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## *Mattiastrum pulumurense* (Cynoglossinae, Boraginaceae), a new endemic species from Türkiye

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**Abstract:** A new species, *Mattiastrum pulumurense*, has been described from Tunceli in eastern Türkiye. It is generally distinguished from other species (except *M. racemosum* var. *scabridum*) by a sparsely hairy or glabrescent above-ground part. It is most similar morphologically to *M. longipes*, *M. calycinum*, and *Paracaryum hedgei* (*P. hedgei* is potentially a member of the genus *Mattiastrum*). However, it differs from *M. longipes* and *M. calycinum* by its 3–3.5-mm-long and linear lanceolate scales, 2.5–4.5-mm-long anthers, and 10–15-mm-long styles; it differs from *Paracaryum hedgei* by its 3–3.5-mm-long scales, 2.5–4.5-mm-long anthers. In addition, this new species differs from *M. racemosum* var. *scabridum* by having 3–3.5-mm-long scales and no scale appendages. A description of the new species, an illustration, a comparative Table of morphological characters, detailed photographs, and a distribution map of the new species together with adjacent species were provided. In addition, the evolutionary relationships of these species were calculated using both Bayesian inference and maximum likelihood analyses based on the ribosomal internal transcribed spacer (ITS1-5.8S-ITS2) and combined chloroplast data set (rps16 and trnL genes, trnL-trnF intergenic spacer). According to the phylogeny-based combined chloroplast data set, both populations of *Mattiastrum pulumurense* generate a monophyletic clade and are closely related to *M. longipes*, *P. hedgei*, and *M. calycinum*. According to ITS-based phylogeny, *Mattiastrum pulumurense* is closely related to *Rindera tetraspis*, which is seen in the paraphyletic and nested genera *Mattiastrum-Paracaryum-Rindera*.

**Key words:** Endemic, *Paracaryum*, phylogeny, taxonomy, Tunceli, Türkiye

### 1. Introduction

The genera *Paracaryum* Boiss. and *Mattiastrum* (Boiss.) Brand are members of subtribe Cynoglossinae Dumort (Chacón et al., 2016). Both genera have been accepted under various combinations and statuses in the literature, including genus, subgenus, and section (De Candolle, 1846; Boissier, 1849; Brand, 1915; Mill, 1977). In fact, Greuter (1981) reduced them all to synonyms under *Cynoglossum* L. Currently, these two taxa are accepted as separate genera (Chacón et al., 2016; Pourghorban et al., 2020). There are 36 species classified under *Mattiastrum*<sup>1</sup> and 29 species under *Paracaryum*<sup>2</sup>. However, phylogenetic studies have shown that whether called *Paracaryum* or *Mattiastrum*, none of the examined taxa form monophyletic clades, either together or

separately (Weigend et al., 2013; Cohen, 2014; Chacón et al., 2016; Pourghorban et al., 2020). According to Pourghorban et al. (2020), *Mattiastrum*, *Solenanthes* Ledeb., *Rindera* Pall., *Trachelanthus* Kunze, *Paracaryum*, and some species of *Cynoglossum* and *Lindelofia* Lehm. collectively form a moderately supported clade III, along with clade IV which includes all studied *Mattiastrum* species, all *Paracaryum* species, and all *Rindera* species except *R. tetraspis* Pall. Species within these genera are nested together. Surprisingly, *R. tetraspis* occurs far from clade IV, in a sister position to *Trachelanthus hissaricus* Lipsky and *Solenanthes karateginus* Lipsky, although it has broadly winged and smooth-surfaced nutlets (clade IIIA). This clade lacks support from any morphological synapomorphy (Pourghorban et al., 2020).

<sup>1</sup>POWO (2024a) onward (continuously updated). *Mattiastrum*. Plants of World Online. Kew Royal Botanical Garden [online]. Website <https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:4673-1>. [accessed 12 02 2024].

<sup>2</sup>POWO (2024b) onward (continuously updated). *Paracaryum*. Plants of World Online. Kew Royal Botanical Garden [online]. Website <https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:4727-1>. [accessed 12 02 2024].

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These two genera are distributed from the East Aegean Islands and Anatolia to West Himalaya<sup>1,2</sup>. In neighboring countries such as Russia, Iran, Syria, and Palestine, there are 9, 42, and 3 species of *Paracaryum/Mattiastrum*, respectively (Shishkin, 1953; Mouterde, 1966; Rechinger, 1967). In Türkiye, there are 31 taxa belonging to *Paracaryum* (Mill, 1978; Dođru-Koca, 2012). According to Mill (1978), the genus *Paracaryum* is divided into three subgenera: *Mattiastrum*, *Modestomattiastrum* (Brand) R. Mill, and *Paracaryum*. Subgenus *Paracaryum* have nutlets with strongly incurved wings, while the other two subgenera have flat-winged nutlets. These taxa (subgen. *Mattiastrum* & subgen. *Modestomattiastrum*) are divided based on the morphology of the inside of the corolla. Taxa with scales longer than broad and anthers situated above the scales belong to the subgen. *Mattiastrum*, while taxa with scales approximately equal or broader than long belong to the subgen. *Modestomattiastrum* (Mill, 1978). Recently, two new *Paracaryum* and a new *Mattiastrum* species were described (*P. bingolianum* Behçet & İlçim, *P. leventshikii* Yıldırım, *M. turcicum* Hamzaođlu) from Türkiye (Behçet and İlçim, 2015; Yıldırım, 2018; Hamzaođlu and Özbek, 2022). *P. bingolianum* and *M. turcicum* belong to the subgen. *Modestomattiastrum*, while *P. leventshikii* is a member of the subgen. *Mattiastrum*.

During various field trips with different purposes, two unidentified populations were collected from Pülümür, a district of Tunceli. After morphological and phylogenetical studies, these populations have been described as a new species within the genus *Mattiastrum*. Herein, the description of the new species, its distribution, and phylogenetic situation are provided.

## 2. Materials and methods

### 2.1. Sampling

The examined specimens belonging to the new species and closely related species are stored in Hacettepe University Herbarium (HUB). In addition, many herbarium specimens were examined in herbaria HUB, GAZI, ANK, ISTE, ISTF, G, P, E, K. For identification, several materials were examined (Mill, 1978; Koca, 2009; Rechinger, 1967). For the morphological terminology, Mill (1978) was followed.

### 2.2. Molecular studies and phylogenetic analysis

Genomic DNA from the populations of the new species, *Mattiastrum corymbiforme* (DC.) Brand, *M. incanum* (Ledeb.) Brand, *M. calycinum* (Boiss. & Balanasa) Brand, *Paracaryum hedgei* Aytac & R.R. Mill and *M. longipes* (Boiss.) Brand was extracted using a Qiagen DNeasy Plant Mini Kit (Hilden, Germany; Cat No: 69196) according to the modified manufacturer's instructions. Primers and PCR conditions were used as described by Pourghorban et al. (2020). The data set was mainly generated from the data

set in Pourghorban et al. (2020), but additional sequences were added. The outgroup was selected following Pourghorban et al. (2020). All DNA sequences used were obtained from GenBank. Their accession numbers are given at the end of the trees (Figures 1 and 2). The sequences were aligned using MAFFT v.7 (Kato et al., 2019). Evolutionary substitution models were calculated in JModelTest v.2.1.7 (Guindon and Gascuel, 2003; Darriba et al., 2012) as K81uf+gamma for chloroplasts and TIM2+gamma for ITS. Maximum likelihood analysis and Bayesian inference were inferred using raxmlGUI v.4.0b08 with 100 runs and 1000 bootstrap replicates (Silvestro, 2012; Stamatakis, 2014) and MrBayes v.3.2.7a (Ronquist et al., 2012) with 10 million generations, respectively. The ESS values in the log files were checked using Tracer v.1.7 (Rambaut et al., 2018). The bootstrap values obtained from maximum likelihood analysis were added near the posterior probabilities.

## 3. Results

### 3.1. Phylogenetic relationships

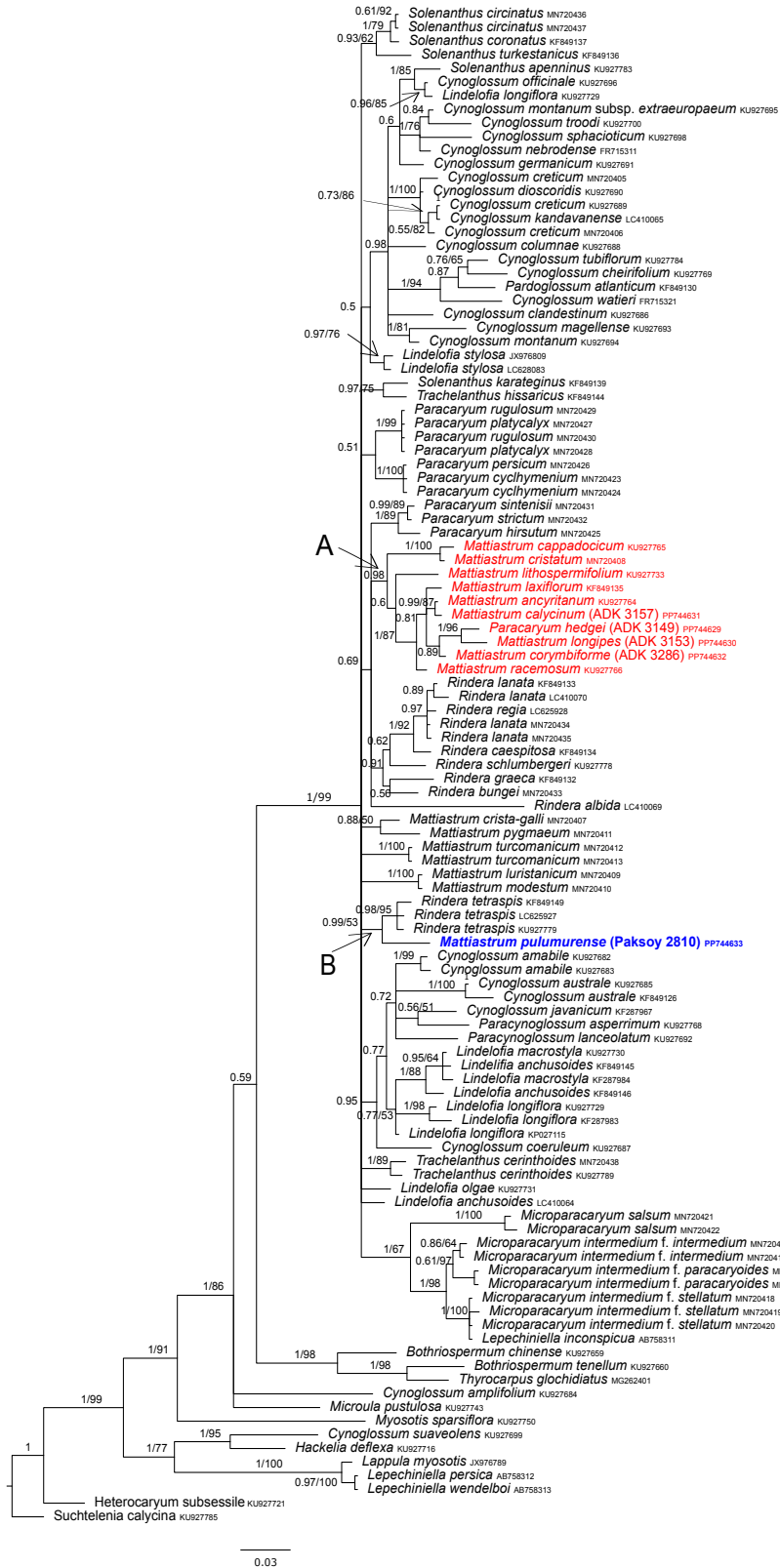
Tree topologies derived from Bayesian inference of combined chloroplast (rps16+trnL+trnL-trnF) and ITS are shown in Figures 1 and 2, respectively. According to the phylogenetic tree based on the combined chloroplast data set, the first-time studied species *Mattiastrum calycinum*, *P. hedgei*, *M. longipes*, and *M. incanum* form a moderately supported clade (PP=0.63) (Figure 1, clade A), together with *M. cappadocicum* (Boiss. & Balanasa) Brand, *M. cristatum* (Schreb.) Brand, *M. racemosum* (Schreb.) Brand, *P. ancyritanum* Boiss. and *M. laxiflorum* (Trautv.) Czerep. Within clade A, there is a subclade containing *M. longipes*, *M. calycinum*, *P. hedgei*, and both populations of *M. pulumurensis* (PP=0.61 BS=83) (Figure 1, clade B). According to the phylogenetic hypothesis based on the ITS data set, *Mattiastrum calycinum*, *P. hedgei*, *M. longipes* and *M. corymbiforme* form a strongly supported clade (PP=0.98) with *M. cappadocicum*, *M. cristatum*, *M. lithospermifolium* (Lam.) Brand, *M. laxiflorum*, *M. racemosum*, and *P. ancyritanum* (Figure 2, clade A). However, this clade does not occur in maximum likelihood analysis. *Mattiastrum pulumurensis* is placed as a sister to the *Rindera tetraspis* populations (Figure 2, clade B).

### 3.2. Morphological examinations

According to Mill (1978), the morphological characteristics of the new species indicate that it belongs to the subgenus *Mattiastrum* (now accepted as the genus *Mattiastrum*) of the genus *Paracaryum*. This is because it has flat-winged nutlets, corolla scales that are longer than broad, and a style that extends from the calyx. The closely related species are thus established as *M. racemosum*, *P. hedgei*, *M. incanum*, *M. corymbiforme*, *M. longipes*, *M. aucheri*, *M. calycinum*, *M. ancyritanum*, and *M. paphlagonicum*.



**Figure 1.** The Bayesian inference hypothesis based on the combined chloroplast data set (rps16 and trnL genes, trnL-trnF intergenic spacer). Bootstrap branch support values derived from maximum likelihood analysis were added near the posterior probability on the branches.



**Figure 2.** The Bayesian inference hypothesis based on the ITS. Bootstrap branch support values derived from maximum likelihood analysis were added near the posterior probability on the branches.

In addition, the recently described species *P. leventshikii* has similar characters to this hypothetical new species (Yıldırım, 2018). Table shows the unique combination of characters that define each species, by comparing the new species with adjacent species.

### 3.3. Taxonomic treatment

***Mattiastrum pulumurensense*** Doğru-Koca, Paksoy, M. Gökmen & G. Yılmaz, *sp. nov.* (Figures 3–5).

**Type:** Türkiye. Tunceli, Pülümür, Saltaş location of Şampaşakaraderbent village, 1850–1900 m, 16 vi 2022, M. Gökmen 462 (holo. HUB!).

**Paratype:** Tunceli, Pülümür, Karagöz (Gürük) village, 2000–2100 m, 21 v 2017, Paksoy 2810 (HUB!, ANK!).

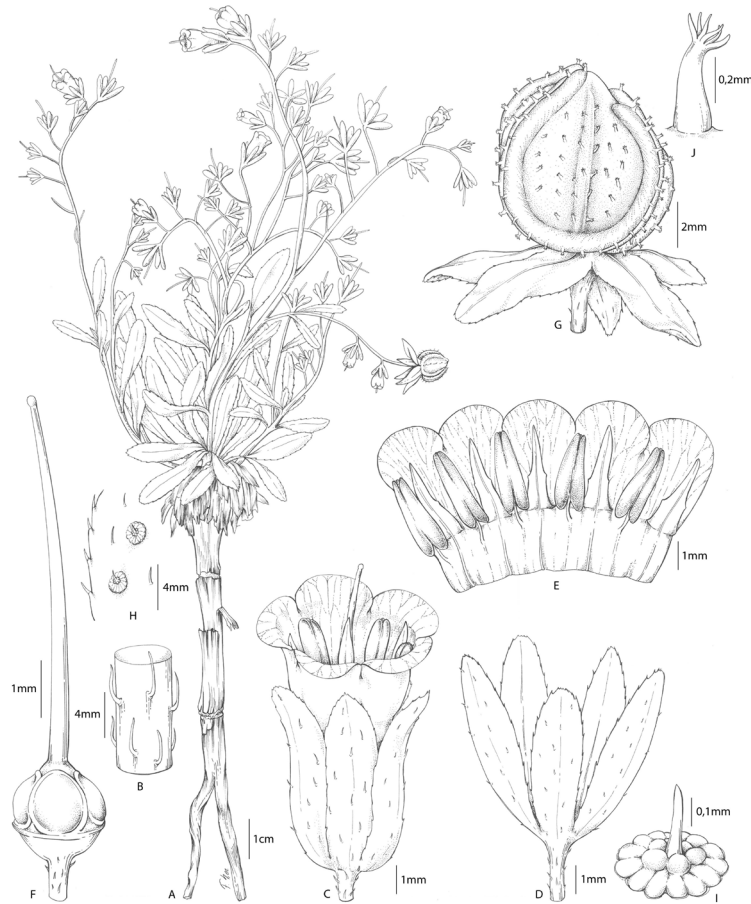
**Diagnosis:** It is generally distinguished from other species (except *M. racemosum* var. *scabridum* (Rech.f.) R.R.Mill) by a sparsely hairy or glabrescent stem. *Mattiastrum pulumurensense* differs from *Paracaryum hedgeri* by its 3–3.5-mm-long and linear lanceolate scales (not 1.5–2 mm and linear oblong), glochidiate nutlet disc (not nonglochidiate); differs from *M. longipes* by its 3–3.5-mm-long and linear lanceolate scales (not 1.2–2 mm, not linear oblong), 2.5–4.5-mm-long anthers (not 1.2–2 mm),

**Table.** Morphological comparison between the new species *Mattiastrum pulumurensense* (emphasized with blue) and *Mattiastrum* species with flat-winged nutlets, scales longer than broad, and styles longer than calyx. The data are based on Mill (1978), Aytaç & Mill (2005), Koca (2009), Yıldırım (2018), and on morphological studies of specimens from the cited herbaria. The red character states indicate diagnostic ones.

	Indumentum	Calyx length (mm)	Corolla length (mm)	Tube and limb rate	Scales (mm)	Appendages	Anthers (mm)	Styles (mm)	Nutlets (mm)
<i>Mattiastrum incanum</i>	Grey villous	4–14	8–16	Tube subequaling or slightly longer than limb	3–5	Conspicuous	1.8–4.5	7–20	5–12 × 5–10
<i>Mattiastrum corymbiforme</i>	Grey villous	5–12	8–16	Tube subequaling or slightly longer than limb	3–5	Conspicuous	2–4	8–17	8–13 × 7–12
<i>Mattiastrum racemosum</i> var. <i>scabridum</i>	Glabrescent	4–10	6–15(–17)	Tube subequaling or ± shorter than limb	1–2.6	Conspicuous	1.8–4	8–20	8–12 × 7–10
<i>Paracaryum hedgeri</i>	Adpressed-hirsute	4.5–6	9–13	Tube ± shorter than limb	1.5–2	-	2–4	10–16	10–12 × 8–11
<i>Mattiastrum pulumurensense</i>	Sparsely adpressed-hirsute to glabrescent	(4–) 7–11	5–16	Tube equaling to or shorter than limb	3–3.5	-	2.5–4.5	10–15	10–11 diam.
<i>Mattiastrum longipes</i>	Long adpressed-hirsute	3.2–6	5–8	Tube ± half of limb	1.2–2	-	1.2–2	5–8	7.5–10 × 7–10
<i>Mattiastrum calycinum</i>	Adpressed-hirsute above, glabrescent below	(6.3–) 7–10	10–13	Tube 2–3 × limb	1.9–3	-	0.7–2.6	11–15	6.5–9.5 (–11) diam.
<i>Paracaryum leventshikii</i>	Antrorsely adpressed subhirsute	3–5	7–9	?	?	?	?	12	7–8 × 7–8
<i>Mattiastrum ancyritanum</i>	Adpressed-strigose above, glabrescent below	(5.5–) 6.5–8 (–9)	6–9	Tube longer than limb	1.2–2.5	-	0.7–2.6	7.8–13	6.5–9.5 (–11) diam.

Table. (Continued.)

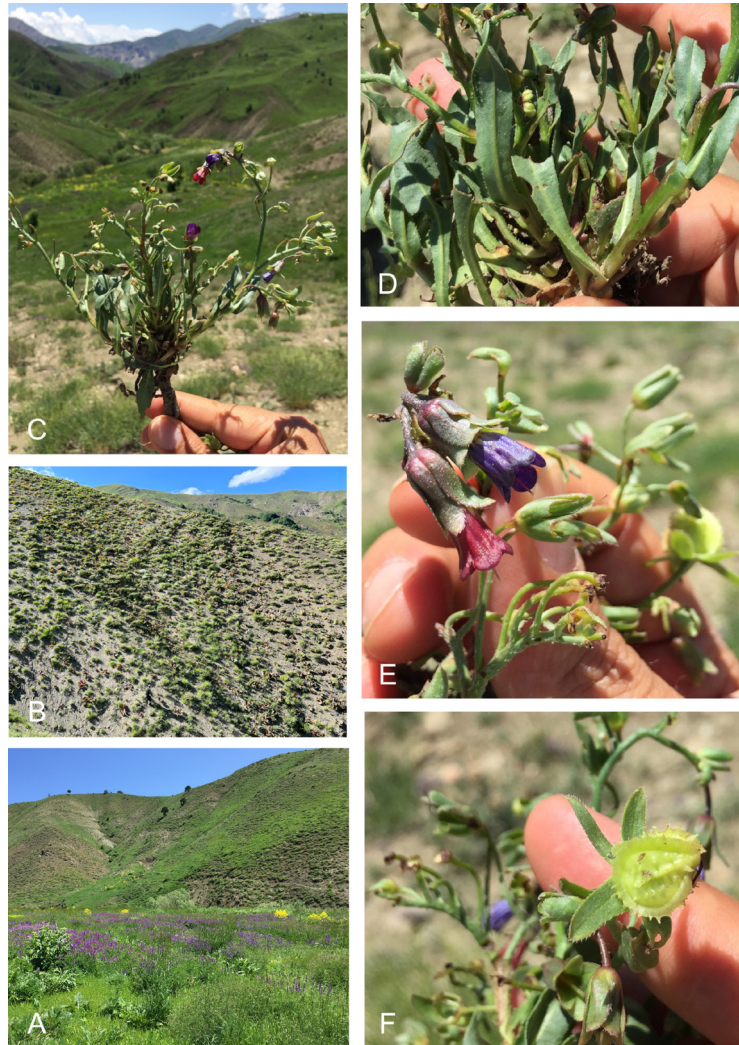
<i>Mattiastrum paphlagicum</i>	Adpressed-strigose above, glabrescent below	4.3–6.7	5.3–6.7	Tube longer than limb	1–1.8	-	0.7–2.6	5.5–7.2	6.5–9.5 (-11) diam.
<i>Mattiastrum aucherii</i>	Grey tomentose	5–8	4–9	Tube longer than limb	1.5–2.1	-	1–1.6	4–8	7–9 diam.



**Figure 3.** Specimen of holotype of *Mattiastrum pulumurense* (Gökmen 462 in HUB). A. Habit, B. Pedicel, C. Flower, D. Calyx, E. Inside of corolla, F. Pistil, G. Nutlet, H. Hairs on leaf lower surface, I. Hair in detail on calyx and leaf. J. Glochid in detail on nutlet.

styles 10–15-mm-long (not 5–8 mm), nutlets 10–11 mm in diameter (not 7.5–10 mm diam.); differs from *M. calycinum* by its corolla tubes equal to or shorter than the limb (not 2–3 × limb), scales 3–3.5-mm-long and linear lanceolate (not 1.9–3 mm and linear oblong), anthers 2.5–4.5-mm-long (not 0.7–2.6 mm), nutlets 10–11 mm in diameter (not 6.5–9.5 mm). Also, it is closely related to *M. racemosum* var. *scabridum* but differs in having scales 3–3.5-mm-long (not 1–2.6 mm) and without scale appendages (not conspicuous appendages).

**Description:** Perennial, pleicorm. Stem tufted, erect or suberect, 10–20-cm-long, branched in the upper half, glabrous at the base, sparsely adpressed-hirsute to glabrescent at the upper part. Basal leaves numerous, gradually tapering into basal, oblong-ob lanceolate or linear-oblong, rarely obovate, 10–50 × 3–10 mm, glabrous above, sparsely adpressed strigose below; cauline leaves sessile, oblong-ob lanceolate or linear-oblong, 5–20 × 1–4 mm, glabrescent above, sparsely adpressed strigose below.



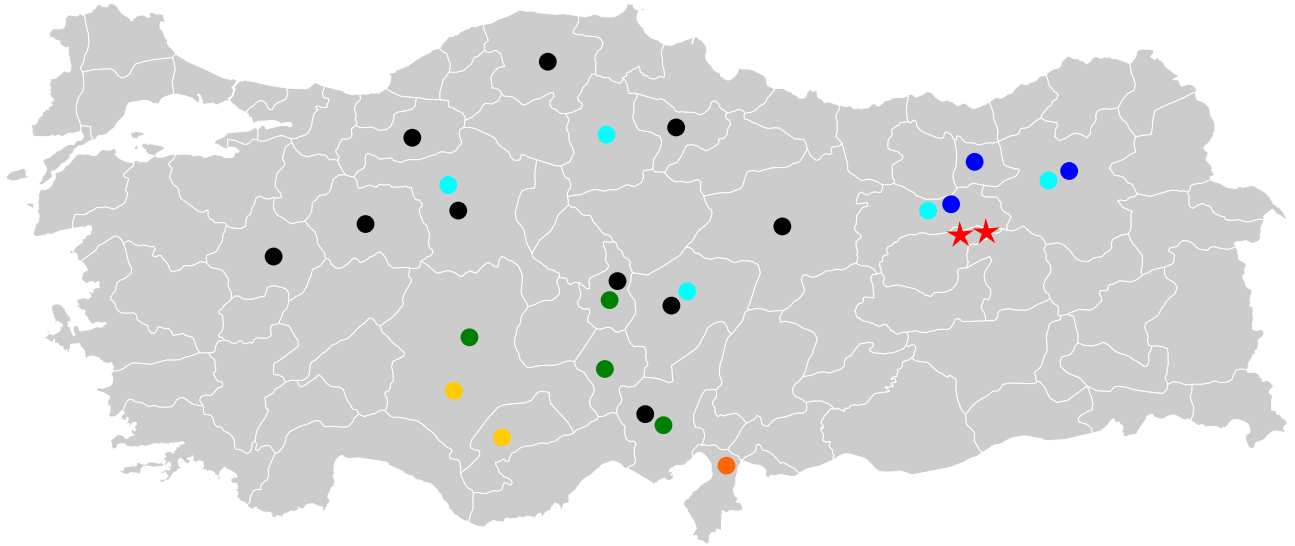
**Figure 4.** Fresh individual and habitat of *Mattiastrum pulumurense* (Gökmen 462 in HUB). A-B. Habitat. C. Habit. D. Basal stem and leaves. E. Campanulate flowers. F. Nutlet.

Inflorescence corymbose-paniculate, up to 20-flowered; pedicel 2–12-mm-long at anthesis, up to 20 mm at fruiting, adpressed-hirsute. Calyx divided nearly to the base, sepals oblong lanceolate or oblong, 7–11 × 1–3 mm at anthesis, longer at fruiting, glabrescent to glabrous outside, hirsute at margin, glabrous inside. Corolla longer than calyx, campanulate, 5–16-mm-long, tube and limb equal or tube shorter than limb, tube 2–8-mm-long, limb 3–8-mm-long, lobes 1–2 × 1.5–4 mm, rounded at apex. Scales linear, gradually tapering into an erect slightly acute apex, 3–3.5-mm-long; appendage absent. Base of anthers situated above base of scales, anthers 2.5–4.5-mm-long. Style exerted from calyx, 10–15-mm-long, stigma slightly spherical. Nutlets orbicular, 10–11 mm in diameter; disc sparsely glochidiate; wing flat, 1–2-mm-wide, nonglochidiate; margin ± entire or denticulate, glochidiate.

**Phenology:** Anthesis May to June; fruiting season June to July.

**Habitat, altitude, and ecology:** Meadows and erosive slopes. 1850–2100 m. The dominant elements of the vegetation are *Rheum ribes* L., *Salvia candidissima* M.Bieb., *Campanula conferta* A.DC., *C. ptarmicifolia* Lam., *C. involucrata* Aucher ex A.DC., *Astragalus kurdicus* Boiss., *A. aduncus* Willd., *A. ascicalyx* Bunge, *Stachys lavandulifolia* Vahl, *Macrotomia densiflora* (Ledeb. ex Nordm.) J.F.Macbr., *Onosma sericea* Willd., *Linum obtusatum* (Boiss.) Stapf, *Aethionema capitatum* Boiss. & Balansa, *Asperula xylorrhiza* Nábelek, *A. glomerata* (M.Bieb.) Griseb., *Veronica orientalis* Mill., *Polygala pruinosa* Boiss., *Centaurea carduiiformis* DC., *Gundelia vitekii* Armağan, *Silene montbretiana* Boiss., *Muscari*





**Figure 5.** Distribution map of *Mattiastrium pulumurense* (stars) and related taxa (circles) in Türkiye. Red: *M. pulumurense*; Blue: *M. corymbiforme*; Turquoise: *M. incanum*; Orange: *M. racemosum* var. *scabridum*; Green: *M. longipes*; Black: *M. calycinum*.

*erzincanicum* Eker, *Muscari tenuiflorum* Tausch, *Achillea arabica* Kotschy, *Chardinia orientalis* (L.) Kuntze, *Klasea serratuloides* (Fisch. & C.A.Mey. ex DC.) Greuter & Wagenitz, *Euphorbia virgata* Desf., *Bunaea trifida* (Vahl) C.A.Mey., *Verbascum heterodontum* Hub.-Mor.

**Distribution and conservation:** The microendemic species *Mattiastrium pulumurense* occurs in Tunceli Province in Eastern Türkiye (Figure 5). It was collected from two adjacent localities in the district of Pülümür. It is an element of the Irano-Turanian phytogeographic region. The distribution localities are subject to overgrazing. No other threats have been observed in the area. Detailed numbers of individuals and populations are not available. “Data deficient (DD)” is proposed here due to inadequate information to assess the threat category or conservation status.

**Etymology:** The specific epithet is dedicated to Pülümür District of Tunceli Province, where the new species was collected.

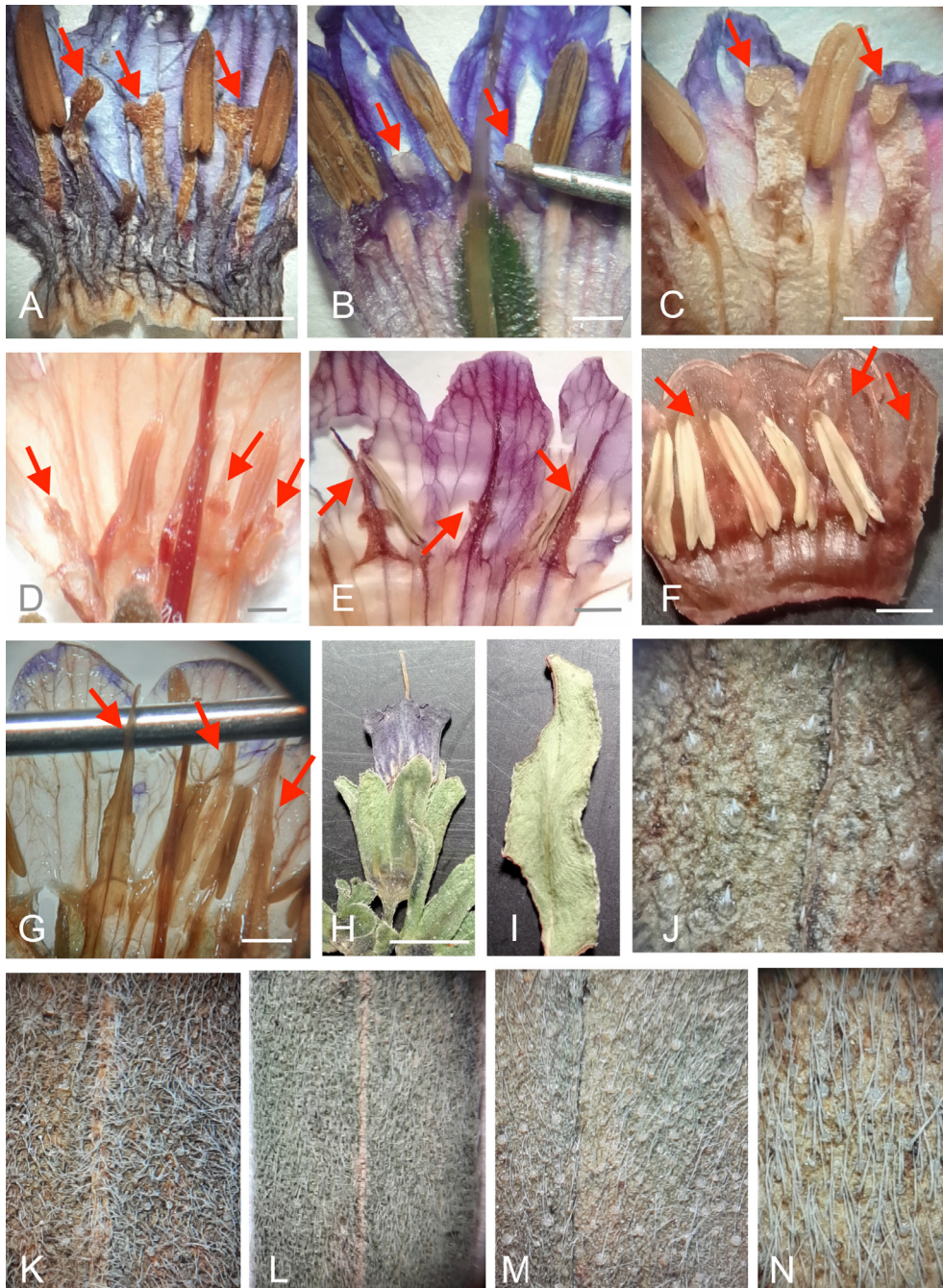
#### 4. Discussion

The new species differs from the other *Mattiastrium* (or *Paracaryum*) species, except *M. racemosum* var. *scabridum*, in the type and density of the indumentum (Figures 4 and 6). Both populations are glabrous on the basal stem, sparsely addressed strigose on the basal leaves, and sparsely addressed-hirsute to glabrescent on the upper stem, cauline leaves, and inflorescence. However, the hairs with or without tuberculate bases are  $\pm$  dense for almost the entire aerial part, especially on the upper stem in the

genus. Some species have a villose indumentum (i.g. *M. corymbiforme*, *M. incanum* etc.), others are tomentose (e.g., *M. aucheri*), and more commonly, species exhibit dense hirsute or strigose hairs (e.g., *M. racemosum* and *M. calycinum*). *M. racemosum* var. *scabridum*, still known only from the type locality, is  $\pm$  glabrescent like the new species. Although the density of the indumentum initially suggested that it was var. *scabridum*, the distinct differences in the appendages and the length of the scales indicate that it is a new species (Figures 6D–6G).

The presence of lateral appendages on the scales is diagnostic in the genus *Mattiastrium*. Some species have conspicuous appendages such as *M. racemosum*, *M. incanum*, and *M. corymbiforme* (Figures 6D–6E). Some lack lateral appendages, such as *M. longipes*, *M. aucheri*, *M. calycinum*, *M. ancyritanum*, *M. paphlagonicum*, and *P. hedgei* (Mill, 1978) (Figures 6A–6C). The new species also lacks lateral appendages (Figures 6F–6G). Regarding the length of the scale, the new species is very similar to *P. incanum*-*M. corymbiforme*, and *M. racemosum* var. *scabridum* (Figures 6D–6G). However, it differs from them in the absence of scale appendages. Actually, *P. hedgei* has no appendage, but its smaller calyx, corolla, scales, and anthers are different from *M. pulumurense* (Figure 6B).

Another important characteristic is the ratio of corolla tube to limb. In fact, the tube being longer than the limb is a common character state in *Mattiastrium*. However, in some flowers, the tube may be equal to the limb, as in the new species. In this character, it is closely related to *M. incanum*, *M. corymbiforme*, *M. racemosum*. Additionally, in some flowers, the tube may be shorter than the limb, as in *M. longipes* and *P. hedgei* (Figures 6A and 6F). This is an



**Figure 6.** Compared morphological characteristics of *Mattiastrum pulumurense* and closely related species. A-G. Inside of flowers. A. *M. longipes*, scales sometimes bilobed (ADK 3153). B. *Paracaryum hedgei*, linear oblong scales without appendage (ADK 3149). C. *M. calycinum*, linear oblong scales incurving at apex (ADK 3157). D. *M. racemosum* var. *scabridum*, scales with subterminal appendages (Haradjian 566). E. *M. corymbiforme*, scales with median appendages (ADK 3286). F. *M. pulumurense*, linear lanceolate scales shorter than tube (Gökmen 462). G. *M. pulumurense*, linear lanceolate scales without appendage (Paksoy 2810). H. Flower of *M. pulumurense* (Gökmen 462). I-N Basal leaf indumentum. I. *M. pulumurense*, glabrous upper surface of basal leaves (Gökmen 462). J. *M. pulumurense* sparsely adpressed-hirsute lower surface of basal leaves (Paksoy 2810). K. *M. longipes*, long adpressed hirsute hairs (ADK 3153). L. *P. hedgei* adpressed strigose hairs (ADK 3149). M. *M. corymbiforme*, grey-villose hairs (ADK 3286). N. *M. calycinum* long adpressed strigose hairs (ADK 3157). The scales are 5 mm in H and 1 mm in the rest.

unusual character state and is also found in some flowers of *M. pulumurens*.

The recently described species *Paracaryum leventshikii* (Yıldırım, 2018) seems to be closely related to *M. pulumurens* (Table). However, the protologue lacks some information on scales, appendages, and the proportion of tube to limbs. This species differed from *P. ancyritanum*, *P. calycinum*, and *P. paphlagonicum* mainly by its smaller flowers, including sepals, corolla, and style. From this, it could be deduced that *P. leventshikii* has tubes longer than the limbs. Thus, it is differentiated from *M. pulumurens* not only in the size of the nutlet but also in the ratio of tube to limb. In addition, its calyx is given as 3–5-mm-long in the protologue. *M. pulumurens* usually has a very long calyx (7–11 mm), but rarely smaller flowers could be found, especially towards the end of the inflorescence.

In conclusion, *Mattiastrum pulumurens* is a unique species based on the combination of the character states that have sparsely hairy or glabrescent aerial parts; flat-winged nutlets 10–11 mm in diameter; the styles extended from the calyx; without appendages, 3–3.5-mm-long, longer than broad scales; 2.5–4.5-mm-long anthers, and thus easily distinguished from the other *Mattiastrum* species. Thus, the number of *Paracaryum* and *Mattiastrum* species in Türkiye increases to 32. The phylogenetic relationships of the new species were revealed, and the distribution map and detailed morphological knowledge were provided.

#### Identification key to the species of the genus *Mattiastrum* with scales longer than broad and styles longer than calyx (based on Mill, 1978):

1. Scales without lateral appendages
2. Corolla tube equal to or shorter than limb
3. Sparsely hairy or glabrescent, scales 3–3.5-mm-long, anthers 2.5–4.5-mm-long, ..... *M. pulumurens*
3. Densely hairy, scales 1.5–2-mm-long, anthers 1.2–2.5 (–4)-mm-long
4. Corolla 9–13-mm-long, style 10–16 mm, nutlet 10–12-mm-long ..... *P. hedgei*
4. Corolla 5–7 (–8)-mm-long, style 4–8 mm, nutlet 7.5–10-mm-long ..... *M. longipes*
2. Corolla tube longer than limb ..... *M. calycinum*, *M. ancyritanum*, *M. paphlagonicum*, *M. aucheri*, *P. leventshikii*
1. Scales with lateral appendages ..... *M. incanum*, *M. corymbiforme*, *M. racemosum*

*Rindera tetraspis*, the type species of the genus, has more or less dense lanates (grey lanate or white lanate) outside the calyx, corolla with minute scales or no scales, approximately 15 mm diameter nutlets (Rinder, 1953), so it can be easily

distinguished from the genus *Mattiastrum*. However, in the phylogenetic analysis here, *M. pulumurens* and *R. tetraspis* are distant relatives according to the chloroplast data set, but close relatives according to the ITS data set. The remaining *Rindera* species generate a monophyletic clade, which is closely related to *Mattiastrum* and some species of *Paracaryum* (Figure 2, clade A). This topology is consistent with Pourghorban et al. (2020). This is related to the fact that the two organelles have different evolutionary histories. According to analyses based on the ITS data set, *M. pulumurens* and *R. tetraspis* had a common ancestor at some point in their evolutionary processes and were most likely fertilized together. Based on this, it is understood that ITS data alone cannot solve the systematic problems in Cynoglossineae, in agreement with Pourghorban et al. (2020). However, as the *M. pulumurens* species later specialized in Tunceli, at least according to current data, it is closely related to the genus *Mattiastrum*, both in terms of morphological characters and chloroplast data (Figure 1, clade A). According to the chloroplast tree, two populations (type and paratypa) of *M. pulumurens* generate a monophyletic clade with very strong posterior probability and medium bootstrap support values (PP = 0.99, BS = 87). Although it is not clear which is closer, the new species is closely related to *M. longipes*, *P. hedgei*, and *M. calycinum* (moderate PP = 0.61 but strong BS = 83). The species in this clade share flat-winged nutlets, long styles without trapeziform scales, and long corolla and calyx. However, the new species is distinguished from *M. longipes*, *P. hedgei*, and *M. calycinum* by numerous morphological characters discussed above.

#### Additional specimens examined

All the specimens identified as *Mattiastrum* or *Paracaryum* kept in cited herbaria in Materials and Methods were examined. The species below were used for additional DNA sequence to reveal the evolutionary relationships of *Mattiastrum pulumurens*. *Mattiastrum calycinum* Kayseri: Talas, Alidağ, transmitter road, south slopes, steppe, 1680–1700 m, 29 v 2007, ADK 3157 (HUB, Herb. Yıldırım). *Mattiastrum corymbiforme* Gümüşhane: Gümüşhane to Şiran, before 5 km, Sarıca and Bolluk villages junction, steppe, 1290–1300 m, 17 vi 2007, ADK 3286 (HUB, Herb. Yıldırım). *Mattiastrum incanum* Ankara: Beytepe campus, around dining hall, steppe, yemekhane çevresi, bozkır, approximately 1000 m, 09 vi 2006, ADK 2896 (HUB, Herb. Yıldırım). *Mattiastrum longipes* Kayseri: Talas, Alidağ, around Akçakaya village, roadsides, 1524 m, rocky, 29 v 2007, ADK 3153 (HUB, Herb. Yıldırım). *Paracaryum hedgei* Konya: Ereğli, around İvriz Dam, cultivated *Pinus nigra* and *Cedrus libani* mixed forest openings, 1100–1200 m, 25 v 2007, ADK 3149, (HUB, Herb. Yıldırım).

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**Authors’ contributions**

GY, MG, and MYP conducted the excursions. ADK designed the investigation, collected morphological and phylogenetic data. All the authors collaborated on the revision of the final version of the manuscript.

**References**

- Aytaç Z, Mill RR (2005). Two new species of Boraginaceae (Tribe Cynoglosseae) from Turkey. *Edinburgh Journal of Botany* (61): 109-118. <https://doi.org/10.1017/S0960428605000284>
- Behçet L, İlçim A (2015). *Paracaryum bingoelianum* (Boraginaceae), a new species from Turkey. *Turkish Journal of Botany* 39 (2): 334-340. <https://doi.org/10.3906/bot-1309-58>
- Boissier E (1849). *Paracaryum*. *Diagnoses Plantarum Orientalium Novarum* 1 (11):128.
- Brand A (1915). XIX. Neue *Borraginaceen*-Studien. *Feddes Rep.* 14: 149-156.
- Chacón J, Luebert F, Hilger HH, Ovchinnikova S, Selvi F et al. (2016). The borage family (Boraginaceae s.str.): a revised infrafamilial classification based on new phylogenetic evidence, with emphasis on the placement of some enigmatic genera. *Taxon* 65 (3): 523-546. <https://doi.org/10.12705/653.6>
- Cohen J (2014). A phylogenetic analysis of morphological and molecular characters of Boraginaceae: evolutionary relationships, taxonomy, and patterns of character evolution. *Cladistics* 30: 139–169. <https://doi.org/10.1111/cla.12036>
- Darriba D, Taboada GL, Doallo R, Posada D (2012). jModelTest 2: More models, new heuristics and parallel computing. *Nature Methods* 9: 772. <https://doi.org/10.1038/nmeth.2109>
- Doğru-Koca A (2012). *Paracaryum*. In: Güner A, Aslan S, Ekim T, Vural M, Babaç MT (editors). *Türkiye Bitkileri Listesi (Damarlı Bitkiler)*. İstanbul, Türkiye: Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmaları Derneği Yayını, pp. 240-242 (in Turkish).
- De Candolle AP (1846). Sectio II. *Paracaryum* Alph. DC. *Prodromus Systematis Naturalis Regni Vegetabilis* 10:158-162.
- Greuter W. (1981). *Med-Checklist Notulae*, 3. *Willdenowia* 11(1): 23-43.
- Guindon S, Gascuel O (2003). A simple, fast and accurate method to estimate large phylogenies by maximum-likelihood. *Systematic Biology* 52: 696-704. <https://doi.org/10.1080/10635150390235520>
- Hamzaoğlu E, Özbek F (2022). A new species of *Mattiastrum* (Boraginaceae) from Turkey. *Phytotaxa* 568: 231. <https://doi.org/10.11646/phytotaxa.568.2.8>
- Katoh K, Rozewicki J, Yamada KD (2019). MAFFT online service: Multiple sequence alignment, interactive sequence choice and visualization. *Briefings Bioinform* 20: 1160-1166. <https://doi.org/10.1093/bib/bbx108>
- Koca A (2009). *Türkiye’deki Paracaryum* (DC.) Boiss. (Boraginaceae) Cinsinin Revizyonu. PhD, Hacettepe University, Ankara, Türkiye, pp. 312 (in Turkish).
- Mill RR (1977). *Paracaryum*, in *Materials for Flora of Turkey XXXIV*. Notes R.B.G. Edinburgh 35: 303-308.
- Mill RR (1978). *Paracaryum* (DC.) Boiss. In: Davis PH (Ed.). *Flora of Turkey and the East Aegean Islands*, vol. 6. Edinburgh, UK: Edinburgh University Press, pp. 282-300.
- Mouterde PSJ (1966). *Paracaryum* (DC.) Boiss. *Nouvelle Flore du Liban et de la Syrie*, Tome III, Texte. Beyrouth-Liban, Lebanon: Dar El-Machreq Éditeurs, pp. 58 (in French).
- Pourghorban Z, Salmaki Y, Weigend M (2020). Phylogenetic relationships within the subtribe Cynoglossinae (Cynoglossoideae: Boraginaceae): new insights from nuclear and plastid DNA sequence data. *Plant Systematics and Evolution* 306:45. <https://doi.org/10.1007/s00606-020-01671-x>
- Rambaut A, Drummond AJ, Xie D, Baele G, Suchard MA (2018). Posterior summarisation in Bayesian phylogenetics using Tracer 1.7. *Systematic Biology* 67: 901–904. <https://doi.org/10.1093/sysbio/syy032>
- Rechinger KH (1967). *Boraginaceae*. *Flora Iranica*, 48/15.4, Verlagsanstalt Graz, Austria: Akademische Druck. Pp. 281.
- Rinder A (1953). *Rindera* Pall. In: Shishkin BK (editor). *Flora of USSR* 19: 419-434. Jerusalem: Israel Program for Scientific Translations. Pp. 419-435. [Translated from Komarov, V.I. (ed.), 1950. *Flora SSSR. Izdatel'stvo Akademii Nauk SSSR, Moscow-Leningrad*, in Russian].
- Ronquist F, Teslenko M, Van der Mark P, Ayres DL, Darling A et al. (2012). MrBayes 3.2: Efficient Bayesian phylogenetic inference and model choice across a large model space. *Systematic Biology* 61: 539-542. <https://doi.org/10.1093/sysbio/sys029>
- Silvestro M (2012). raxmlGUI: A graphical front-end for RAxML. *Organisms Diversity Evolution* 12: 335-337. <https://doi.org/10.1007/s13127-011-0056-0>

- Shishkin BK (Ed.). (1953). *Paracaryum* Boiss.. Flora of USSR 19: 419-434. Jerusalem: Israel Program for Scientific Translations. Pp. 435-448. [Translated from Komarov, V.I. (ed.), 1950. Flora SSSR. *Izdatel'stvo Akademii Nauk SSSR, Moscow-Leningrad, in Russian*].
- Stamatakis A (2014). RAxML version 8: A tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics* 30: 1312-1313. <https://doi.org/10.1093/bioinformatics/btu033>
- Weigend M, Luebert F, Selvi F, Brokamp G, Hilger HH (2013). Multiple origins for Hound's tongues (*Cynoglossum* L.) and Navel seeds (*Omphalodes* Mill.). The phylogeny of the borage family (Boraginaceae s.str.). *Molecular Phylogenetics and Evolution* 68: 604-618. <https://doi.org/10.1016/j.ympev.2013.04.009>
- Yıldırım Ş (2018). Five new species, a new subspecies and a new combination and status from gypsaceum areas of Ankara province, Turkey. *Ot Sistematiği Botanik Dergisi* 25 (2):1-22.