect. *Pseudomelissa* to *Clinopodium* based on molecular phylogenetic and morphologic studies. Our current morphometric analysis also supported their treatment. Now, Turkish *Micromeria* species consist of 2 sections, namely sect. *Micromeria* and *Cymularia*, and 8 species (13 taxa), namely *M. cristata* (Hampe) Griseb. subsp. *cristata*, subsp. *xylorrhiza* (Boiss. & Heldr.) P.H.Davis, subsp. *orientalis* P.H.Davis, subsp. *carminea* (P.H.Davis) P.H.Davis, and subsp. *phrygia* P.H.Davis, *M. elliptica* K.Koch, *M. cremnophila* Boiss. & Heldr. subsp. *anatolica* P.H.Davis and subsp. *amana* (Rech.f.) P.H.Davis, *M. myrtifolia* Boiss. & Hohen., *M. juliana* (L.) Benth. ex Rchb., *M. graeca* (L.) Benth. ex Rchb. subsp. *graeca, M. nervosa* (Desf.) Benth., and *M. cymuligera*.

Leaf characters, such as length, width, margin, base, and apex, and floral characters, such as the shape and size of bracteole, calyx, corolla, and calyx teeth, indumentums of calyx throat and length of corolla are the most important diagnostic characters in Turkish *Micromeria* (Figures 2-4). Our data matrix has 9 leaf (characters 1-9) and 18 inflorescence (characters 10-27) characters and their states. Therefore, our phenogram depicted the taxonomic relationship among the species well (Figure 1).

M. cymuligera was described by P.E.E. Boissier & C. Haussknecht in 1879. The species differs from the other *Micromeria* species by its annual habits, ovate-acuminate bracteoles, resupinate corollas, and special anther structures (Bräuchler et al., 2005, 2008). The

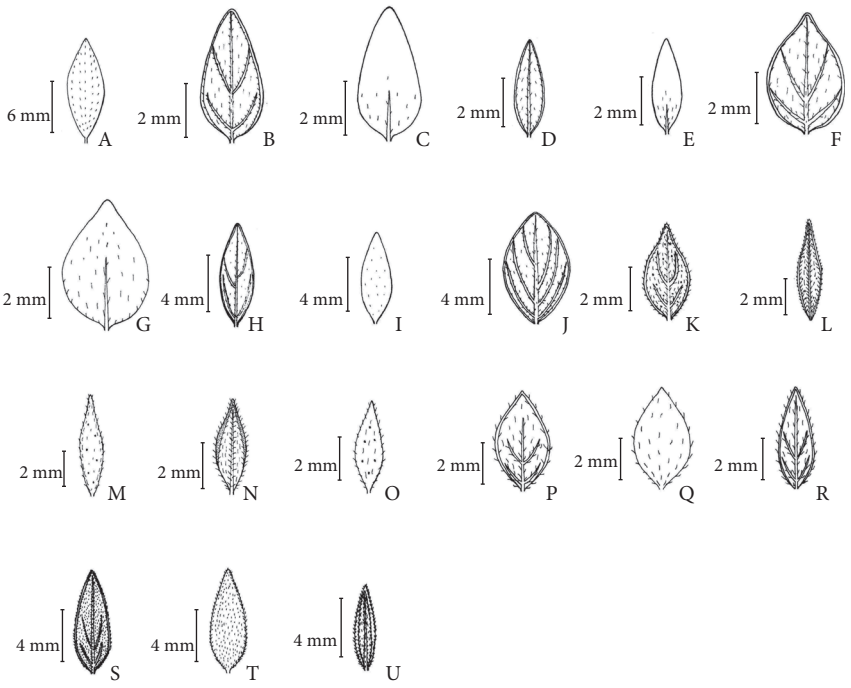

Figure 3. Leaves: a) *M. graeca* subsp. *graeca* (Dirmenci 3681) (upper surface); b) *M. cremnophila* subsp. *amana* (Dirmenci 3050) (ovate leaf); c) *M. cremnophila* subsp. *amana* (Dirmenci 3050) (ovate leaf, upper surface**);** d) *M. cremnophila* subsp. *amana* (Dirmenci 3050) (oblong-elliptic leaf); e) *M. cremnophila* subsp. *amana* (Dirmenci 3050) (oblong-elliptic leaf, upper surface); f) *M. cremnophila* subsp. *anatolica* (Arabacı 2071); g) *M. cremnophila* subsp. *anatolica* (Arabacı 2071) (upper surface); h) *M. elliptica* (Yıldız 16467); i) *M. elliptica* (Yıldız 16467) (upper surface); j) *M. elliptica* (Yıldız 16467) (broadly elliptic leaf); k) *M. cristata* subsp. *cristata* (Dirmenci 3611); l) *M. cristata* subsp. *xylorrhiza* (Dirmenci 3465); m) *M. cristata* subsp. *xylorrhiza* (upper surface); n) *M. cristata* subsp. *phrygia* (Dirmenci 3444); o) *M. cristata* subsp. *phrygia* (upper surface); p) *M. cristata* subsp. *orientalis* (Arabacı 2073) (elliptic leaf); q) *M. cristata* subsp. *orientalis* (Arabacı 2073) (elliptic leaf, upper surface); r) *M. cristata* subsp. *orientalis* (Arabacı 2073) (lanceolate leaf); s) *M. cristata* subsp. *carminea* (Dirmenci 3251) (lanceolate leaf); t) *M. cristata* subsp. *carminea* (Dirmenci 3251) (lanceolate leaf, upper surface); u) *M. cristata* subsp. *carminea* (Dirmenci 3251) (revolute leaf).

species has not been collected since 1865 in spite of many expeditions to its known locations and other potential areas. Therefore, we have not got inadequate information to make a direct or indirect assessment of its taxonomic position. Bräuchler et al. (2008) stated that *M. cymuligera* is an isolated species within the genus. Their molecular phylogenetic study revealed that the species is more closely related to the genus *Mentha* rather than *Micromeria* s.str. According to their taxonomic treatment (Bräuchler et al., 2010), *Micromeria cymuligera* is similar to *Mentha pulegium* in terms of some morphological characters. They also suggested that the species could be evaluated as a monotypic genus as "*Cymularia*" (Bräuchler et al., 2008). In the present study, we tested their hypothesis. Our results agreed with their findings. According to the phenogram (Figure 1), the species is more similar to *Mentha* and traditional *Clinopodium* than *Micromeria* based on 27 morphological characters. However, more and newer materials, field observations, and ecological, karyological, palynological, and molecular studies are needed to reach a final conclusion about *Micromeria cymuligera.*

Leaf and floral character definitions and states in the genera *Micromeria, Clinopodium,* and *Mentha*:

1. Leaf shape structures: lanceolate (0); linear-lanceolate (1); oblong-lanceolate (2); elliptic-lanceolate (3); ovate (4); ovate-oblong (5);

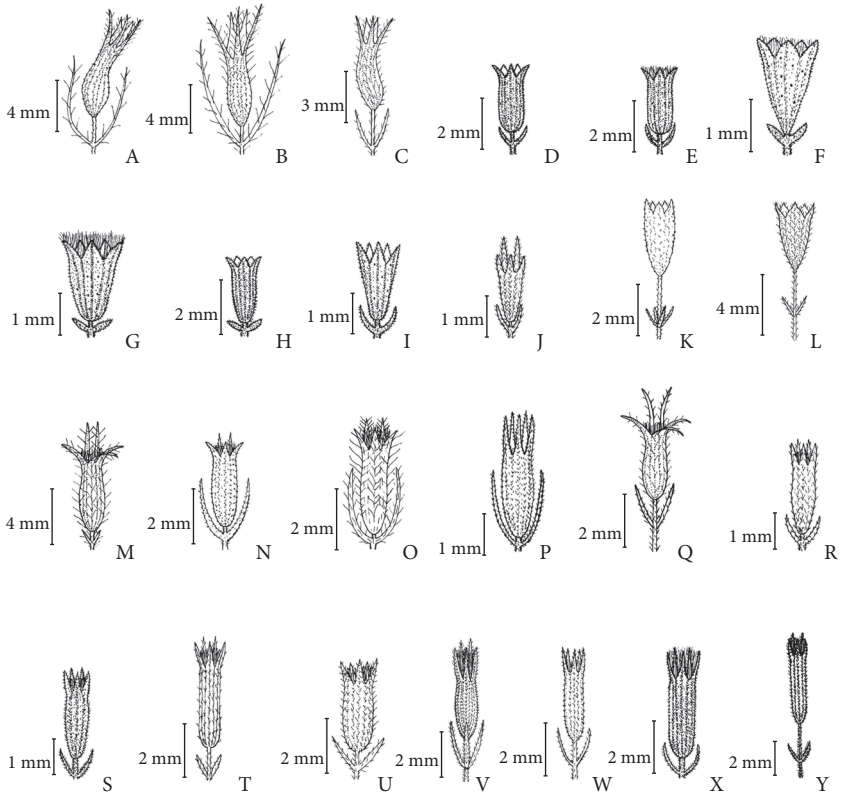

Figure 4. Calyx: a) *Clinopodium vulgare* subsp. *vulgare* (Dirmenci 3677); b) *C. vulgare* subsp. *arundanum* (Dirmenci 3453); c) *C. umbrosum* (Yıldız 16679); d) *C. serpyllifolium* subsp. *serpyllifolium* (Yıldız 16282); e) *C. serpyllifolium* subsp. *giresunicum* (Yıldız 16393-a); f) *C. serpyllifolium* subsp. *brachycalyx* (Dirmenci 3099); g) *C. serpyllifolium* subsp. *barbatum* (Dirmenci 3085); h) *C. congestum* (Satıl 1502); i) *C. cilicicum* (Dirmenci 3088); j) *C. dolichodontum* (Dirmenci 3089); k) *C. caricum* (Dirmenci 3477); l) *C. molle* (Dirmenci 3461); m) *Micromeria nervosa* (Dirmenci 3112); n) *M. myrtifolia* (Dirmenci 3065); o) *M. myrtifolia* (Dirmenci 1759); p) *M. juliana* (Dirmenci 3153); q) *M. graeca* subsp. *graeca* (Dirmenci 3681); r) *M. cremnophila* subsp. *amana* (Dirmenci 3050); s) *M. cremnophila* subsp. *anatolica* (Arabacı 2071); t) *M. elliptica* (Yıldız 16467); u) *M. cristata* subsp. *cristata* (Dirmenci 3611); v) *M. cristata* subsp. *xylorrhiza* (Dirmenci 3465); w) *M. cristata* subsp. *phrygia* (Dirmenci 3444); x) *M. cristata* subsp. *orientalis* (Arabacı 2073); y) *Micromeria cristata* subsp. *carminea* (Dirmenci 3251).

ovate-elliptic (6); ovate-oblong-elliptic (7); ovate-elliptic-lanceolate (8); ovate-orbicular (9); ovate-broadly ovate (10). **2.** Leaf length (mm): $x \leq 10$ (0); $10 < x < 20$ (1); $20 \leq x$ (2). **3.** Leaf width (mm): $x < 5$ (0); $5 \leq x \leq 10$ (1); $10 < x$ (2). **4.** Leaf apex: obtuse (0); obtuse-acute (1); acute (2); subacute-acuminate (3). **5.** Leaf margin: entire (0); obscurely crenate-dentate (1); conspicuously crenate-dentate (2); serrate (3); obscurely revolute (4); revolute (5); narrowly revolute (6); narrowly or broadly revolute (7). **6.** Leaf margin thickening: flat (0); thickened (1). **7.** Leaf base: rounded-truncate (0); rounded (1); ± rounded (2); ± rounded-cuneate (3); cuneate (4). **8.** Petiole (mm): $x < 1$ (0); $1 \leq x$ (1). **9.** Leaf indumentum: glabrous-pubescent-hirsute (0); pubescent (1); pubescent-pilose (2); pubescent-hispidulous (3); scabrid-pubescent (4); hispidulous (5); adpressed canescent (6); adpressed velvety (7); adpressed velvety-tomentose (8); tomentellous (9); pilose (10); hirsute-pilose (11); villous (12). **10.** Inflorescence shape: thyrsoid (0); cyme (1); spike (2); capitate (3). **11.** Inflorescence length (cm): $x < 5$ (0); $5 \leq x \leq 10$ (1); $10 < x$ (2). **12.** Inflorescence (verticillaster) width (cm): $x < 1$ (0); $1 \leq x \leq 2$ (1); $2 < x$ (2). **13.** Internode: distant (0); distant below, condensed above (1); condensed (2). **14.** Flowers in verticillaster: $x < 10$ (0);

10 ≤ x (1). **15.** Pedicel (mm): x < 1 (0); 1 ≤ x ≤ 2 (1); 2 < x (2). **16.** Shape of bracteoles: ovate (0); lanceolate (1); linear-lanceolate (2); linear (3); linear-subulate (4); subulate (5). **17.** Bracteole length (mm): x < 1.2 (0); 1.2 ≤ x ≤ 2 (1); 2 < x (2). **18.** Shape of calyx: turbinate (0); obconical-cylindrical (1); tubular-turbinate (2); cylindrical (3); tubular (4); narrowly tubular (5); tubular-curved (6). **19.** Calyx length (mm): x ≤ 2.5 (0); 2.5 < x < 7 (1); 7 ≤ x (2). **20.** Calyx width (mm): x ≤ 1 (0); 1 < x (1). **21.** Symmetry of calyx: actinomorphic (0); sub-bilabiate (1); bilabiate (2). **22.** Shape of calyx teeth: triangular (0); narrowly triangular (1); lanceolate (2); narrowly lanceolate (3); lanceolate-subulate (4); subulate (5). **23.** Length of lower calyx teeth (mm): x ≤ 1.2 (0); 1.2 < x (1). **24.** Length of upper calyx teeth (mm): x ≤ 0.6 (0); 0.6 < x (1). **25.** Apex of calyx teeth: obtuse (0); acute (1); acute-acuminate (2); acuminate (3). **26.** Indumentum of calyx throat: bearded (0); naked or glabrous (1). **27.** Corolla length (mm): x ≤ 6 (0); 6 < x (1).

Specimens examined:

–*Micromeria cristata* subsp. *cristata*: *Frivaldsky* (isotype K); *Dirmenci* 3611 & *Akçiçek* (INU). – subsp. *xylorrhiza D.* 13813 (E, K); *Lambert* & *Thorp* 573 (E, K); *Dirmenci* 3465 & *Akçiçek* (INU); *Dirmenci* 3662 & *Akçiçek*; *H.Peşmen* & *A.Güner* 2336 (AEF, HUB); D. 15561 (E, K). – subsp. *orientalis McNeill* 461 (holotype E, isotype K); *Yıldız* 9953; *Arabacı* 2073 (INU); *Dirmenci* 3505 & *Arabacı*; *Kotschy* 453 (K, BM). – subsp. *carminea Balansa* 243 (BM); *Davis* 13403 (holotype K, isotype E, ANK); *Dirmenci* 3251 (INU); *Dirmenci* 3664 & *Akçiçek*. subsp. *phrygia Davis* 18457 (holotype E, isotype K); *Dirmenci* 3444 (INU); *Dirmenci* 3665 & *Akçiçek*; *Baytop* & *Tuzlacı* (ISTE 33991); (ISTE 35698); *Davis* 18363 (K); *Yıldız* & *Dirmenci* 3151; *Dirmenci* 1944. – *M. elliptica D.* 47562 (E, K); *Yıldız* 16286 & *Dirmenci*; *Yıldız* 16467 & *Dirmenci* (INU); *Dirmenci* 3610 & *Akçiçek*; *M.Koyuncu* 10541 & et al. (AEF); *A.Güner* 4902 & *M.Vural* (GAZI, AEF); *H.Duman* 6183 (ESSE). – *M. cremnophila* subsp. *anatolica: N.Çelik* 1459 (AEF); *M.Koyuncu* (AEF 14434); *Davis* 21852 (ANK); *Arabacı* 2072 (INU); *Dirmenci* 3504 & *Arabacı*; *Davis* 23258 & *O.Polunin* (holotype E, isotype ANK, BM, K); *K.Alpınar* (ISTE 62187); *T.Ekim* 7773 (GAZI); *D.* 23996 (E, K, BM). – subsp. *amana*: *D.* 19217 (ANK, BM, E, EGE, K); *D.* 19870 (E, K, BM); *Davis et al.* 19542 (BM); *Davis et al.* 19565 (K, BM); *Davis* 19546 (K); *Dirmenci* 3050 *Arabacı* (INU); *Dirmenci* 3237; *Dirmenci* 3450 & *Akçiçek*; *Haradjian* 3887 (isotype E). – *M. myrtifolia*: *Kotschy* 305 (isotype K, BM); *Dirmenci* 1759 & *Arabacı* (INU); *Dirmenci* 3080 & *Arabacı*; *Dirmenci* 3065 & *Arabacı* (INU). – *M. juliana*: *A.Baytop* (ISTE 13619); *Dirmenci* 3159 & *Yıldız* (INU); *Yıldız* & *Dirmenci* 3120; *Yıldız* & *Dirmenci* 3116; *Yıldız* & *Dirmenci* 3118. – *M. graeca* subsp. *graeca*: *Dirmenci* 3681 & *Akçiçek* (INU); *Rennard* (BM); *Tuzlacı* (ISTE 51605); *E.Sezik* 356-b (E); *Alava* 6612 (E); *Coode* & *Jones* 681 (E). – *M. nervosa*: *D.* 41218 (E, K); *Yıldız* & *Dirmenci* 3112 (INU); *D.* 40382 (E); *Gathorne-Hardy* 164 (E). – *M. cymuligera*: *Hausskn.* (holotype G). – *Clinopodium molle*: *Dirmenci* 3461 (INU); *Yıldız*, *Dirmenci* 3674 & *Arabacı*; *Dirmenci* 3680, *Arabacı* & *Akçiçek*; *Kotschy* 1841:552a (holotype K); *Davis* 23883 & *Polunin* (ANK, K, BM). – *C. caricum*: *Davis* 13422 (holotype K, isotype E); *Dirmenci* 3477 (INU); *Dirmenci* 3663 & *Akçiçek*. – *C. dolichodontum*: *Davis* 16356 (holotype K, isotype E, EGE); *Dirmenci* 1407; *Dirmenci* 3090 & *Arabacı*; *Dirmenci* 3089 (INU); *Dirmenci* 3091 & *Arabacı*; *Dirmenci* 3482 & *Arabacı*. – *C. cilicicum*: *Shie* 315 (holotype K); *Dirmenci* 3088 & *Arabacı* (INU); *Dirmenci* 3486 & *Arabacı*. – *C. congestum*: *Satıl* 1502 (INU); *Dirmenci* 3500 & *Arabacı*; *Haussknecht* (isotype BM, K); *McNeill* 796 (E); *Sintenis* 1403 (K); *Arabacı* 2145. – *C. serpyllifolium* subsp. *serpyllifolium*: *D.* 47661 (E, K); *Yıldız* 16350 & *Dirmenci*; *Yıldız* 16710 & *Arabacı*; D. 16469 (E); *Davis* 47541 (K); *Yıldız* 16282 (INU); *Yıldız* 16855; *Dirmenci* 3645 & *Akçiçek*. – subsp. *giresunicum*: *Davis* 20750 (holotype E, isotype K, BM); *Yıldız* 16393 (INU); *Dirmenci* 3666 & *Akçiçek*. – subsp. *barbatum*: Kotschy 342 (isotype K); *H. Peşmen et al.* 2082 (EGE); *E.Tuzlacı* (ISTE 35983); *Dirmenci* 3085 & *Arabacı* (INU); *Dirmenci* 3093 & *Arabacı*; *Dirmenci* 3455 & *Akçiçek*. – subsp. *brachycalyx*: *Yıldız* 16415 & *Dirmenci*; *Balansa* 538 (holotype K, isotype BM); *Dirmenci* (3238-a); *Dirmenci* 3087 & *Arabacı*; *Dirmenci* 3099 (INU). – *C. umbrosum*: *Yıldız* 16366 (INU); *Yıldız* 16679 & *Arabacı* (INU); *Dirmenci* 3453 & *Akçiçek*. – *C. vulgare* subsp. *vulgare*: *Yıldız* 16538 (INU); *Dirmenci* 3677 & *Arabacı* (INU); *Dirmenci* 3602 & *Akçiçek*. – subsp. *arundanum*: *Dirmenci* 3449 & *Akçiçek* (INU); *Dirmenci* 3453 (INU). – *Mentha aquatica*: *M.Vural*

8453 (GAZI); *M.Vural* 3319 (GAZI); *A.Güner* 6829 (GAZI). – *M. pulegium*: *M.Vural* 7090 (GAZI); *A.Güner* 9570 (GAZI).

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