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A TAXONOMIC REVISION OF TANACETUM POLYCEPHALUM (ASTERACEAE, ANTHEMIDEAE) SPECIES COMPLEX FROM IRAN

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Tanacetum polycephalum is one of the most problematic species of *T.* sect. *Xanthoglossa*. In this study, forty-three quantitative and qualitative morphological characters were measured for thirty-four different populations of *T. polycephalum* and four populations of its allies, e. g. *T. canescens*, *T. tabrisianum*, and *T. elbursense*. The data matrix was analyzed by cluster and principal co-ordinate analysis using the PAST software. The results indicated that the *T. polycephalum* complex contains three distinct groups, which could be recognized as segregated taxa. Herein, *T. azerbaidjanicum* comb. & stat. nov. and *T. argyrophyllum* are known as separate species. A diagnostic identification key and notes about habitats, phytogeography, chromosome data, and distributions are presented.

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بازنگری تاکسونومیکی کمپلکس گونه‌ای *Tanacetum polycephalum* (Asteraceae, Anthemideae) از ایران

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گونه Tanacetum polycephalum یکی از پیچیده‌ترین گونه‌های بخش Xanthoglossa می‌باشد. در این مطالعه، ۴۳ صفت ریخت‌شناسی کمی و کیفی برای ۳۴ جمعیت مختلف از گونه T. polycephalum و ۴ جمعیت از گونه‌های نزدیک به آن مانند T. canescens، T. tabrisianum و T. elbursense مورد بررسی قرار گرفت. تجزیه و تحلیل داده‌ها بوسیله نرم‌افزار PAST با روش خوشه‌ای و تجزیه به مختصات اصلی (PCoA) انجام شد. نتایج نشان داد کمپلکس T. polycephalum شامل سه گروه مختلف می‌باشد که هر کدام از آنها را می‌توان به عنوان یک آرایه مجزا در نظر گرفت. در اینجا گونه T. azerbaidjanicum comb. & stat. nov به عنوان یک ترکیب جدید و گونه T. argyrophyllum به عنوان یک گونه مجزا و مستقل از T. polycephalum شناخته می‌شود، همچنین کلید صفات تشخیصی و مطالبی درباره زیستگاه، پراکندگی جغرافیایی، اطلاعات کروموزومی و پراکنش گونه‌ها ارائه شده است.

INTRODUCTION

Tanacetum L., with 160 species, is the third-largest genus of the tribe Anthemideae of Asteraceae, following *Artemisia* L. and *Anthemis* L. (Oberprieler &

al. 2006). The genus includes perennial herbs and subshrubs distributed in the circum-Mediterranean region; central, southwestern, and eastern Asia; and some parts of North America (Oberprieler & al. 2009). Since the monograph of Bremer & Humphries (1993) on Anthemideae, no comprehensive taxonomic revision or updated species conspectus of the genus has been made available. Several authors (Mozaffarian 2005; Djavadi 2008; Sonboli & al. 2010a, 2010b, 2011b; Kazemi & al. 2014a, 2014b; Korkmaz & al. 2015) introduced new species and combinations in *Tanacetum* s. l. occurring in Iran and adjacent areas. Few phylogenetically deviating species from *Tanacetum* have, in turn, been excluded and transferred to other related genera (e. g. Sonboli & al. 2011a; Sonboli & Oberprieler 2012).

Considering a high-level morphological polymorphism, circumscription and infraspecific taxonomy of some polymorphic taxa are problematic and remain controversial. *Tanacetum polycephalum* Sch. Bip. is one of the complex species from *T.* sect. *Xanthoglossa* (DC.) Sch. Bip. and shows a close affinity to *T. elbursense* Mozaff., *T. tabrisianum* (Boiss.) Sosn. & Takht. and *T. canescens* DC. (Podlech 1986; Mozaffarian 2005). The species is an Irano-Turanian element, Armeno-Iranian province, and Atropatanian subprovince (Takhtajan 1986). It is distributed mainly in Iran, Turkey, Iraq, the Caucasus, and adjacent areas (Grierson 1975; Podlech 1986; Tzvelev 1995; Mozaffarian 2005). Podlech (1986) in his treatment for 'Flora Iranica' reported seven subspecies, namely *T. polycephalum* subsp. *polycephalum*, *T. polycephalum* subsp. *argyrophyllum* (K.Koch) Podlech, *T. polycephalum* subsp. *azerbaidjanicum* Podlech, *T. polycephalum* subsp. *duderanum* (Boiss.) Podlech, *T. polycephalum* subsp. *farsicum* Podlech, *T. polycephalum* subsp. *heterophyllum* (Boiss.) Podlech and *T. polycephalum* subsp. *junesarense* (Bornm.) Podlech. Mozaffarian (2005, 2008), mainly based on morphological and geographical evidence, treated *T. polycephalum* subsp. *azerbaidjanicum* as a synonym of *T. canescens.* The author subdivided *T. polycephalum* into three subspecies, i.e. *T. polycephalum* subsp. *polycephalum*, *T. polycephalum* subsp. *argyrophyllum*, and *T. polycephalum* subsp. *duderanum* (Mozaffarian 2005).

In the Flora of Turkey, *T. argyrophyllum* (K.Koch) Tzvelev has been considered an accepted species with three varieties, one of which is *T. argyrophyllum* var. *polycephalum* (Schultz Bip.) Grierson (Grierson 1975). Tzvelev (1995) in the Flora of USSR introduced *T. duderanum* (Boiss.) Tzvelev and *T. heterophyllum* Boiss. as distinct and separate species.

For the *T. polycephalum* species complex, different ploidy levels ranging from diploid (2*n*=18), tetraploid (2*n*=4*x*=36), hexaploid (2*n*=6*x*=54), octaploid (2*n*=8*x*=72) to decaploid (2*n*=10*x*=90) have been reported (Chehregani & Mehanfar 2008; Chehregani & Hajisadeghian 2009; Chehreghani & al. 2011; Inceer & al. 2012; Olanj & al. 2013, 2015; Ghasemkhani & al. 2013; Javadi 2017; Kurşat 2020). The great morphological and cytogenetic variations point out the infraspecific polymorphism within the species as well the necessity of related taxonomic investigations. The objectives of the present study are: (1) to provide a comprehensive morphological survey using clustering methods on the *T. polycephalum* complex and related taxa, and (2) to shed light on the infraspecific taxonomy as well to present a detailed taxonomic classification.

MATERIAL AND METHODS

This study is based on herbarium specimens and fresh material. Thirty-eight populations belonging to seven subspecies of *Tanacetum polycephalum* (34 populations) and its allies, e.g. *T. canescens* (two populations), *T. tabrisianum* (one population), and *T. elbursense* (one population) were studied, in analyses of morphological characters, the first three letters of the species or subspecies are considered as code (Table 1). Several sheets of herbarium specimens have been examined for each taxon deposited at the Herbarium of Medicinal Plants and Drugs Research Institute (MPH) of Shahid Beheshti University. Type images of each taxon were obtained from Herbaria of Royal Botanic Garden Kew (K), Conservatory and Botanical Garden Geneva (G), Natural History Museum of Wien (W), Missouri Botanic Garden (MO), Berlin Botanical Garden and Botanical Museum (B). Identification of the species was done using 'Flora Iranica' (Podlech 1986), 'Flora of Iran' (Mozaffarian 2008), and other floras of adjacent areas (Grierson 1975; Tzvelev 1995). Distribution maps for each taxon were provided using the computer program DMAP version 7.2 (Morton 1993-2007).

Morphological characters were selected from species descriptions in the relevant references (Podlech 1986; Mozaffarian 2008) and from personal observations of materials. A total of 43 morphological characters (Table 2) were measured, of which 30 were quantitative and 13 qualitative (binary). Different subsets of the characters were used depending on the type of analysis and the group being considered. For multivariate statistical analyses, quantitative data were standardized (mean = 0, variance = 1) and used to determine Euclidean and Gower distances for clustering. Different distance measures were used to check the consistency of clustering results. The unweighted pair group method with arithmetic mean

(UPGMA) was used for grouping the accessions (Podani 2000). For ordination, Principal Co-ordinate Analysis (PCoA) method was applied for standardized data (Podani 2000). In order to determine the most variable characters among the taxa, factor analysis based on PCA was performed on standardized data. The analyses were carried out using PAST version 2.17c (Hammer & al. 2001).

RESULTS

Multivariate Analyses

The UPGMA dendrogram constructed from Gower's similarity matrix showed three clearly separated groups (Fig. 1). Group I is composed of five subspecies of *T. polycephalum*, e.g. *T. polycephalum* subsp. *polycephalum*, *T. polycephalum* subsp. *heterophyllum*, *T. polycephalum* subsp. *farsicum*, *T. polycephalum* subsp. *duderanum*, and *T. polycephalum* subsp. *junesarense*. Group II includes *T. polycephalum* subsp. *argyrophyllum*. Group III comprises *T. polycephalum* subsp. *azerbaidjanicum*, *T. canescens*, *T. tabrisianum* and *T. elbursense*. The cophenetic correlation obtained was high (r = 0.96), indicating a good fit between values from the cluster analysis and those of the dissimilarity matrix.

Group I is composed of the majority of the infraspecific taxa of *T. polycephalum* and formed a cluster that includes five subspecies. It consists of two subclusters. The first includes *T. polycephalum* subsp. *polycephalum* and *T. polycephalum* subsp. *heterophyllum*. They show close morphological similarities with each other and could be found in the same habitats. The second subcluster includes *T. polycephalum* subsp. *farsicum*, *T. polycephalum* subsp. *duderanum* and *T. polycephalum* subsp. *junesarense*. The first two subspecies have a close affinity but are distinct geographically. Group II includes *T. polycephalum* subsp. *argyrophyllum*, which is phenetically separated from the subspecies of Group I. Group III is divided into two subclusters; *Tanacetum polycephalum* subsp. *azerbaijanicum* along with *T. canescens*, and *T. tabrisianum* with *T. elbursense* are located in the subclusters (Fig. 1).

The results of the principal co-ordinate analysis (PCoA) of morphological characters are similar to those of the cluster analysis (Fig. 2). Based on it, three main groups are determined (Fig. 2). The analyses of morphological data based on UPGMA and PCoA methods revealed that *T. polycephalum* subsp. *argyrophyllum* and *T. polycephalum* subsp. *azerbaidjanicum* could be separated from *T. polycephalum* and considered a separate species. Thus, the former *T. polycephalum* could be divided into three distinct species, e.g. *T. polycephalum*, *T. argyrophyllum*, and *T. azerbaidjanicum*, the latter of which is raised to a specific rank here (Fig. 1. &.2). The diagnostic characters for each species are given in Table 3.

DISCUSSION

Tanacetum polycephalum is a widespread species distributed in mountainous habitats. The preferential altitudinal range of *T. polycephalum* throughout its distributional range in the Zagros and Alborz Mountain ranges is between 1600 to 3900 m. *Tanacetum polycephalum* subsp. *polycephalum*, *T. polycephalum* subsp. *heterophyllum*, and *T. polycephalum* subsp. *farsicum* occurs in Zagros (W and SW Iran, NW Iraq, and SW Turkey). The two former subspecies are seen mainly at altitudes below 2400m, while the latter one is found above these elevations. *Tanacetum polycephalum* subsp. *duderanum* and *T. polycephalum* subsp. *junesarense* occur in Alborz (N of Iran). *Tanacetum argyrophyllum* and *T. azerbaidjanicum* are present in Azerbaijan mountain (NW Iran and S Caucasus). Therefore, geography in conjunction with ecology could be attributed as the driving factor for speciation.

The number of the capitulum is a polymorphic character. The results demonstrated that the characters of capitula are of great importance for the delimitation of the studied taxa. The *T. argyrophyllum* and *T. azerbaidjanicum* possess the highest (20-80 (-120) and the lowest (5-8) capitula numbers, respectively. The shape and color of involucral bracts are useful in the delimitation of subspecies of *T. polycephalum*.

Polyploidy is recognized as one of the possible diversification forces in *Tanacetum* (Olanj & al. 2013). Several ploidy levels have already been reported within the *T. polycephalum* group (Chehregani & Mehanfar 2008; Chehregani & Hajisadeghian 2009; Chehregani & al. 2011; Inceer & al. 2012, Olanj & al. 2013, 2015; Kurset 2020). While *T. canescens* is a diploid species, *T. azerbaidjanicum* is tetraploid (Olanj & al. 2013, 2015).

Table 1. Selected specimens and voucher information of *Tanacetum polycephalum* and its allies.

No.	Taxa	Code	Altitude (m)	Selected specimens and vouchers
1	*T. argyrophyllum* (K.Koch) Tezvelv	ARG1	1860	Iran: West Azerbaijan, Sonboli & al. 1214
		ARG2	2100	Iran: West Azerbaijan, Sonboli 1771
		ARG3	1990	Iran: West Azerbaijan, Sonboli 1757
		ARG4	1900	Iran: West Azerbaijan, Mojjarad 1381
		ARG5	2100	Iran: West Azerbaijan, Sonboli 1125
2	*T. azerbaidjanicum* (Podlech) Sonboli & Behju	AZR1	1860	Iran: West Azerbaijan, Sonboli & al. 1212
		AZR2	1700	Iran: West Azerbaijan, Olanj 1864
		AZR3	1660	Iran: West Azerbaijan, Sonboli & al. 1234
		AZR4	1600	Iran: West Azerbaijan, Sonboli & al. 1326
		AZR5	1750	Iran: West Azerbaijan, Mojjarad 1380
3	*T. polycephalum* subsp. *duderanum* (Boiss.) Podlech	DUD1	2100	Iran. Semnan, Sonboli & Gholipour 1283
		DUD2	2650	Iran. Mazandaran, Sonboli & Yousefzadeh 1060
		DUD3	1850	Iran. Qazvin, Sonboli & al. 1490
		DUD4	2200	Iran. Tehran, Sonboli 1297
		DUD5	2000	Iran. Khorassan, Gholipour 1623
		DUD6	2500	Iran. Tehran, Behjou 2205
4	*T. polycephalum* subsp. *farsicum Podlech*	FAR1	3000	Iran. Isfahan, Sonboli & al. 1175
		FAR2	2850	Iran. Yazd, Kanani & Gholipour 1280
		FAR3	3178	Iran. Kohkiluyeh-va-Boyerahmad, Bahadori 1980
		FAR4	2300	Iran. Lorestan, Gholipour 1441
		FAR5	2400	Iran. Hamedan, Behjou 2191
		FAR6	2600	Iran. Kurdistan, Behjou & Ghaderi 2241
5	*T. polycephalum* subsp. *heterophyllum* (Boiss.) Podlech	HET1	2280	Iran. Hamedan, Najafi 1418
		HET2	2420	Iran. Hamedan, Behjou 2194
		HET3	2090	Iran. Hamedan, Behjou 2199
		HET4	1900	Iran. Hamedan, Behjou 2197
6	*T. polycephalum* subsp. *junesarense* (Bornm.) Podlech	JUN1	2450	Iran. Tehran, Sonboli & al. 1095
		JUN2	2200	Iran. Tehran, Sonboli & Kazempour 1383
		JUN3	2650	Iran. Tehran, Yousefzadeh 1515
7	*T. polycephalum* subsp. *polycephalum*	POL1	2550	Iran. Isfahan, Sonboli & al. 1162
		POL2	2900	Iran. Markazi, Gholipour 1696
		POL3	2370	Iran. Hamedan, Behjou 2187
		POL4	1800	Iran. Isfahan, Sonboli & Gholipour 1152
		POL5	1700	Iran. Kurdistan, Behjou & Ghaderi 2240
8	*T. canescens* DC.	CAN1	1260	Iran: East Azerbaijan, Sonboli 1679
		CAN2	2024	Iran. Zanjan, Sonboli 1417
9	*T. elbursense* Mozaff.	ELB	1950	Iran. Tehran, Sonboli & al. 1108
10	*T. tabrisianum* (Boiss.) Sosn. & Takht.	TAB	1900	Iran. Qazvin, Sonboli 1122

Table 2. Morphological characters and character states used in the multivariate analyses in studied taxa.

No.	Character	No.	Character
1	Plant height (cm)	**16**	Number of capitula on each stem branch
2	Basal leave length (cm)	**17**	Capitulum length (mm)
3	Basal leave peduncle length (mm)	**18**	Capitulum width (mm)
4	Pairs of the primary segment of basal leave	**19**	Exterior involucral bract length (mm)
5	Primary segments of basal leave length (mm)	**20**	Interior involucral bract length (mm)
6	Primary segments of basal leave width (mm)	**21**	Interior involucral bract width (mm)
7	Pairs of the secondary segment of basal leave	**22**	Number of ray florets in capitulum
8	Secondary segments of basal leave length (mm)	**23**	Ray floret length (mm)
9	Cauline leave length (cm)	**24**	Length of ray floret teeth (mm)
10	Pairs of the primary segment of cauline leave	**25**	Disk florets length (mm)
11	Primary segments of cauline leave length (mm)	**26**	Stamen length (mm)
12	Primary segments of cauline leave width (mm)	**27**	Pistil length (mm)
13	Pairs of the second segment of cauline leave	**28**	Achene length (mm)
14	Secondary segments of cauline leave length (mm)	**29**	Pappus length (mm)
15	Capitula peduncle length (cm)	**30**	Number of achene ribs
31	Distribution of leave through stem	Regularly along the stem (0), In the lower part of the stem (1)	
32	The similarity between basal leave and cauline leave	0: Similar (0), Different (1)	
33	The pattern of basal leave division	2-pinnatisect (0), 3-pinnatisect (1)	
34	The pattern of cauline leave division	Pinnatisect (0), Pinnatifide (1)	
35	Fan-shaped appendages in cauline leave	Absent (0), Present (1)	
36	Inflorescence arrangement	loose corymbs (0), Dense corymbs (1), Paniculate-corymbous (2)	
37	Number of capitula	Few (X<10) (0), Mediocre (10<X<50) (1), Numerous (X>50) (2)	
38	Shape of capitulum	Globular or Hemispheric (0), Ovate (1), Napiform (2)	
39	Shape of exterior involucral bract	Ovate-Triangular (0), Lanceolate (1), Narrow lanceolate (2)	
40	Status of involucral bract	No carina (0), carinate (2)	
41	Color of involucral bracts margin	Pallid (0), Brown (1)	
42	Status of involucral bracts margin	Entire (0), Lacerate (1)	
43	Terminal inflation on disk floret	Absent (0), Present (1)	

Table 3. Comparison of diagnostic morphological characters and chromosome numbers of different subspecies of *T. polycephalum* and its relatives.

Character / **Taxa**	***T. polycephalum***					***T. argyrophyllum***	***T. azerbaidjanicum***	***T. canescens***	***T. tabrisianum***	***T. elbursense***
	polycephalum	***heterophyllum***	***duderanum***	***farsicum***	***junesarense***					
Basal leave division	3-pinnatisect	3-pinnatisect	3-pinnatisect	3-pinnatisect	3-pinnatisect	3-pinnatisect	2-pinnatisect	2-pinnatisect	2-pinnatisect	2-pinnatifide
Cauline leave appendage	Present	Present	Present	Present	Present	Absent	Absent	Absent	Absent	Absent
Shape of Inflorescence	Loose corymbs	Loose corymbs	Dense corymbs	Dense corymbs	Dense corymbs	Paniculate-Corymbs	Dense corymbs	Dense corymbs	solitary	solitary
Number of capitula	10-50	10-50(-70)	10-30	8-30	5-15	20-80-(-120)	5-8	3-5	1	1
Shape of capitulum	Globular	Broad Ovate	Globular or Napiform	Globular or Hemispheric	Napiform or ± Globular	Ovate	Napiform	Hemispheric	Hemispheric	Hemispheric
Capitulum size (mm)	4-5×4-5	4-5×4-6	3.5-4.5×4.5-6	3.5-4.5×4.5-6	4-6×6-8	3-4×3-3.5	5-7×5-8	4.5-5.5×5-7	5-8×8-12	5-8×10-14
Shape of outer bract	Lanceolate or Oblong-Triangular	Narrow Lanceolate	Triangular-Ovate	Ovate-Triangular	Lanceolate	Narrow lanceolate	Narrow Ovate	Narrow lanceolate	Ovate-lanceolate	Triangular-Ovate
Color of bract margin	Pallid	Pallid	Light Brown	Dark Brown	Light Brown	Pallid	Pallid	Pallid	Pallid	Pallid
Inner bract margin	Entire	Entire	Lacerate	Denticulate-Lacerate	± Lacerate	Entire	Entire	Entire	Lacerate	Lacerate
Status of bract	± Carinate	Carinate	No carina	No carina	No carina	± Carinate	No carina	No carina	No carina	No carina
Disk floret Inflation	Absent	Absent	Absent	Absent	Absent	Present	Present	Absent	Absent	Present
Achene length (mm)	2-2.3	2.4-2.7	2.3-2.6	2.2-2.5	2.2-2.5	1.8-2.2	3.7-4.2	3.8-5	4.3-5	4.3-5.5
Number of achene ribs	5-6	5-7	5-6	5-7	5-6	4-6	9-13	13-15	9-15	12-14
Ploidy level	No report	Tetraploid, Hexaploid	Tetraploid	Hexaploid	No report	Diploid, Tetraploid, Aneuploid	Tetraploid	Diploid	Hexaploid	No report

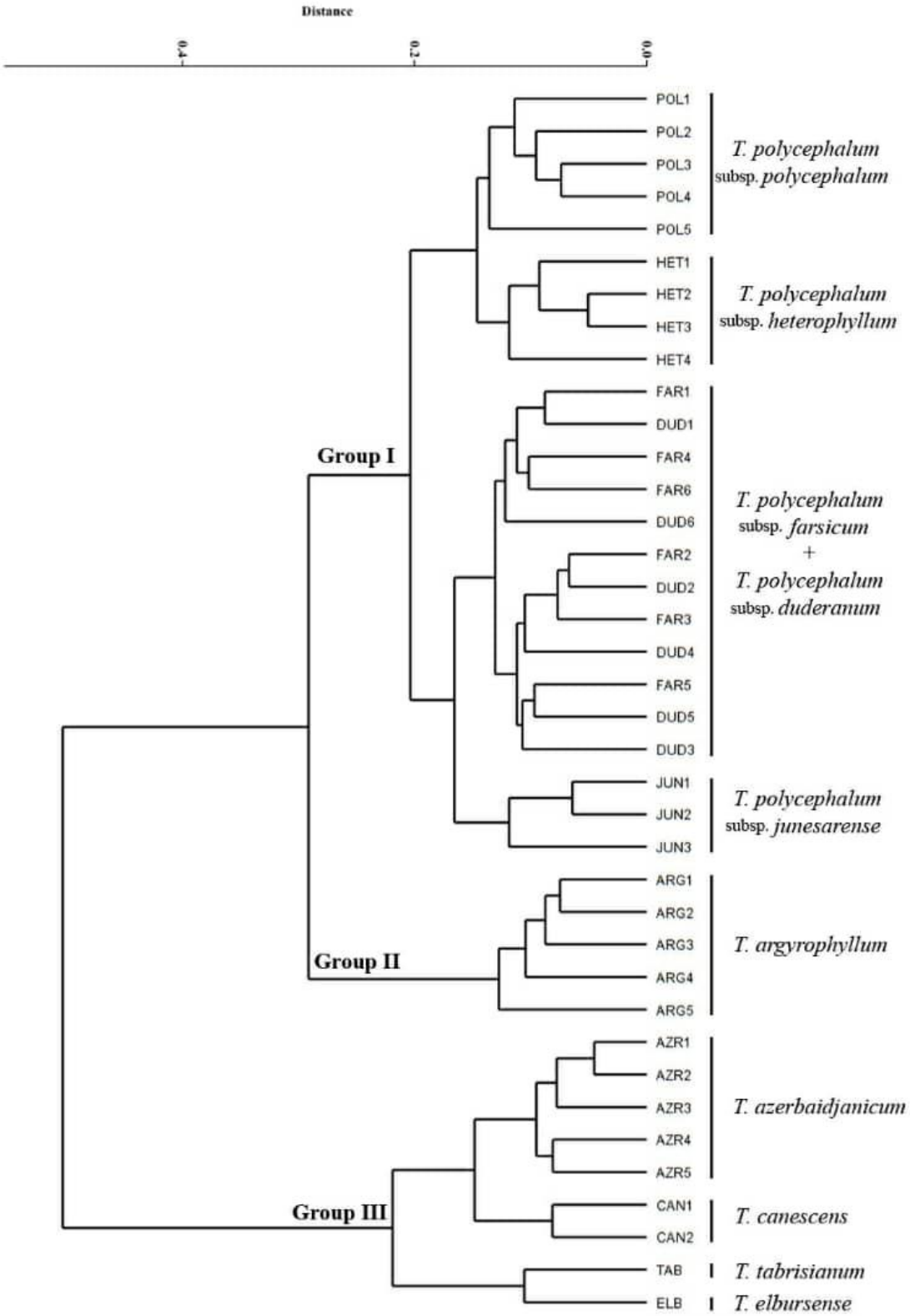

Fig. 1. Dendrogram based on UPGMA method using morphological characters in *Tanacetum polycephalum* and its allies. Gover index was used as a measure of similarity.

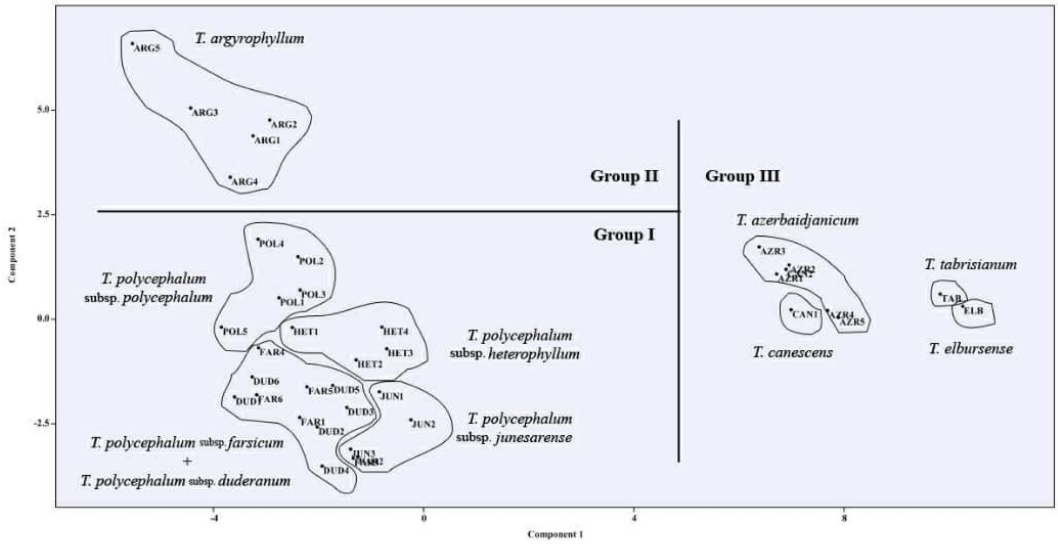

Fig. 2. Ordination based on PCA method using morphological characters in *Tanacetum polycephalum* and its allies.

Podlech (1986) described *T. polycephalum* subsp. *azerbaidjanicum* from Iran, West Azerbaijan Province (SW side of Lake Urmia). Mozaffarian (2005) later considered this subspecies as a synonym of *T. canescens*. The present study indicates that this taxon should be resurrected as a distinct entity and also be given a distinct species rank. Several characteristics such as achene size, number, and shape of capitula, presence or absence of disk floret inflation, and the number of achene ribs separated two close relative species *T. azerbaidjanicum* and *T. canescens*. Therefore, a new combination and rank, e.g. *T. azerbaidjanicum* (Podlech) Sonboli & Behjou is here introduced. The differences among species and subspecies of this complex are presented in Table 3. The morphological characteristics of achenes can readily separate *T. azerbaidjanicum* from all members of the *T. polycephalum* species complex (Moradi Behjou & al., 2016).

Taxonomic treatment

Identification key of *T. polycephalum* and close relative species:

1. Achene less than 3 mm, ribs less than 7..... **2**
- Achene longer than 3 mm, ribs more than 9..... **3**
2. Capitula >70, ovate, less than 3.5 mm in width ..... …..***T. argyrophyllum***
- Capitula <70, hemispheric, more than 4 mm in diam. ..... ***T. polycephalum***
3. Capitula 5-8, napiform..... ***T. azerbaidjanicum***
- Capitula 1-5, ± hemispheric..... **4**
4. Capitula 3-5, less than 7 mm in diam. ..***T. canescens***
- Capitula solitary, more than 8 mm in diam. **5**
5. Capitula less than 12 mm in diam.; marginal flowers ± tubular ..... ***T. tabrisianum***
- Capitula more than 12 mm in diam.; marginal flowers 3-4-lobed ..... ***T. elbursense***

Tanacetum polycephalum Sch. Bip. Tanacet. 47 (1844).

Distribution: Iran, Turkey, Azerbaijan, Iraq

Identification key to the subspecies of *T. polycephalum*

1. Involucral bracts carinate, pale-margined, entire.... **2**
- Involucral bracts without carina, margin brown, lacerate **3**
2. Capitula globular, bract with slender carina .....subsp. ***polycephalum***
- Capitula broadly ovate, bract with prominent carina .....subsp. ***heterophyllum***
3. Capitula 10-30, outer bracts ovate-triangular **4**
- Capitula 5-15, outer bracts lanceolate ..... subsp. ***junesarense***
4. Bract margin light brown, apex with a broad appendage, deeply lacerate ..... subsp. ***duderanum***
- Bract margin dark brown, apex narrowly marginate, denticulate-lacerate.....subsp. ***farsicum***

T. polycephalum Sch. Bip. subsp. ***polycephalum***

Type: Th. Kotschy 341 (K!, Isotype).

Syn.: *Pyrethrum polycephalum* (Sch. Bip.) Boiss., Fl. Or. 3: 351 (1875); *Tanacetum argyrophyllum* (C.

Koch) Tzvel. var. *polycephalum* (Sch. Bip.) Grierson, Notes Roy. Bot. Gard. Edinb. 33: 434 (1975), comb. illegit.
Diagnosis: Capitula numerous, 10-50, in loose corymbs, globular, 4-5 mm diameter; bract pale-margined, slender carinate dorsally, sparsely pubescent, outer lanceolate or oblong-triangle, acute, inner bracts twice as long as outer ones, margin narrow with broad membranous apex.
Flowering time: June-July
Habitat: Mountains, stony slopes, 1100-2700 (-3200) m a.s.l. (Figs. 3A, B).
Chromosome Number: No chromosome report in references was found for this taxon.
Phytogeography: Irano-Turanian element (Armeno-Iranian province, Kurdo-Zagrosian subprovince) (Takhtajan 1986).
Distribution: Iran (Western parts), Turkey (Southeastern part), Iraq (Northeastern part) (Fig. 4A)
Representative Specimens Examined: IRAN. **Hamedan**: Darreh-Moradbeig, Alvand Mountain, 2300 m, 7 August 2014, Behjou 2187, 2188, 2189 (MPH); **Markazi**: Arak to Borujerd, near Tureh. Hesar village, Raswand Mountain, 2900 m, 25 June 2009, Gholipour 1696 (MPH); **Esfahan**: Khansar to Damaneh, 2250 m, 19 June 2007, Sonboli & al. 1162 (MPH); Meymeh to Muteh, 2060 m, 14 June 2007, Sonboli & Gholipour 1159 (MPH); Kashan, Ghamsar to Ghohroud, 1800 m, 14 June 2007, Sonboli & Gholipour 1152 (MPH).

T. polycephalum subsp. ***heterophyllum*** (Boiss.) Podlech, Fl. Iranica, 158: 117 (1986)
Type: Th. Kotschy 433 (K!, Isotype)
Syn.: *Tanacetum heterophyllum* Boiss., Diagn. Pl. Or. Nov. Ser. 1, 6: 90 (1845). *Pyrethrum szovitsii* Boiss. l.c. Ser. 1, 11: 25 (1849) p.p. *P. myriophyllum* C.A.Mey. var. *variegatum* Boiss., F1. Or. 3: 351 (1875).
Diagnosis: Capitula numerous, 10-50 (-70), in simple or compound loose or dense corymbs, broad ovate, length 4-5 mm long, width 4-6 mm; bract pallid, prominent carinate dorsally, sparsely pilose, outer lanceolate, acute, inner longer, oblong, ± obtuse, margin narrow with tinny hyaline apex or rarely brown.
Flowering time: May-June.
Habitat: Mountains, stony slopes, 1350-3000 m a.s.l. (Figs. 3C, D).
Chromosome Number: Hexaploid with chromosome number of 2n =6x= 54 (Olanj & al. 2015) and tetraploid with chromosome number of 2n =4x= 36 (Olanj & al. 2015).
Distribution: IRAN (Western and Southern parts), IRAQ (North-Eastern part) (Fig. 4B).
Representative Specimens Examined: IRAN. **Kordestan**: Sanandaj to Divandarreh, Zagheh Pass, 2200 m, 1 June 2011, Olanj 1890 (MPH); Sanandaj, Sarab-e Ghamish road, Chatan village, 1840 m, 13 July 2011, Olanj 1892 (MPH). **Hamedan**: Kabudarahang, Goltapeh, Subashi village, 2400 m, 14 August 2014, Behjou 2194, 2195 (MPH); Asadabad, Tajabad village, 2100 m, 18 August 2014, Behjou 2199 (MPH); Alvand Mountain, 22600 m, 19 July 2003, Najafi 1482 (MPH); Asadabad, Gallehbor Region, 2280 m, 15 July 2014, Behjou 2199 (MPH); **Fars**: Kuh-e Sabz Pushan prope Shiraz, 25 May 1842 Kotschy 433 (K). **IRAQ.** Sulaymaniyah: Pira Magrun (Pir Omar Magrun), 1800-2400 m, Haussknecht-photo (K).

T. polycephalum subsp. ***farsicum*** Podlech, Fl. Iranica, 158: 118 (1986)
Type: Archibald 3021(K!, holotype).
Diagnosis: Capitula numerous, 8-30, in loose or dense corymbs, globular or hemispheric, length 3.5-4.5 mm, width 4.5-6 mm; bracts with dark brown margin, outer ovate-triangular, acute, inner bracts twice as long as outer ones, oblong, apex narrowly marginate, denticulate-lacerate, ± crispy pilose.
Flowering time: May-July.
Habitat: Mountains, stony slopes, (1500) 2300-3900 m a.s.l. (Figs. 3E-G).
Chromosome Number: Hexaploid with chromosome number of 2n = 6x= 54 (Olanj & al. 2015).
Distribution: Endemic to Iran (Western and Central parts). (Fig. 4C (circle)).
Representative Specimens Examined: IRAN. **Hamedan**: Ghanjnameh to Tuyserkan, 2640 m, 8 August 2014, Behjou 2191, 2192 (MPH); Ghanjnameh, Alvand Mountain, 2735 m, 22 August 2014, Behjou 2200, 2201 (MPH); Mountain, 2735 m, 22 August 2014, Behjou 2200, 2201 (MPH); Razan, Yaremcheh-Bagh village, Bughati Mountain, 2350-2450 m, 10 August 2014, Behjou 2193 (MPH); **Lorestan**: Borujerd, Garin Mountain, 2300 m, 24 May 2008, Gholipour 1441 (MPH); **Esfahan**: Semirom to Shahreza, Surmand Mountain, 2850-2950 m, 18 June 2007, Sonboli & al. 1177 (MPH); Semirom to Shahreza, Mehregan road, Narmeh, 2970-3050 m, 18 June 2007, Sonboli & al. 1175 (MPH); Kashan, Ghamsar to ghohrud, 2700 m, 17 June 2007, Sonboli & Gholipour 1154 (MPH); **Kohkiluyeh va Boyerahmad**: Yasuj, Sisakht, Dena protected area, 3000-3200 m, 16 June 2007, Sonboli & al. 1167 (MPH); Yasuj, Sisakht, Bizhan pass, 3178 m, 17 July 2007, Bahadori 1980 (MPH); Tang-i Sirdan inter Valles Kuhrang et Bazoft, 3990 m, 7 August 1966, Archibald 3021-photo (K). **Fars**: Eghlid, Bol Mountain, 3200 m, 9 July 2004, Sonboli & al. 1487 (MPH); **Yazd**: Taft, Tezerjan, Shirkuh Mountain, Barfkhaneh, 2850 m, 3 May 2008, Kanani & Gholipour 1280 (MPH).

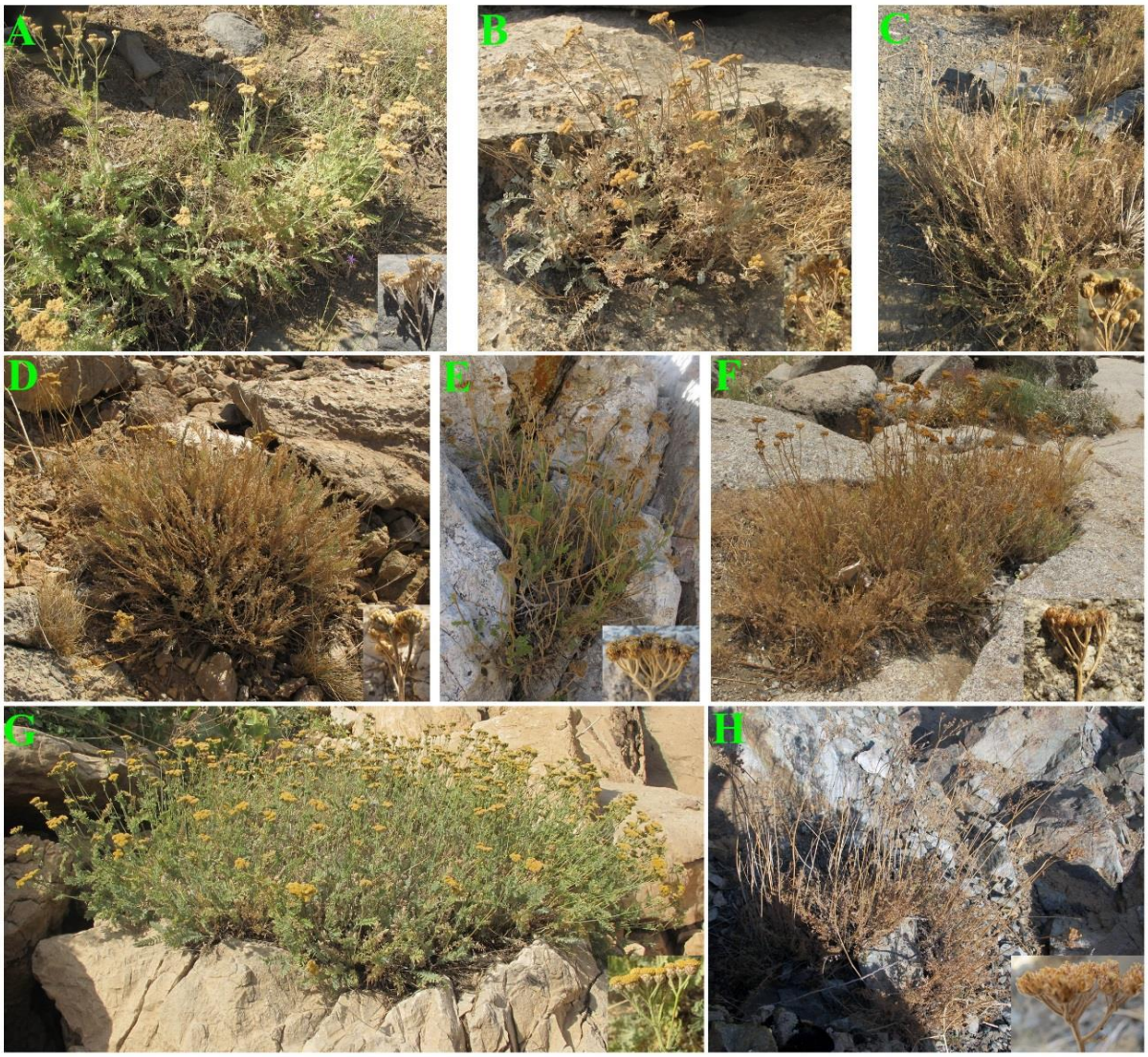

Fig. 3. Natural habitats of *Tanacetum polycephalum.* A and B, T. *polycephalum* subsp. *polycephalum*; C and D, *T. polycephalum* subsp. *heterophyllum*; E, F, G, *T. polycephalum* subsp. *farsicum*; H, *T. polycephalum* subsp. *duderanum.*

T. polycephalum subsp. ***duderanum*** (Boiss.) Podlech**,** Fl. Iranica, 158: 120 (1986**)**

Type: Th. Kotschy 266 (K!, Isotype)

Syn.: *P. myriophyllum* C.A. Mey., Verz. Pfl. Cauc. 74 (1831) non *Tanacetum myriophyllum* Willd. (1789). *Pyrethrum duderanum* Boiss., Diagn. Pl. Or. Nov. Ser. 1, 11: 26 (1849). *P. myriophyllum* var. *eriocephalum* Boiss., F1. Or. 3: 351 (1875). *Chrysanthemum myriophyllum* Willd. var. *eriocephalum* (Boiss.) Bornm., Feddes Repert. 49: 307 (1940). *Tanacetum duderanum* (Boiss.) Tzvel., Fl. URSS. *Chrysanthemum Shahrudense* Rech.f., Aell. & Esfand., Österr. Bot. Zeitschr. 97: 230 (1950). 26: 332 (1961)..

Diagnosis: Capitula numerous, 10-30, in simple or compound dense corymbs, globular or napiform, length 3.5-4.5 mm, width 4.5-6 mm; bracts with light brown margin, outer triangular-ovate, acute, inner longer, narrowly ovate, apex with a long appendage, deep lacerate, dense crispy or sericeous.

Flowering time: May-June

Habitat: Mountains, stony slopes, (1300) 1500-2800 (-3200) m a.s.l. (Fig. 3H).

Chromosome Number: Tetraploid with chromosome number of 2n = 4x= 36 (Olanj & al. 2013, 2015).
Distribution: Iran (Northern and Eastern parts), Talysh (Southern part). (Fig. 4D).
Representative Specimens Examined: IRAN. **Mazandaran**: Siahbisheh, Pol-e zanguleh, Golestanak safe region, 2800-3200 m, 17 August 2011, Sonboli & Mehregan 1795, 1796, 1797 (MPH); Siahbisheh, Allamol, 2480 m, 9 July 2009, Sonboli & al.1615 (MPH); Polur to Lasem, Vazna, 2600-2700 m, 18 June 2006, Sonboli & Yousefzadeh, 1060 (MPH). **Tehran**: Chalus road, Velayat to Dizin, 2200m, 9 July 2009, Sonboli & al. 1651 (MPH); Velenjak, Tuchal Mountain, 2900 m, 30 May 2008, Sonboli 1484, Najafi 1488, Behjou 2205 (MPH); Darakeh, Palang-Chal, 2300 m, 6 September 2014, Behjou & Sayadi 2205 (MPH); Fasham, Shemshak to Dizin, 3100m, 30 June 2010, Sonboli & al. 1651 (MPH); In fauce Dow Darreh (Dudera), Kotschy 266-photo (K); **Qazvin**: Kavandaj to Shekarnab, Hajiabad road, 1850 m, 24 May 2006, Sonboli & al. 1057 (MPH); Qazvin to Buein Zahra, Danesfahan, Yazan village, 1800-1900 m, 18 May 2007, Sonboli & al. 1490 (MPH); **Zanjan**: Soltanieh to Gheydar, Selvar village, 2024 m, 24 June 2007, Sonboli & Gholipour 1415 (MPH); Zanjan to rudbar, Tarom road, 2400 m, 8 June 2007, Sonboli & Gholipour 1422 (MPH); Semnan, Shahmirzad to Chashm, 2100 m, 30 May 2008, Sonboli & Gholipour 1283 (MPH); **Khorasan**: Bojnurd to Mashad, 2100 m, 5 June 2010, Gholipour 1623 (MPH).
Note: According to Podlech (1984), several populations growing in different parts of Iran were considered as *T. polycephalum* subsp. *duderanum*, while, based on our sampling, it is distributed mainly in the northern parts of Iran. The populations growing in central and western parts of Iran could be referred to *T. polycephalum* subsp. *farsicum*.

T. polycephalum subsp. ***junesarense*** (Bornm.) Podlech., Fl. Iranica, 158: 119 (1986)
Type: Bornmueller 7407 (B! holotype)
Syn.: *Pyrethrum modestum* Heimerl ex Stapf var. *demavendicum* Bornm., Bull. Herb. Boissier, Ser. 2,7: 39 (1907). *Chrysanthemum junesarense* Bornm., Feddes Repert. 51: 109 (1942)..
Diagnosis: Capitula numerous, 5-15, in dense corymbs, broad napiform or ± globular, length 4-6 mm, width 6-8 mm; bracts with light brown margin, outer lanceolate, acute, inner bracts twice as long as outer ones, oblong, obtuse, densely villose with crispy hairs.
Flowering time: May-June
Habitat: Mountains, stony -slopes, 2300-2700 m a.s.l.
Chromosome Number: No chromosome report in references was found for this taxon.
Distribution: Endemic to Iran (northern part). (Fig. 4C (square).
Representative Specimens Examined: IRAN. **Tehran**: Firuzkuh to Semnan, 2200 m, 6 May 2008, Sonboli & Kazempour 1383 (MPH); Firuzkuh to Semnan, Bashm Mountain, 2400-2500 m, 30 May 2006, Sonboli & al. 1095 (MPH); Firuzkuh to Lasem, 2600-2700 m, 15 June 2007, Yousefzadeh 1515 (MPH); Polur, Haraz road, Polur protected area, 2600 m, 26 June 2007, Kanani & al. 1146 (MPH); M. Elburz in fauce Yunizar (Junesar), in vale Lar, 2700 m, 13 July 1902, Bornmuller 7407-photo (B); **Semnan**: Shahmirzad to Chashm, 2100 m, 30 May 2008, Sonboli & Gholipour 1284 (MPH).

T. argyrophyllum (K. Koch) Tzvel., Sched. Herb. Fl. URSS. 16: 121 (1966)
Type: C. Koch s.n. (in Landon)
Syn.: *Achillea bipinnata* L., Sp. Pl. ed. 2, 1265 (1763), non *Tanacetum bipinnatum* Sch. Bip. (1844); *T. myriophyllum* Willd., Tract. De Achilleis 50 (1789), nom. illegit; *Pyrethrum myriophyllum* auct. non C. A. Meyer (1831); *Pyrethrum myriophyllum* C.A. Mey var. *subvirescens* DC., Prodr. 6: 59 (1838). *Gymnocline argyrophylla* C. Koch in Linnaea 24: 340 (1851); *Chrysanthemum myriophyllum* (Willd.) Náb. in Publ. Fac. Sci. Univ. Masaryk Brno 52:23 (1925), comb. illegit. *T. polycephalum* Sch. Bip. subsp. *argyrophyllum* (C. Koch) Podl., Fl. Iranica, 158: 117 (1986), **syn. nov**.
Flowering time: June-July
Habitat: Mountains, stony slopes, 1000-2500 m. a.s.l.
Chromosome Number: Two ploidy levels have been reported for this species. Diploid with 2n = 18 (Inceer & al. 2012, Olanj & al. 2015) and tetraploid with 2n =4x=36 (Kurşat 2020; Olanj & al. 2015). Furthermore,

aneuploidy (2n=35) has also been reported for this taxon (Olanj & al. 2015).

Distribution: Iran (North-Western part), Turkey (North-Eastern & Central parts), Iraq (North-Eastern part), Caucasus (Eastern and Southern parts). (Fig. 4E).

Representative Specimens Examined: IRAN. **West Azerbaijan**: Urmia, Anhar Roud, Suluk Village, 1800-2300 m, 3 July 2007, Sonboli & al. 1338 (MPH); Takab, Takht-e Soleyman, Amirabad village, 2370-2385 m, 7 July 2003, Najafi 1478 (MPH); Takab, Moeinbolagh neck, Boluz protected area, 2200-2240 m, 27 July 2003, Najafi 1479 (MPH); Urmia, Silvana road, Movana village, 1610 m, 11 July 2011, Sonboli 1752 (MPH); Urmia, Serow road, Golsheikhan village, 1990 m, 10 July 2011, Sonboli & Mojarrad 1757 (MPH); Salmas, Silvana road, 2000 m, 4 July 2011, Olanj 1870 (MPH); Urmia, Ghasemlou valley, 1600 m, 15 July 2011, Olanj 1866 (MPH); Naghadeh, Soltan Yaghub region, 2000 m, 20 June 2008, Mojjarad 1381 (MPH); Khoy, Chaldoran road, Sheivan-Kandy village, 1900 m, 6 June 2011, Olanj 1850 (MPH); Urmia, Ghoshchi neck, 1860 m, 2 July 2007, Sonboli & al. 1214 (MPH). **East Azerbaijan**: Marand, Mishou-Dagh, Near Yam, 1900-2200 m, 2 June 2008, Sonboli & al. 1338 (MPH); Kleibar, Peygham village, 1940 m, 6 June 2011, Olanj 1852 (MPH). **Kordestan**: Sanandaj to Divandarreh, Zagheh pass, 2100 m, 1 June 2011, Olanj 1890 (MPH). TURKEY. **Van:** Demirkus-photo 5433!, 5819!, (VAN).

T. azerbaidjanicum (Podlech) Sonboli & Behjou comb. & stat. nov.

Typus: M. Jacobs 6857 (W!, holotypus)

Syn.: *T. polycephalum* Sch. Bip. subsp. *azerbaidjanicum* Podl., Fl. Iranica, 158: 119 (1986), **syn. nov**.

Description: Perennial, 30-45 cm, with long, ligneous, gross, branched rhizome, grayish from profuse fine tomentum of appressed hairs. Stems numerous, fertile and sterile, erect, firm, with white, curled dense hairs at base, sparse tomentum of ascending hairs above, ribs prominent, striate, from the base to the middle or a little above the middle bearing 3-4 leaves, upper naked. Basal leaves 4-17 cm (incl. petiole), 5-7 cm wide, grayish from profuse fine tomentum, with punctate glands; petiole long, 1-8 cm, with more or less wide sheath at base, hairs long, dense, appressed and gray, above canaliculated; lamina almost equal in length, tripinnatisect, 8-12 pairs of primary oblanceolate-oblong segments, secondary segments often lobed or divided, terminal lobes and segments oblanceolate, rarely oblong, acute, up to 0.5-0.6 mm wide. Cauline leaves similar to the basal ones, sessile, upper become gradually smaller. Capitula few (1-5 (-8)), on peduncles 1-3 cm long, in dense corymbs, terminal, peduncles with dense, gray tomentum. Involucres napiform or conical in outline, 4-8 mm in diameter and 5-7 mm long; Involucral yellow, herbaceous, outer narrow ovate, obtuse, with dense long white hairs, less than 3.5 mm long, 1.7 mm broad, with long, ciliate cuts, inner oblong spatulate, obtuse, from middle to the apex broader, hyaline, scarious, with deep cuts, 4-6 mm long and 1.5-1.8 mm wide. Florets hermaphroditic, receptacle convex, peripheral female florets ligulate, colored-straw, 3-6, corolla tube 1.5-2.5 mm long and limb 1.2-1.5 mm long, tubular florets of disk glandulous, corolla 3.5 mm long, with terminal inflation. Achenes 3.7-4.2 mm long, 0.8 mm wide, with 9-13 longitudinal ribs, almost incurved, attenuate at base, with very small glandular trichomes, corona 0.2-0.3 mm long, serrate.

Flowering time: June.

Habitat: Mountains, stony slopes, 1100-1850 m. a.s.l.

Chromosome Number: Tetraploid with chromosome number of 2n = 4x=36 (Olanj & al. 2013, 2015).

Distribution: Iran (North-Western part), Iraq (North-Eastern part). (Fig. 4F).

Representative Specimens Examined: IRAN. **West Azerbaijan**: Naghadeh, Soltan Yaghub region, 1800 m, 20 June 2008, Mojjarad 1380 (MPH); Naghadeh, Oshnavieh road, 1800 m, 3 June 2011, Olanj 1864 (MPH); Urmia, Ghasemlou valley, 1600 m, 20 June 2008, Mojjarad 1378 (MPH); Urmia, Ghoshchi neck, 1860 m, 2 July 2007, Sonboli & al. 1212 (MPH); Khoy, Firoragh road, Pasak to Hesar, 1500-1700 m, 2 June 2008, Sonboli & al. 1326 (MPH); Urmia, Ashenaabad, 1700 m, 8 June 2007, Mojjarad 1241 (MPH); Urmia, Serow road, 1600 m, 1 July 2007, Sonboli & al. 1234 (MPH); Lake Rzaiyeh, S.W. side, 1300 m, 12 June 1963, Jacob 6857-photo (W).

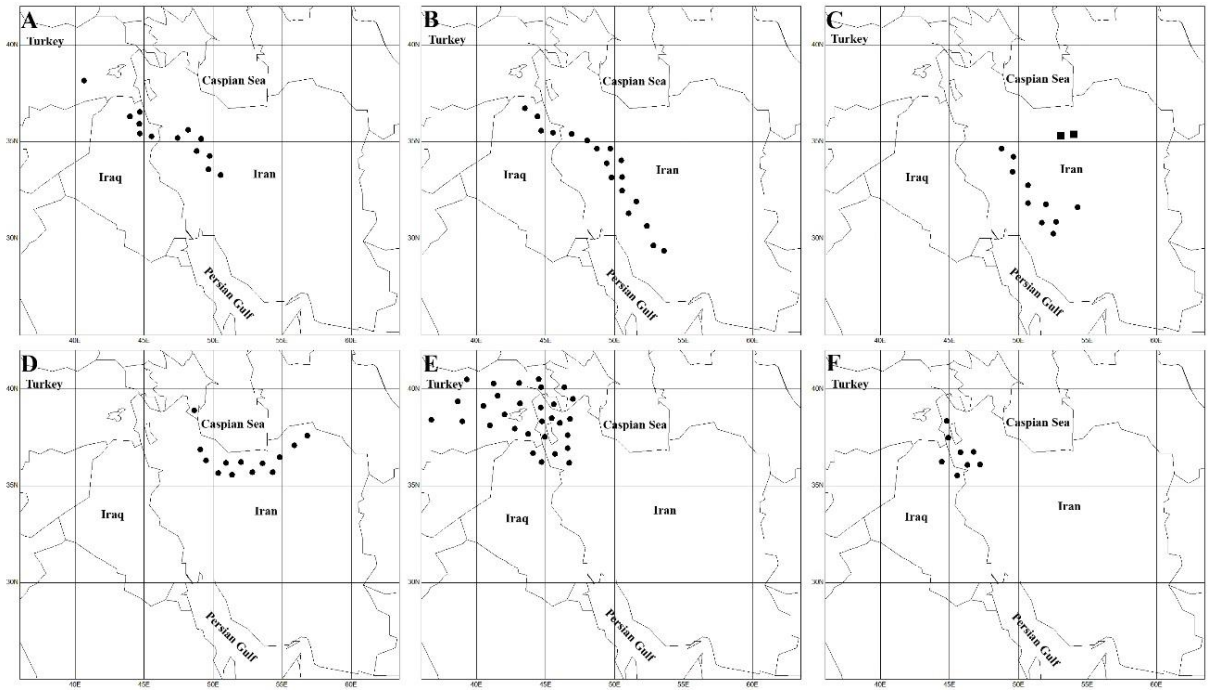

Fig. 4. Distribution map of *Tanacetum polycephalum*. A, *T. polycephalum* subsp. *polycephalum*; B, *T. polycephalum* subsp. *heterophyllum*; C, *T. polycephalum* subsp. *farsicum* (circle) and *T. polycephalum* subsp. *junesarense* (square); D, *T. polycephalum* subsp. *duderanum*; E, *T. argyrophyllum*; F, *T. azerbaidjanicum*.

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