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Research article

Tragopogon davutii-turanii: a new species of *Tragopogon* from Anatolia

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A new salsify species, *Tragopogon davutii-turanii*, is described from Anatolia based on micro-/macro-morphological and molecular evidence. The new species is morphologically similar to *T. vvedenskyi* and *T. abbreviatus*, but differs from *T. vvedenskyi* mainly in ligule colour and from *T. abbreviatus* by achene characters and number of phyllaries. In contrast to morphological similarities, based on the phylogenetic tree obtained from nrDNA ITS sequences *T. davutii-turanii* is closely related to *T. stenophyllus* and *T. coelesyriacus*. Diagnostic characters, description, and conservation status of the new species, as well as micro- and macro-morphological features of its achenes and pollen grains, are provided.

Keywords: Anatolia, Cichorieae, nrDNA ITS, *Tragopogon abbreviatus*, *Tragopogon coelesyriacus*

Introduction

Tragopogon is a member of the tribe Cichorieae Lam. & DC. (Bremer 1994, Soltis et al. 2004, Mavrodiev et al. 2008, Suárez-Santiago et al. 2011). The genus with about 150 species is one of the largest genera of the subtribe Scorzonerinae Dumort. (Mavrodiev et al. 2005). Most members of the genus are distributed in Eurasia, with east Europe and West Asia being the main diversity centres (Mavrodiev et al. 2005, Bell et al. 2012).

Hybridization, commonly followed by polyploidization, between closely related species, blurs the taxonomic relationships within *Tragopogon* and makes species delimitation challenging (Ownbey 1950, Krahulec et al. 2005, Mavrodiev et al. 2005, 2007, Suárez-Santiago et al. 2011). Morphological variation within members of *Tragopogon* has led to different interpretations and misidentifications, and adequate plant material including leaves, flowers, and mature fruits is necessary for accurate identification (Matthews 1975, Coşkunçelebi et al. 2020, Gültepe et al. 2021).

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The first list of Turkish *Tragopogon* was prepared by Matthews (1975) without any sub-generic classification in The flora of Turkey and East Aegean Islands. Later, this list was updated but without making any taxonomic re-evaluation by Coşkunçelebi and Gültepe (2012) in the checklist of vascular Turkish plants. According to this checklist, 22 taxa and three doubtful species have been recorded from Turkey. During the last decade, several new species, records, and combinations of *Tragopogon* from Anatolia have been published, highlighting the remarkable levels of diversity and endemism (26 taxa; 13 endemics) of this genus in the country (Gültepe et al. 2016, Coşkunçelebi et al. 2017, 2020).

Tragopogon longirostris Bisch. ex Sch. Bip. comprised two varieties (*T. longirostris* var. *longirostris*, *T. longirostris* var. *abbreviatus* Boiss.) in the Flora of Turkey (Matthews 1975). *Tragopogon longirostris* var. *abbreviatus* was subsequently elevated to species rank (*T. abbreviatus* (Boiss.) Coşkunç. & M.Gultepe) based on morphological and molecular evidence (Coşkunçelebi et al. 2020). Furthermore, contrary to Greuter (2003), Coşkunçelebi et al. (2020) stated that *T. longirostris* var. *longirostris* is not a member of the *T. porrifolius* complex. In the same paper, they adopted the name *T. coelesyriacus* Boiss. instead of *T. longirostris* var. *longirostris* as Feinbrun-Dothan (1978) and Dimopoulos et al. (2016) did in the Flora Palestina and the Flora of Greece, respectively.

During revisional studies of *Tragopogon* in Turkey, the present authors collected lots of specimens identified at first glance as *T. abbreviatus*. Further examination of these specimens revealed that some of them are different in achene and leaf characters. These plants are described here as a new species, compared with all possibly related species (*T. abbreviatus*, *T. coelesyriacus*, *T. angustissimus* S.A.Nikitin (syn. *T. vvedenskyi* M.Popov ex Pavlov) and *T. stenophyllus* Jord.).

Material and methods

Morphological characters were noted from the authors' own specimens stored at KTUB. Ligule colour and habitat properties were also compiled from the authors' field notes. At least 15 measurements for each character were scored to describe the new species. All specimens stored at KTUB have been checked according to the relevant literature (Borisova 1964, Matthews 1975, Richardson 1976, Rechinger 1977, Davis et al. 1988, Sída and Tan 2000, Özhatay and Kültür 2006, Özhatay et al. 1999, 2009, 2011) and compared with samples kept in national (ANK, ISTE, ISTF, ISTO, GAZI, HUB, KATO, RUB) and international herbaria (E, K, P, G). Detailed locality information of additionally examined specimens is given in the Supporting information. Additional material required for micro-/macro- morphological, molecular, and palynological studies were obtained from the collections stored at KTUB; however, diagnostic features of *T. coelesyriacus*, *T. abbreviatus*, *T. vvedenskyi* and *T. stenophyllus* were compiled from the literature (Jordan 1849, Borisova 1964, Matthews 1975, Coşkunçelebi et al. 2020).

At least three mature achenes for each species including *Tragopogon davutii-turanii* (Coşkunçelebi & M. Gültepe 225), *T. abbreviatus* (Coşkunçelebi & M. Gültepe 188), and *T. coelesyriacus* (Coşkunçelebi & M. Gültepe 166) were prepared according to Coşkunçelebi et al. (2000), observed, and photographed at different magnifications under the scanning electron microscopic (SEM) in order to explore variation in achene micromorphology. Achene material of *T. stenophyllus* and *T. vvedenskyi* were not available, and these species were excluded from the micromorphological studies. Achene micrographs were generated by using JSM- 6510LV scanning electron microscope after coating with gold at Recep Tayyip Erdogan University. For the descriptive terminology of achenes, Barthlott (1981), Blanca and Díaz de la Guardia (1997) and Sukhorukov and Nilova (2015) were followed.

Pollen grains of *T. davutii-turanii* taken from the herbarium specimen Coşkunçelebi & M. Gültepe 225 were used for both light microscope (LM) and SEM studies. For LM observations, pollen grains were prepared according to the methods of Erdtman (1952), and measurements were taken with an Olympus BX-51 LM. The dimensions of pollen were determined based on approximately 30 pollen grains. Equatorial and polar views of acetolysed pollen grains were observed and photographed at different magnifications under SEM. The descriptive terminology of pollen grains follows Blackmore (1982) and Punt et al. (2007). Features of the pollen grains of *T. abbreviatus* (*T. porrifolius* subsp. *abbreviatus*) and *T. coelesyriacus* (*T. porrifolius* subsp. *longirostris*) are given according to Gültepe et al. (2018). However, pollen material of *T. stenophyllus* and *T. vvedenskyi* were not included in this study because they were not available.

Genomic DNA was extracted from herbarium materials following the modified extraction procedure of Doyle and Doyle (1987). Amplification and sequencing of nrDNA ITS regions were carried out according to Gültepe et al. (2010). Phylogenetic analyses were performed on an ITS dataset consisting of 115 accessions, four of which were newly generated sequences (individuals belonging to the new species), and a sequence belonging to *T. vvedenskyi* obtained from GenBank (KF050362); 110 sequences, thirteen of which were used as outgroups, were obtained from Gültepe et al. (2021).

The 115 sequences were aligned with Muscle ver. 3.8.31 (Edgar 2004) and edited in PhyDE ver. 0.9971 (Müller et al. 2010). Indels were coded as binary characters according to the simple indel coding (SIC) method (Simmons and Ochoterena 2000) implemented in the program SeqState ver. 1.40 (Müller 2005a) and added as informative characters at the end of the sequence data set before the analysis.

Phylogenetic relationships were reconstructed using maximum parsimony (MP), maximum likelihood (ML) and Bayesian inference (BI) analyses. MP analyses were carried out using the parsimony ratchet (Nixon 1999) with PRAP (Müller 2004). The generated command files contain standard ratchet settings (200 ratchet iterations with 25% of the positions randomly up-weighted (weight = 2) during each replicate and 10 random addition cycles). The analysis was run in PAUP* ver. 4.0b10 (Swofford 2003) using a heuristic search with the following parameters: all characters having equal weight, gaps being treated as 'missing', a simple

addition of sequences, TBR branching swapping, maxtrees setting to 100 and auto-increased by 100, one non-binary starting tree arbitrarily dichotomized before branch swapping, only one tree saved. A majority-rule consensus tree was calculated from the most parsimonious trees. Jackknife (JK) support values for the nodes found in the MP analysis were calculated in PAUP* applying the optimal jackknife parameters according to Farris et al. (1996) and Müller (2005b) with the following parameters: 10 000 jackknife replicates using the TBR branch swapping algorithm with 36.788% of characters deleted and one tree held during each replicate.

Prior to ML and BI analyses, the nucleotide substitution models that best fit the datasets were determined for the ITS regions with MrModeltest ver. 2.3 (Nylander 2004) following the Akaike information criterion (AIC). The ML analyses were performed by RAxML-HPC2 (Stamatakis 2006) on the Cipres gateway (Miller et al. 2010). Rapid bootstrapping (with the maximum set of 1000 replicates) integrated with a thorough ML search for the optimal tree was carried out using the resource-efficient CAT approximation (Stamatakis 2006) of the general time-reversible (GTR) model of nucleotide substitution with the gamma model of rate heterogeneity as the predefined substitution model in RAxML for all DNA partitions and BINCAT for the binary partitions.

The BI analyses in MrBayes ver. 3.2 (Ronquist et al. 2012) were performed with four simultaneous runs of Metropolis-coupled Markov chain Monte Carlo (MCMCMC), each with four parallel Markov chains. Each chain was run for 20 million generations and, starting with a random tree, one tree was saved every 1000th generation. To ensure convergence of the run, a conservative burn-in of 0.2 (i.e. discarding the first 20% of the trees) was applied, during which the average standard deviation of the split frequencies between the runs dropped below 0.01 and after which the effective sampling size (ESS) for all parameters was well above 200 in each run. The post-burn-in trees were used to generate a maximum clade credibility tree of which the nodes with less than 0.5 posterior probability supports were collapsed. TreeGraph ver. 2 (Stöver and Müller 2010) was used to assess the tree topologies and to visualize the trees.

Results

Taxonomy

Tragopogon davutii-turanii **Coskunç. & M.Gultepe sp. nov. (Fig. 1–2)**

Type: Turkey, A8 Bayburt: Kop Mountain pass., around the cemetery, 2417 m a.s.l., 23 July 2011, Coşkunçelebi & M. Gültepe 285 (holotype: KTUB; isotypes: GAZI, RUB).

Diagnosis

A species that differs from *T. abbreviatus* by having an achene beak shorter than the achene body (versus equal to or longer than achene body), achene beak 6–11 mm long (versus 9–19 mm), and only 5–6 phyllaries (versus 8); it differs from *T. coelesyriacus* by a having short and straight beak (versus long and curved), from *T. vvedenskyi* by having purple flowers (versus yellow), and from *T. stenophyllus* by the number of phyllaries (5–6 versus 8–12) and a beak shorter than the achene body (versus longer than achene body).

Description

Annual or biennial, floccose or glabrous, 13–64 cm tall; stems branched; root collar sometimes with remnants of previous year's leaves. Cauline leaves 2.00–16.00 × 0.20–0.42 cm, linear; basal leaves 7.0–25.0 × 0.2–0.5 cm, linear to narrowly

Figure 1. *Tragopogon davutii-turanii* sp. nov. (a) Holotype (Coşkunçelebi & M. Gültepe 285), (b) habitat (Coşkunçelebi & M. Gültepe 240).

Figure 2. *Tragopogon davutii-turanii* sp. nov. (Coşkunçelebi & M. Gültepe 240). (a) Fruiting capitulum, (b) flowering capitulum, (c) phyllaries, (d) achene.

linear. Peduncles slightly thickened below the capitula; involucre floccose or not at base. Phyllaries 5.0(–6.0), 17.0–29.0 × 2.0–3.5 mm in flower and 30.0–56.0 × 2.7–5.5 mm in fruit, lanceolate, acute, longer than flowers. Ligules purple, 9–15 mm long. Achenes (including beak) 19–25 mm long, gradually narrowed into a beak, sulcate with five longitudinal rows of separate scales and five rows of shorter scales in between; beak 6–11 mm long, without scales, shorter than achene body, clavate at apex. Pappus 19–27 mm long, dark brown; annulus sparsely hairy.

Phenology

Flowering in May–July, fruiting in June–August.

Habitat

1600–2500 m a.s.l., cultivated areas, slopes and meadows.

Distribution

Endemic to the northeast Anatolia (Fig. 3).

Paratypes: Turkey, A7 Giresun: between Eğribel Pass and Şebinkarahisar, hilly meadows, 1760 m, 17 July 2012, Coşkunçelebi & M. Gültepe 411 (KTUB), N40 25- E038 22; between Eğribel Pass and Şebinkarahisar, hilly meadows, 1805 m, 17 July 2012, Coşkunçelebi & M. Gültepe 413 (KTUB), N40 25-E038 22; A7 Gümüşhane: Köse, Köse Mountain, 2035 m, 27 July 2011, Coşkunçelebi & M. Gültepe 225 (KTUB), N40 17-E039 34.49; between Alucra and Şiran, entrance of Hacıhasan Village, 1661 m, 27 June 2011, Coşkunçelebi & M. Gültepe 228 (KTUB), N40 08-E038 53; after from Pirahmet, 1909 m, 4 July 2011, Coşkunçelebi & M. Gültepe 230 (KTUB), N40 15-E039 29; Şiran, Kırıntı, Village to Kırıntı Plateau, 1866 m, 6 July 2011, Coşkunçelebi & M. Gültepe 240 (KTUB), N40 17-E039 00; Köse, above Köse Damp, 1702 m, 30 July 2012, Coşkunçelebi & M. Gültepe 429 (KTUB), N40 15-E039 37; between Gümüşhane and Yağmurdere, Kostandağı Pass, 2214 m, 30 July 2012, Coşkunçelebi & M. Gültepe 430 (KTUB), N40 31-E039 46; B7 Erzincan: between Kemah

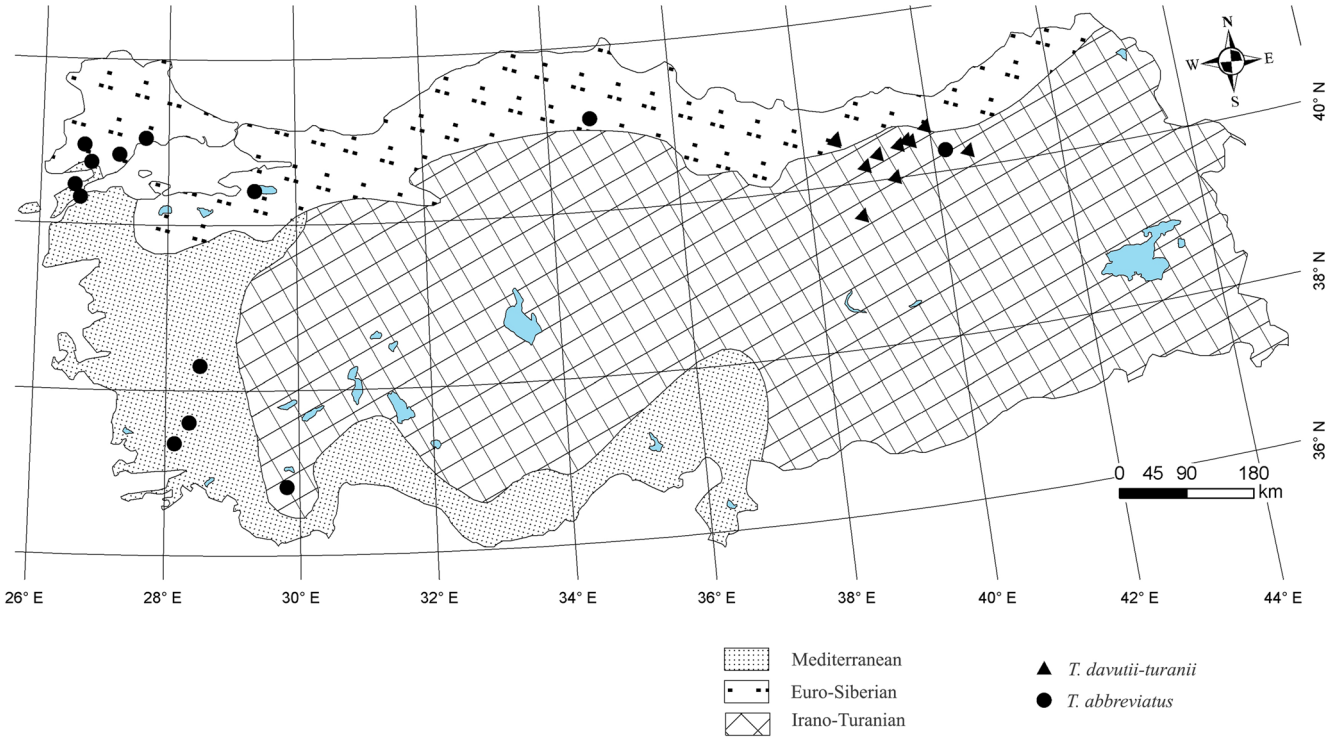

Figure 3. Distribution map of *Tragopogon davutii-turanii* and *T. abbreviatus* in the floristic regions of Turkey.

and İliç, Savaş Gediği, 1674 m, 4 July 2011, Coşkunçelebi & M. Gültepe 233 (KTUB), N39 36-E038 39; between Kelkit and Erzincan, Ahmediye, roadsides, 2102 m, 30 July 2012, Coşkunçelebi & M. Gültepe 18 (KTUB), N39 53-E039 21; between Kelkit and Erzincan, Ahmediye, roadsides, 2102 m, 30 July 2012, Coşkunçelebi & M. Gültepe 427 (KTUB), N39 53-E039 21.

Key to *Tragopogon davutii-turanii* and closely related taxa in Turkey

In the Flora of Turkey and the East Aegean Islands, representatives of *Tragopogon* are first grouped according to ligule colour (Matthews 1975). The purple-coloured species are further divided into two groups: those having achene wings with scales fused into longitudinal rows and those that do not. *Tragopogon davutii-turanii* with purple ligules and achenes without wings can be inserted into the diagnostic key of the Matthews (1975) with some modifications as follows:

1. Capitula 3–5 cm long; pappus purplish..... *T. coloratus*
– Capitula (5–) 6–11 cm long; pappus greyish brown 2
2. Plant perennial, less than 12 cm tall..... *T. subacaulis*
– Plant annual or biennial, more than 12 cm tall..... 3
3. Achene beak not clavate at apex..... *T. porrifolius*
– Achene beak clavate at apex..... 4
4. Beak shorter than achene body, basal leaves linear to narrowly linear ..... ***T. davutii-turanii***
– Beak equal/longer than achene body, basal leaves linear... 5
5. Phyllaries 8; achene with five longitudinal rows of separate scales and five rows of shorter scales in between; achene beak slightly curved..... *T. abbreviatus*
– Phyllaries 5–8; achene with 10 longitudinal rows of short separate scales; achene beak curved ..... *T. coelesyriacus*

Eponymy

This new species is named in honour of Dr Davut Turan who is an eminent fish taxonomist at Recep Tayyip Erdogan University, Turkey.

Micro-morphological features of achenes and pollen grains

Pollen grains of *T. davutii-turanii* are tricolporate with echinate perforate ornamentation. The length of the polar and equatorial axes is 36.51 and 39.96 µm, respectively. The pollen shape is oblate-spheroidal (P/E; 0.91) (Fig. 4).

Lower parts of the achenes of *T. davutii-turanii* are often marked by tiny papillae. The outer epidermal cells vary in shape and especially in the rib area, forming stout multilayered conglomerations (tongue-shaped) (Fig. 5g–h). The epidermal cells of the multi-layered conglomerations on the lower part of achene are elliptical–circular in shape, the periclinal walls are striate with convex/concave curvature, and the anticlinal walls are indistinct. The achene beak of *T. davutii-turanii* lacks tongue-shaped ornamentations (Fig. 5e–f). The epidermal cells of the achene beak of *T. davutii-turanii* are elliptical–tetragonal in shape with micro-projections towards apex, the anticlinal walls are indistinct, the periclinal walls are generally striate, and curvatures are concave (Fig. 5e). As seen

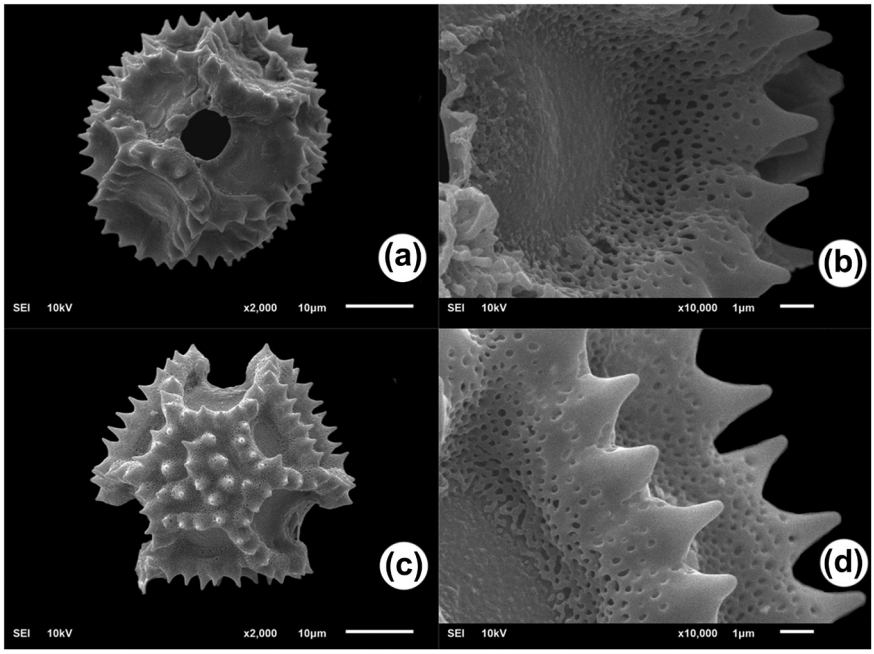

Figure 4. SEM micrographs of pollen grains of *Tragopogon davutii-turanii* (Coşkunçelebi & M. Gültepe 225). (a) Equatorial view, (b) ornamentation of spine bases in equatorial view, (c) polar view, (d) ornamentation of spine bases in polar view.

in Fig. 5a–d, i–l, *T. coelesyriacus* and *T. abbreviatus* have stout multi-layered conglomerations both on the lower parts of the achene and the achene beak. Except for multi-layered conglomerations on the achene beak surface, the achene micromorphological features of *T. coelesyriacus* and *T. abbreviatus* are very similar to those of *T. davutii-turanii*. The epidermal cells of the multi-layered conglomerations in the lower part of the achene are elliptical–circular in shape, the periclinal walls are striate with convex/concave curvature, and the anticlinal walls are indistinct on both related species. The epidermal cells of the achene beak of the related species are elliptical–tetragonal in shape with micro-projections towards the apex, the anticlinal walls are indistinct, the periclinal walls are generally striate, and curvatures are concave. Furthermore, the width of achenes of *T. coelesyriacus* is smaller than those of the other two examined species (Fig. 5).

Molecular phylogeny

The MJ cladogram (majority rule consensus tree from ML analysis) based on ITS sequences (Fig. 6) shows that all *Tragopogon* species are separated from outgroup taxa and form a monophyletic group with strong support (ML = 100, JK = 100 and PP = 1.0). The examined *Tragopogon* taxa are resolved in five distinct clades (Fig. 6). Clade I consists of species with thickened peduncles below the capitula, but some of these species have yellow flowers and some have purple flowers. *Tragopogon davutii-turanii* belongs to Clade I and is resolved as a distinct species sister to *T. stenophyllus* which has purple flowers. However, *T. coelesyriacus* is externally related to *T. davutii-turanii* and *T. stenophyllus* (Fig. 6). Although *T. abbreviatus* and *T. vvedenskyi* are morphologically similar to *T. davutii-turanii,* they are placed in other subclades within the same clade. (Fig. 6- Clade I).

Discussion

Tragopogon davutii-turanii has a substantial number of populations throughout northeast Anatolia (Fig. 3) and has probably been overlooked among the samples of *T. abbreviatus* which is common in Turkey and which can be confused with *T. davutii-turanii* at first glance. After the taxonomic reassessment of *T. abbreviatus* by Coşkunçelebi et al. (2020), some individuals were separated in the phylogenetic tree, and upon closer inspection, these individuals were found to have shorter achene beaks and narrowly linear leaves. These specimens in gross morphology are very similar to *T. vvedenskyi*, especially with respect to leaf shape and achene features (Table 1). However, they have purple flowers while *T. vvedenskyi* is characterized by yellow flowers (Table 1).

Since *Tragopogon* is a relatively new genus with high species diversity and diversification rates, analyses based on molecular markers, including nuclear and plastid DNA, show poor resolution (Bell et al. 2012, Mavrodiev et al. 2012, Gültepe et al. 2021). Besides, even if there is no support and most of the taxa collapse after cutting the 50 % threshold resulting in a polytomy, there are distinct clades in the tree (Fig. 6). *Tragopogon davutii-turanii* is resolved with the purple-flowered species in the phylogenetic tree and as closely related to *T. coelesyriacus*; however, it is the sister species of *T. stenophyllus*. The genus has lots of taxonomically unresolved taxa (Mavrodiev et al. 2007) and one of these is *T. stenophyllus*. This species is listed as a synonym of *T. angustifolius* in

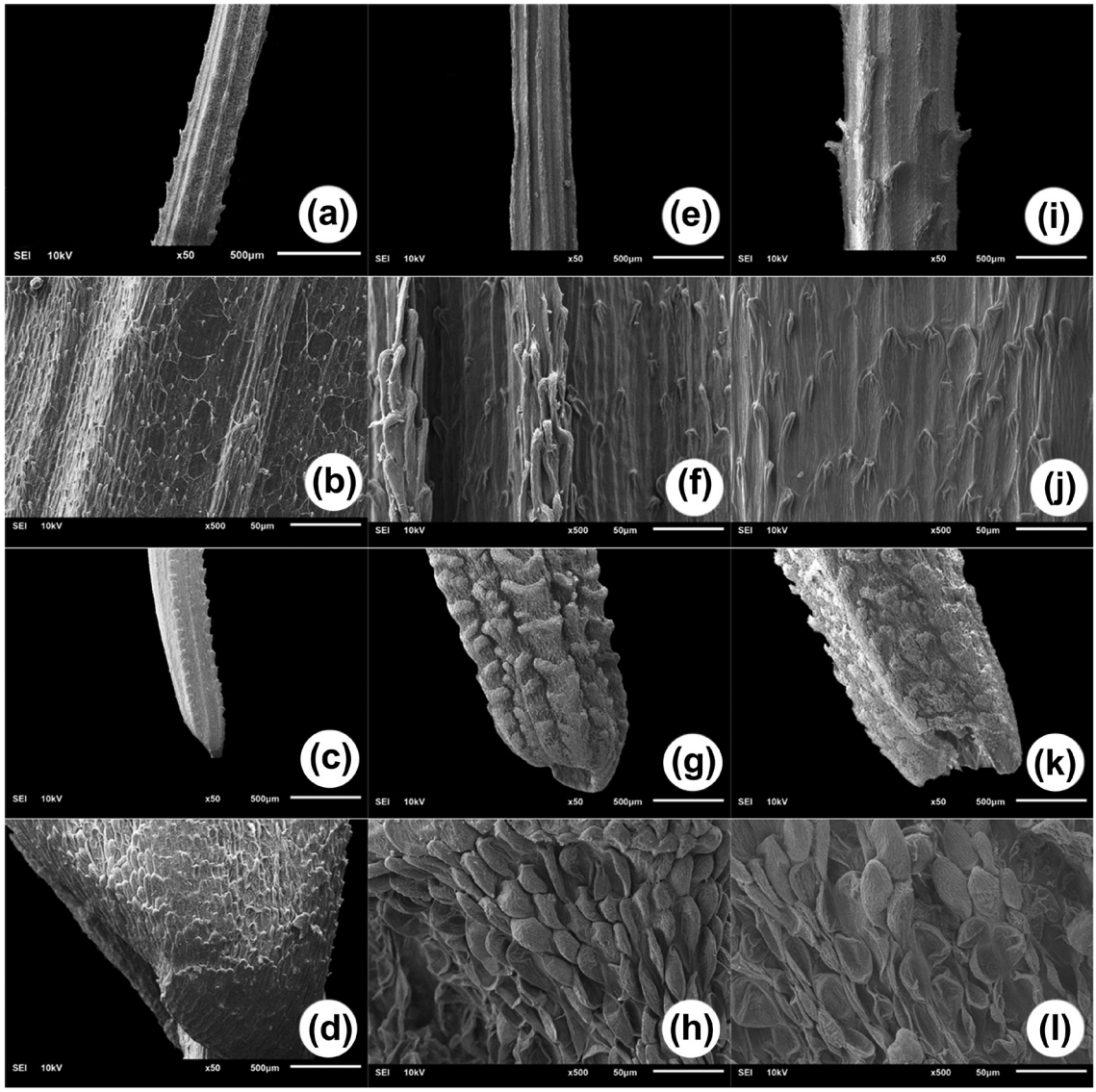

Figure 5. Scanning electron micrographs of achenes. (a–d) *Tragopogon coelesyriacus* (Coşkunçelebi & M. Gültepe 166), (e–h) *Tragopogon davutii-turanii* (Coşkunçelebi & M. Gültepe 225), (i–l) *T. abbreviatus* (Coşkunçelebi & M. Gültepe 188). (a, e, i) Beak, (b, f, j) beak detail, (c, g, k) lower part of the achene, (d, h, l) lower part of the achene detail.

the Cichorieae Systematics Portal (Kilian et al. 2009), while it is accepted as a synonym of *T. crocifolius* subsp. *crocifolius* according to another database (WFO). Moreover, it is also a matter of debate whether the species identity of the sequence data obtained from GenBank is correct. In addition to the above-mentioned problems, low sequence differences were achieved from the nuclear marker used in the study, so it also resulted in poor resolution in the genus as stated in the literature (Mavrodiev et al. 2005, 2007, 2012).

Despite all these reservations, the available morphological and molecular data adequately support specific rank for the northeast Anatolian plants. *Tragopogon davutii-turanii* differs from *T. coelesyriacus* by having narrowly linear leaves, which is a notable difference between these two species. Furthermore, *T. davutii-turanii* has shorter achenes and achene beaks, and these features are different from those of *T. coelesyriacus* (Table 1). Within Clade I, *T. davutii-turanii* is closer to *T. stenophyllus* than to *T. coelesyriacus* (Fig. 6). Although *T. stenophyllus* has purple flowers, similar to those of *T. davutii-turanii*, the two species differ in phyllary number (8–12 and 5 (–6), respectively). Additionally, *T. davutii-turanii* also differs from *T. abbreviatus* and from the yellow-flowered *T. vvedenskyi* by the length of the achene beak and leaf width (Table 1).

Tragopogon was not divided into sections by Matthews (1975) in the Flora of Turkey. However, Gültepe et al. (2016) adopted and suggested eight sections for Turkish *Tragopogon* species following Borisova (1964). All species of Clade I have achenes with a long beak and long peduncles, which are ± thickened below the flowering capitula. *Tragopogon davutii-turanii* should be included in *Tragopogon* sect.

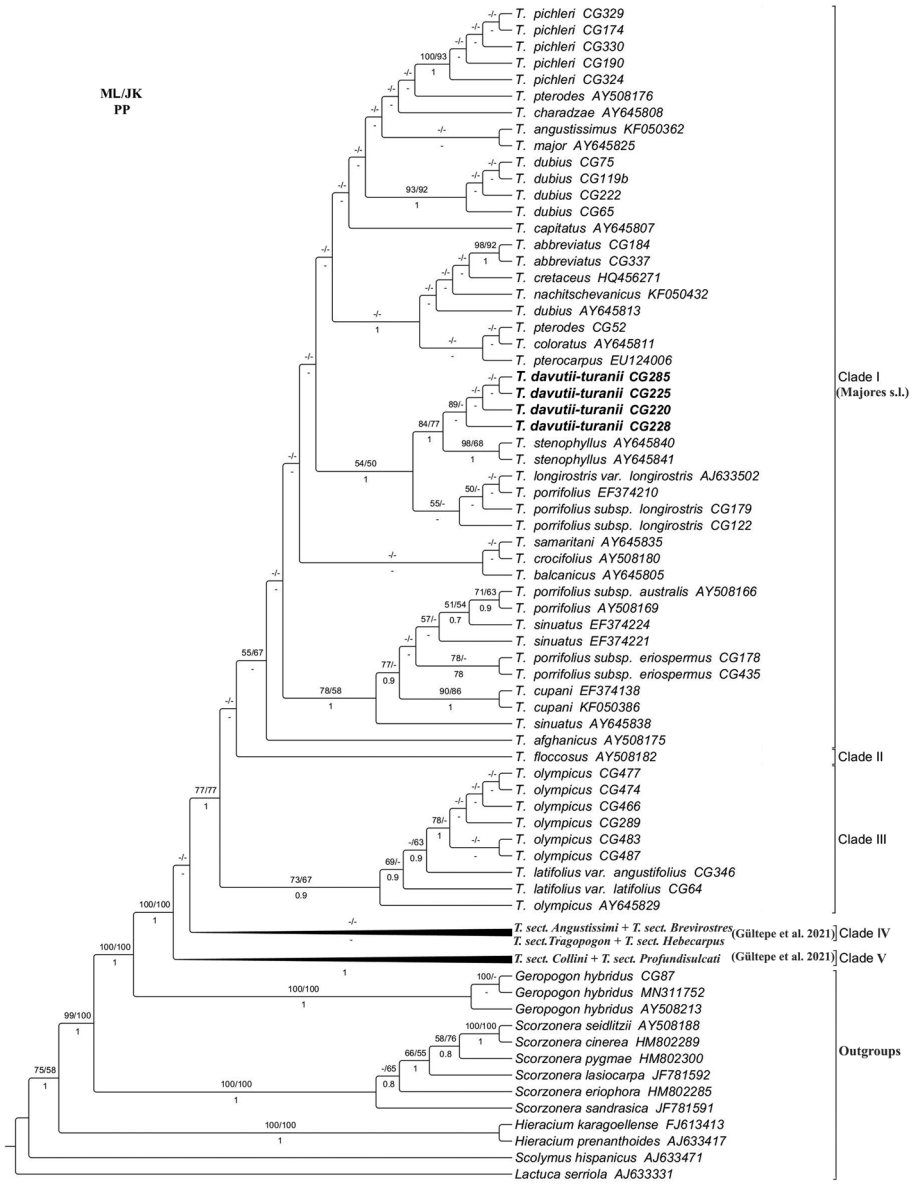

Figure 6. Majority-rule consensus cladogram of *Tragopogon* from ML analysis based on a nrDNA ITS dataset (support values: first-line ML bootstrap and JK jackknife, second-line pp posterior probability). Clade names are in accordance with those of Gültepe et al. (2021), and Clades IV and V are indicated by a thick black bar.

Majores (Artemcz.) Kuthath. because it has a slightly thickened peduncle below medium-sized capitulum, and phyllaries longer than ligules. On the other hand, the subclades representing different sections (e.g. *Chromopappus* Boriss., *Hebecarpus* Boriss., *Majores* s.str.) within the Clade I (Fig. 6) have received low support, and the relationships among them are not resolved. Therefore, our results are consistent with the broad circumscription of section *Majores* by Mavrodiev et al. (2005), and *T. davutii-turanii* should be included in the *Tragopogon* sect. *Majores* s.l.

The chromosome number 2n = 12 has been reported for *T. abbreviatus* (Gültepe et al. 2015) based on specimens (Coşkunçelebi & M. Gültepe 230, Coşkunçelebi and Vladimirov 06-47, Coşkunçelebi & M. Gültepe 391) from Turkey. However, the plant specimens collected from Gümüşhane (Coşkunçelebi & M. Gültepe 230) were instead identified as *T. davutii-turanii* in the present study. Thus, the chromosome number of the new species is 2n = 12 according to Gültepe et al. (2015). Pollen grains of *T. abbreviatus* and *T. coelesyriacus* were reported as oblate-spheroidal in shape and tricolporate with echinate perforate ornamentation by Gültepe et al. (2018). Pollen grains of the new species are also oblate-spheroidal and tricolporate with echinate perforate ornamentation (Fig. 4a–d). Additionally, the length of the polar axes of the pollen grain is 30.51 µm for *T. coelesyriacus* and 30.11 µm for *T. abbreviatus*, the length of the equatorial axes is 33.32 µm for *T. coelesyriacus* and 35.79 µm for *T. abbreviatus* in the same study (Gültepe et al. 2018). However,

Table 1. Morphological comparison of *Tragopogon davutii-turanii* and related species.

Characters	*Tragopogon davutii-turanii*	*Tragopogon abbreviates* (Coşkunçelebi et al. 2020)	*Tragopogon coelesyriacus* (under *T. longirostris*; Matthews 1975, Gültepe 2014)	*Tragopogon angustissimus* (Borisova 1964)	*Tragopogon stenophyllus* (Jordan 1849)
Habit	annual or biennial	biennial	biennial	biennial	annual or biennial
Stem	13–64 cm long, branched	24–92 cm long, branched	12–120 cm long, branched	30–60 cm long, strongly branched	branched or unbranched
Peduncle	slightly thickened below capitulum, involucre floccose or glabrous at base	thickened below capitulum, involucre sparsely floccose or glabrous at base	thickened below capitulum, involucre sparsely floccose or glabrous at base	slightly thickened below capitulum, glabrous	slightly thickened below capitulum, glabrous
Leaves	cauline leaves 2.0–16.0 × 0.2–0.42 cm, linear with flat margin; basal leaves 7.0–25.0 × 0.2–0.5 cm, linear to narrowly linear with flat margin.	cauline leaves 3.5–33.0 × 0.25–1.00 cm, linear or linear to lanceolate with flat margin; basal leaves 3.5–35.0 × 0.20–0.50 cm, linear with flat margin	cauline leaves 5–26 × 0.24–1.20 cm, linear or linear- lanceolate with flat margin; basal leaves 11–25 × 0.27–0.90 cm, linear with flat margin	cauline leaves reduced; basal leaves numerous, very thin, narrowly linear, sometimes filiform, 0.2-0.5 cm-wide,	basal leaves linear, acuminate, dilated at base, tomentose or glabrous at base
Phyllaries	5.0(–6.0), 17.0–29.0 × 2.0–3.5 mm in flower and 30.0–56.0 × 2.7–5.5 mm in fruit, lanceolate, acute, longer than flowers	8, 20–35 × 1.8–4.0 mm in flower and 38–60 × 3.0–8.0 mm in fruit lanceolate, acute, longer than flowers	5–8, 22–37 × 2.5–6.0 mm in flower and 42–95 × 4.5–15.0 mm in fruit lanceolate, acute, longer than flowers	5, 40–50 mm long, narrowly lanceolate; two times as long as flowers	8–12, lanceolate, acuminate, longer than flowers.
Flowers	purple, 9–15 mm long, shorter than phyllaries	purple, 19–24 mm long, shorter than phyllaries	purple, 8–16 mm long, shorter than phyllaries	yellow, 20–25 mm long, shorter than phyllaries	purple, shorter than phyllaries
Achene	19–25 mm long, with five longitudinal rows of separate scales and five rows of shorter scales between	19–35 mm long, with five longitudinal rows of separate scales and five rows of shorter scales between	29–54 mm long, with ten longitudinal rows of short separate scales	18–21 (24) mm long, five-angled, finely sulcate, finely squamose along ribs	scaly, tuberculate
Beak	straight, sulcate and 6–11 mm long, shorter than achene body, clavate at apex	slightly curved, sulcate and 9–19 mm long, equal to or longer than achene body, clavate at apex	beak curved, 17–34 mm long, sulcate, longer than achene body and clavate at apex	beak straight, 4–7(9) mm long, shorter than achene body, inflated at apex	beak longer than achene body
Annulus	sparsely hairy	hairy	hairy	glabrous	hairy
Pappus	19–27 mm long, brown or cream coloured	20–30 mm long, pale greyish-brown or straw coloured	23–35 mm long, pale greyish-brown or straw coloured	20 mm long, brownish-white, sometimes reddish,	shorter than beak and achene body, reddish-white

the length of the polar and equatorial axes of the pollen grain of *T. davutii-turanii* is 38.41 and 42.63 µm, respectively (Fig. 4). Although the pollen types of the three species are similar, the polar and equatorial axes of the pollen grain are larger in *T. davutii-turanii*.

There have been a limited number of surveys on the fruit-coat micromorphology of the genus *Tragopogon* (Blanca and Díaz de la Guardia 1997, Sukhorukov and Nilova 2015). Sukhorukov and Nilova (2015) showed that the body of the achenes is often marked by tiny papillae or mamillae, outer epidermal cells vary in shape, forming stout multi-layered conglomerations named tongue-shaped ornamentation, especially in the rib area. The general achene characteristics of the new and related species are consistent with the view of Sukhorukov and Nilova (2015). However, *T. davutii-turanii* differs from *T. abbreviatus* and *T. coelesyriacus* by not having tongue-shaped ornamentation at the achene beak (Fig. 4e–f).

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Author contributions

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Data availability statement

There are no additional data for this paper.

Supporting information

The Supporting information associated with this article is available with the online version.

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