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Karyological study on 12 species of the genus *Taraxacum* (*Asteraceae*) grown in Turkey

Abstract

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The somatic chromosomes and karyotypes of 12 *Taraxacum* species were determined. All studied species were collected from natural habitats in Marmara Region, NW Turkey. The chromosome numbers of *Taraxacum aznavourii* (2*n* = 24), *T. gracilens* (2*n* = 24), *T. hyberniforme* (2*n* = 32) and T. pseudobrachyglossum (2*n* = 24) are reported here for the first time. The basic chromosome number was found as x = 8 and all the examined taxa are triploid or tetraploid. All the examined species of the sections *Erythrosperma* and Palustria are triploids (2*n* = 3x = 24), while of the section *Scariosa* all are tetraploids (2*n* = 4x = 32), with the exception of T. minimum, which is both triploids and tetraploids. The detailed karyotype features of the 12 *Taraxacum* species are also presented.

Keywords: *Compositae*, chromosome numbers, karyotype, Marmara Region.

Introduction

The genus *Taraxacum* Wiggers is widely distributed in various habitats around the world. The west and central Asian regions are the ancestral centre of *Taraxacum*. The highest species and character diversities of this genus are found especially in Turkey, Iran, Afghanistan, the West Himalayas, North-Central China and the Southern Caucasus (Richards 1973).

Taraxacum species could undergo apomixis or sexual reproduction. Approximately 90% of *Taraxacum* species are apomictic. Generally, sexual *Taraxacum* species are diploid and apomictic species are polyploid (Richards 2003). On the other hand some tetraploids of the section *Piesis* are found to be sexual by Kirschner & al. (1994). In cases where apomictic and diploid sexual plants co-exist, the sexual species differ from the apomicts in size (Valentine & Richards 1967).

Diploid and apomictic species commonly co-exist in *Taraxacum* populations in Central Europe. In Europe, the Netherlands is the northern distribution limit for sexual species; polyploidy apomicts are present at higher latitudes (Dijk van 2003; Dijk Van & al. 2009).

According to Kirscher & al. (1994), sexual *Taraxacum* species have a limited geographical distribution. *Taraxacum serotinum* (Waldst. & Kit.) Fisch. (sect. *Dioszegia*) and *T.*

bessarabicum (Hornem.) Hand.-Mazz. (sect. *Piesis*) are the only sexual species with a wide distribution.

Classifying *Taraxacum* is complicated given the similar morphologies of species within this genus and the presence of apomixes and sexual reproduction (Kirschner & Štěpánek 1996, 2012). In these respect karyological data are useful for systematic classification of *Taraxacum*.

In Turkey, the genus *Taraxacum* is represented by 57 taxa, 18 of which are endemic. These taxa are grouped into 12 sections: *Dioszegia*, *Erythrocarpa*, *Erythrosperma*, *Macrocornuta*, *Oligantha*, *Orientalia*, *Palustria*, *Piesis*, *Primigenia*, *Scariosa*, *Sonchidium*, and *Taraxacum*. The chromosome numbers of 30 *Taraxacum* species occurring in Turkey are recorded in the literature (Doll 1975, 1976b; Richards 1968, 1969; Gedik & al. 2014; Kirschner & Stepanek 1985, 1998; Drabkova & al. 2009). Among these species, seven are diploid ($2n = 2x = 16$), 12 are triploid ($2n = 3x = 24$), four are tetraploid ($2n = 4x = 32$), one is hexaploid ($2n = 48$), and six species have two ploidy levels are recorded for other. The chromosome numbers of almost all *Taraxacum* species from Turkey have been counted by Doll (1975, 1976a). The species mentioned above were collected by Prof. K. Walther from West Anatolia.

The aim of this study is to determine the chromosome number and karyotype features which are important to indicate apomixis or sexual reproduction, of 12 *Taraxacum* species from Turkey.

*S*ect. *Erythrosperma*

1943. *Taraxacum aznavourii* Soest — $2n = 3x = 24$ (Figs 1A & 2A).

Tu: A2(A) Bursa: Uludağ, Kirazlı yayla, 1363 m, 20 Sept 2013, *B. Gürdal 169-16, H. Gürdal* (ISTE 101782).

Taraxacum aznavourii is an endemic taxon of the Turkish flora. The chromosome number of this species is $2n = 24$, triploid. Its karyotype formula is $2n = 3x = 16m + 2m\text{-SAT} + 6sm = 24$. Its chromosome lengths range between from 1.35 to 2.81 µm. Its M_{CA} and CV_{CL} values are 20.18 and 19.343, respectively (Table 1). The present study is the first report of the chromosome number and karyotype of this species.

1944. *Taraxacum buttleri* Soest — $2n = 3x = 24$ (Figs 1B & 2B).

Tu: A3 Sakarya: Taraklı, Karagöl yaylası yolu, 1114 m, 18 May 2014, *B. Gürdal 716-54, M. Koçyiğit, N. & E. Özhatay* (ISTE 102545).

The chromosome number of this species is $2n = 24$, triploid. Its karyotype formula is $2n = 3x = 20m + 1m\text{-SAT} + 3sm = 24$. Its chromosome lengths range from 0.50 to 0.99 µm. Its M_{CA} and CV_{CL} values are 11.43 and 22.541, respectively (Table 1). This species was previously reported also as a triploid ($2n = 24$) (Doll 1976b).

1945. ***Taraxacum gracilens*** Dahlst. — $2n = 3x = 24$ (Figs 1C & 2C).

Tu: A2(A) Bursa: Uludağ, Kirazlı yayla civarı, 1505 m, 26 May 2013, *B. Gürdal 160-16, H. Gürdal* (ISTE 101779).

The chromosome number of *Taraxacum gracilens* is $2n = 24$, triploid. Its karyotype formula is $2n = 3x = 18m + 6sm = 24$. Its chromosome lengths range from 1.12 to 2.12 µm. Its M_{CA} and CV_{CL} values are 22.98 and 18.141, respectively (Table 1). The present study is the first to report the chromosome number and karyotype of this species.

1946. ***Taraxacum pseudobrachyglossum*** Soest — $2n = 3x = 24$ (Figs 1D & 2D).

Tu: A1(E) Tekirdağ: Hayrabolu, Ortaca'ya giderken, 3 km kala, 158 m, 22 Apr 2014, *B. Gürdal 583-59, M. Koçyiğit* (ISTE 102404).

The chromosome number of this endemic species is $2n = 24$, triploid. The karyotype consists of $2n = 3x = 24m$ chromosomes. Its chromosome lengths range from 1.07 to 1.72 µm. Its M_{CA} and CV_{CL} values are 5.97 and 15.365, respectively (Table 1). The present study is the first to report the chromosome number and karyotype of this species.

1947. ***Taraxacum turcicum*** Soest — $2n = 3x = 24$ (Figs 1E & 2E).

Tu: A2(A) Bursa: Uludağ, Karabelen piknik alanı, 1359 m, 26 May 2013, *B. Gürdal 140-16, H. Gürdal* (ISTE 101772).

The chromosome number of the endemic *Taraxacum turcicum* is $2n = 24$, triploid, as previously reported by Doll (1975). Its karyotype formula is: $2n = 3x = 13m + 2m\text{-SAT} + 9sm = 24$. Its chromosome lengths range from 1.16 µm to 3.03 µm. Its M_{CA} and CV_{CL} values are 23.53 and 30.667, respectively (Table 1).

1948. ***Taraxacum waltheri*** R.Doll — $2n = 3x = 24$ (Figs 1F & 2F).

Tu: A3 Sakarya: Sapanca gölü güneyi, S.Ü. Kırkpınar MYO arkasında mesire alanı, 37 m, 17 Apr 2015, *B. Gürdal 845-41, H. Gürdal* (ISTE 107341).

The chromosome number of this endemic species is $2n = 24$, triploid, as previously reported by Doll (1976b). Its karyotype formula is: $2n = 3x = 20m + 1m\text{-SAT} + 3sm = 24$. Its chromosome lengths range from 1.10 to 2.29 µm. Its M_{CA} and CV_{CL} values are 16.28 and 21.034, respectively (Table 1).

Sect. Palustria

1949. *Taraxacum scaturiginosum* G. E. Haglund — 2*n* = 3x = 24 (Figs 1M & 2M).

Tu: A1(E) Tekirdağ: Hayrabolu, Emiryakuplu'dan Ortaca'ya 6 km kala, 141 m, 22 Apr 2014, *B. Gürdal 579-59, M. Koçyiğit* (ISTE 102400).

The chromosome number of this species is 2*n* = 24, triploid. Its karyotype formula is given as 2*n* = 3x = 24 metacentric chromosomes. Its chromosome lengths range from 1.02 to 2.02 µm. Its M_{CA} and CV_{CL} values are 9.09 and 25.819, respectively (Table 1). The chromosome number of this species has been previously reported as 2*n* = 3x = 24 and 2*n* = 4x = 32 (Rice & al. 2014; Richards 1969).

Sect. Scariosa

1950. *Taraxacum aleppicum* Dahlst. — 2*n* = 4x = 32 (Figs 1G & 2G).

Tu: A1 (A) Çanakkale: Çan, Kocayayla çıkıºı, mera, 306 m, 2 Nov 2013, *B. Gürdal 362-17, M. Koçyiğit* (ISTE 102302).

The chromosome number of this species is 2*n* = 32, tetraploid, as previously reported by Doll (1976b). Its karyotype formula is 2*n* = 4x = 28m + 4sm = 32. Its chromosome lengths range from 0.67 to 1.49 µm. Its M_{CA} and CV_{CL} values are 11.86 and 21.649, respectively (Table 1).

1951. *Taraxacum hellenicum* Dahlst. — 2*n* = 4x = 32 (Figs 1H & 2H).

Tu: B1 Çanakkale: Evciler-Çavulu arası, Çavulu'ya 3 km kala, 332 m, 3 Nov 2013, *B. Gürdal 427-17, M. Koçyiğit* (ISTE 102324).

The chromosome number of this species is 2*n* = 32, tetraploid, as previously reported by Doll (1976b). Its karyotype formula is 2*n* = 4x = 30m + 2m-SAT = 32. Its chromosome lengths range from 1.15 to 2.38 µm. Its M_{CA} and CV_{CL} values are 8.99 and 19.631, respectively (Table 1).

1952. *Taraxacum hyberniforme* Soest Dahlst. — 2*n* = 4x = 32 (Figs 1I & 2I).

Tu: A1 (A) Çanakkale: Lapseki, Balcılar-Umurbey yolu, Balcılar'dan 1 km sonra, çam altı, 240 m, 2 Nov 2013, *B. Gürdal 379-17, M. Koçyiğit* (ISTE 102310).

The chromosome number of this species is 2*n* = 32, tetraploid. Its karyotype formula is 2*n* = 4x = 27m + 5m-SAT = 32. Its chromosome lengths range from 1.36 to 2.62 µm. Its

M_{CA} and CV_{CL} values are 7 and 20.316, respectively (Table 1). The present study is the first report of the chromosome number and the karyotype of *Taraxacum hyberniforme*.

1953. *Taraxacum hybernum* Steven — $2n = 4x = 32$ (Figs 1J & 2J).

Tu: A1 (A) Çanakkale: Bayramiç, Karaibrahimler'den Cazgırlar'a giderken 1 km kala, 383 m, 2 Nov 2013, *B. Gürdal 405-17, M. Koçyiğit* (ISTE 102319).

The chromosome number of this species is $2n = 32$, tetraploid. Its karyotype consists of $2n = 4x = 22m + 2m\text{-SAT} + 8sm = 32$ chromosomes. Its chromosome length range between 1.66 and 2.98 µm. Its M_{CA} and CV_{CL} values are 14.86 and 16.324, respectively (Table 1). A previous study reported the chromosome number of this species as $2n = 24$ and $2n = 32$ (Doll 1975).

1954. *Taraxacum minimum* (Brig. ex Guss.) N. Terracc. — $2n = 3x = 24$ (Figs 1K & 2K) & $2n = 4x = 32$ (Figs 1L & 2L).

Tu: A2 (A): Yalova: Selimiye, Onno Tunç anıtı civarı, çayırlık, 716 m, 25 Oct 2013, *B. Gürdal 233-77, M. Koçyiğit* (ISTE 101811). – Figs 1K & 2K.

— A1 (A) Çanakkale: Ezine, Gökçebayır'dan Mecidiye'ye 3 km kala, zeytinlik arası, 125 m, 3 Nov 2013, *B. Gürdal 448-17, M. Koçyiğit* (ISTE 102330). – Figs 1L & 2L

Two polyploidy levels (triploid and tetraploid) are obtained for different populations. The chromosome number of the population from Yalova is given as $2n = 32$, tetraploid. Its karyotype formula is $2n = 4x = 32 = 19m + 5m\text{-SAT} + 8sm = 32$. Its chromosome lengths range from 1.06 to 3.21 µm and its M_{CA} and CV_{CL} values are 8.76 and 28.675, respectively (Table 2). Moreover, the chromosome number of the population from Çanakkale (ISTE 102330) is $2n = 24$, triploid. Its karyotype formula is $2n = 3x = 20m + 4m\text{-SAT} = 24$. Its chromosome lengths range from 1.20 to 3.06 µm and its M_{CA} and CV_{CL} values are 9 and 28.75, respectively (Table 1).

The chromosome number of this species has been previously reported as $2n = 16$ and $2n = 32$ (Richards 1969; Brullo & al. 1997).

Results and Discussion

The karyological studies revealed that the basic chromosome number of *Taraxacum* is x = 8. In the literature, satellite chromosomes have been observed in some species (Erlandsson, 1939; Singh & al. 1974; Krahulcova, 1993; Sato & al. 2007; Grzesiuk & al. 2008; Fazili & al. 2011; Kula & al. 2013). According to Mogie & Richards (1983), satellite chromosomes are absent from the most primitive sections of *Taraxacum*, which are geographically distributed between the Mediterranean Region and Central Asia. Plants in these sections are characterised by large, uniform and metacentric chromosomes and are diploid.

Table 1. Karyological features of studied *Taraxacum* species. **CLR**, chromosome length range; **THL**, total haploid chromosome length; $\mathbf{M_{CA}}$, mean centromeric asymmetry; $\mathbf{CV_{CL}}$, variation coefficient of chromosome length; **KF**, karyotype formula.

***Taraxacum* species**	**2*n***	**CLR (µm)**	**THL (µm)**	**M_{CA}**	**CV_{CL}**	**KF** m-SAT
Sect. *Erythrosperma*						
T. aznavourii	24	1.35– 2.81	17.46	20.18	19.343	16m + 2m-SAT + 6sm
T. buttleri	24	0.50 – 0.99	5.595	11.43	22.541	20m + 1m-SAT + 3sm
T. gracilens	24	1.12 – 2.12	12.916	22.98	18.141	18m + 6m
T. pseudobrachyglossum	24	1.07 – 1.72	10.725	5.97	15.365	24m
T. turcicum	24	1.16 – 3.03	16.259	23.53	30.667	13m +2m-SAT + 9sm
T. waltheri	24	1.10 – 2.29	13.719	16.28	21.034	20m + 1m-SAT + 3sm
Sect. *Palustria*						
T. scaturiginosum	24	1.02 – 2.02	11.431	9.09	25.819	24m
Sect. *Scariosa*						
T. aleppicum	32	0.67 – 1.49	9.459	11.86	21.649	28m + 4sm
T. hellenicum	32	1.15 – 2.38	14.178	8.99	19.631	30m + 2m-SAT
T. hyberniforme	32	1.36 – 2.62	15.974	7.00	20.316	27m + 5m-SAT
T. hybernum	32	1.66 – 2.98	19.979	14.86	16.324	22m + 2m-SAT + 8sm
T. minimum	24	1.20 – 3.06	16.952	9.00	28.75	20m + 4m-SAT
	32	1.06 – 3.21	17.305	8.76	28.675	19m + 5m-SAT + 8sm

Satellite chromosomes have not been observed in sections: *Spectabilia*, *Alpina* and *Celtica*. These sections, however, have been reported to possess chromosomes that carry at least one subterminal NOR (nucleolar ratio) region. A satellite chromosome has been observed in each haploid chromosome set of plants in sections: *Macrocornuta*, *Ceratophora*, *Mongolica*, *Tibetana*, *Parvula*, *Kashmirana*, *Erythrocarpa* and *Palustria*. In section *Hamata*, two satellite chromosomes are found in each triploid cell. The number of chromosomes with the satellites is highly variable in sections *Alpestria*, *Fontana*, *Obliqua*, *Erythrosperma*, *Naevosa*, *Crocea* and may vary even at the same foci and even at the same root (Mogie & Richards 1983). In our study, we observed satellites in the karyotypes of *T. aznavourii, T. buttleri, T. hellenicum, T. hyberniforme, T. hybernum, T. minimum, T. turcicum* and *T. waltheri* (sect. *Erythrosperma* and *Scariosa*). In the karyotype of *T. scaturiginosum* (sect. *Palustria*) satellites were not observed. Section *Scariosa* generally comprises tetraploid species in this study. The other sections investigated in this study comprise triploid species. Previous studies on the karyology of *Taraxacum* were based on chromosome number. Recently, however, the karyotype formula with the chromosome number has been reported (Gedik & al. 2014; Sato & al. 2012, 2015).

Gedik & al. (2014) reported karyotype formula and THL of *T. bellidiforme* Van Soest., *T. revertens* G. Hagl. beside the chromosome numbers. Satellites are seen in these species. The chromosome numbers are found $2n = 24$ for *T. bellidiforme*; $2n = 24$ and $2n = 32$ for *T. revertens*. The THL values of *T. bellidiforme* and *T. revertens* are 28.56 and 32.67, respectively. Intrachromosomal asymmetry index and interchromosomal karyotype asymmetry indexes are also calculated in their study. Fazili & al. (2011) found chromosome number of *Taraxacum officinale* of Kashmir as a triploid ($2n = 3x = 24$) with and it shows that the karyotype exhibits Stebbins IA class of asymmetry, which is the most symmetrical

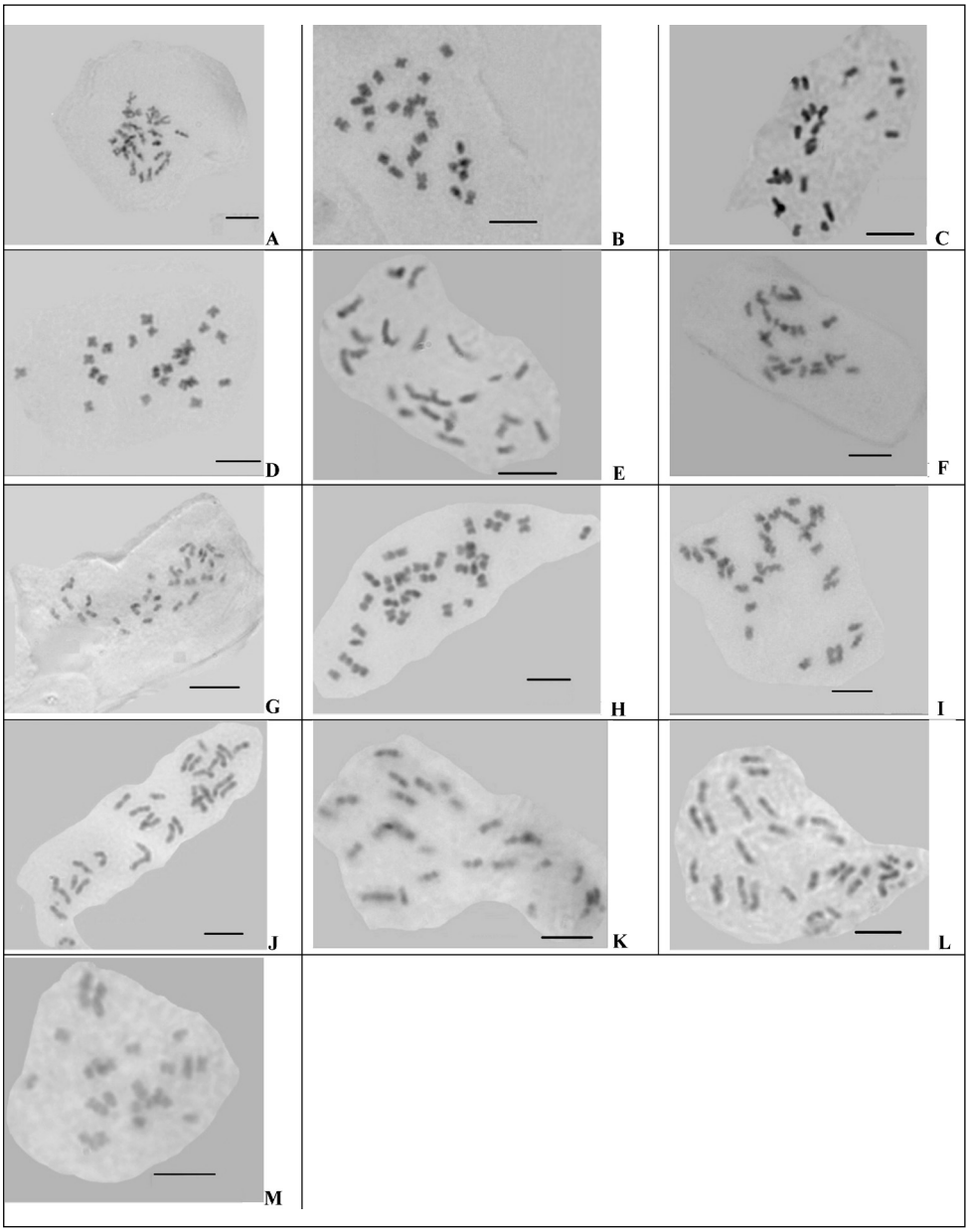

Fig. 1. Mitotic karyotypes of 12 *Taraxacum* species: **A**, *T. aznavourii*, 2*n* = 3x = 24 (ISTE 101782); **B**, *T. buttleri*, 2*n* = 3x = 24 (ISTE 102545); **C**, *T. gracilens*, 2*n* = 3x = 24 (ISTE 101779); **D**, *T. pseudobrachyglossum*, 2*n* = 3x = 24 (ISTE 102404); **E**, *T. turcicum*, 2*n* = 3x = 24 (ISTE 101772); **F**, *T. waltheri*, 2*n* = 3x = 24 (ISTE 107341); **G**, *T. aleppicum*, 2*n* = 4x = 32 (ISTE 102302); **H**, *T. hellenicum*, 2*n* = 4x = 32 (ISTE 102324); I, *T. hyberniforme*, 2*n* = 4x = 32 (ISTE 102310); **J**, *T. hybernum*, 2*n* = 4x = 32 (ISTE 102319); **K & L,** *T. minimum*, 2*n* = 3x = 24 (ISTE 101811) & 2*n* = 4x = 32 (ISTE 102330); **M**, *T. scaturiginosum*, 2*n* = 3x = 24 (ISTE 102400). – Scale bars = 5 µm.

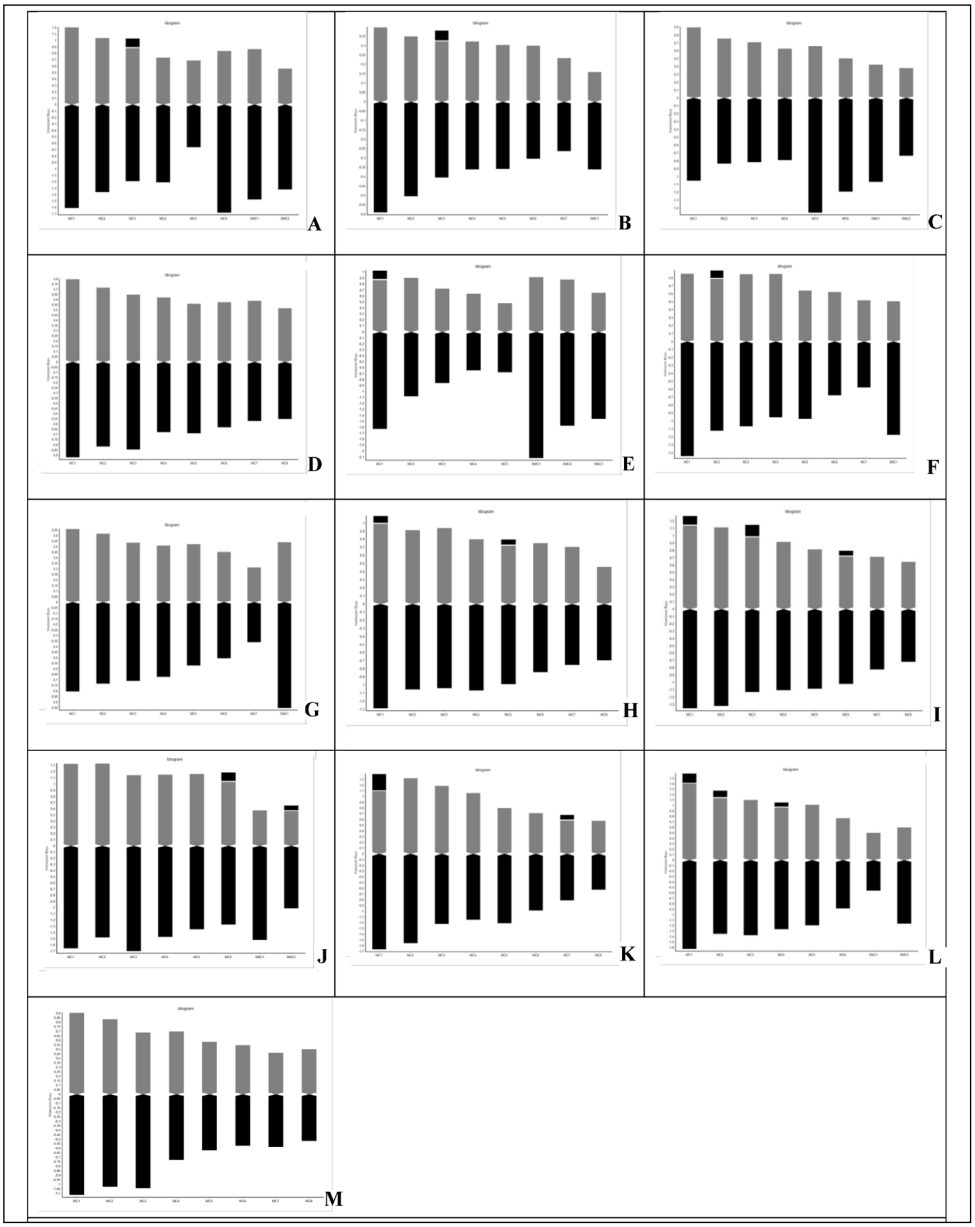

Fig. 2. Idiograms of 12 *Taraxacum* species: **A**, *T. aznavourii*, 2*n* = 3x = 24 (ISTE 101782); **B**, *T. buttleri*, 2*n* = 3x = 24 (ISTE 102545); **C**, *T. gracilens*, 2*n* = 3x = 24 (ISTE 101779); **D**, *T. pseudobrachyglossum*, 2*n* = 3x = 24 (ISTE 102404); **E**, *T. turcicum*, 2*n* = 3x = 24 (ISTE 101772); **F**, *T. waltheri*, 2*n* = 3x = 24 (ISTE 107341); **G**, *T. aleppicum*, 2*n* = 4x = 32 (ISTE 102302); **H**, *T. hellenicum*, 2*n* = 4x = 32 (ISTE 102324); **I**, *T. hyberniforme*, 2*n* = 4x = 32 (ISTE 102310); **J**, *T. hybernum*, 2*n* = 4x = 32 (ISTE 102319); **K & L,** *T. minimum*, 2*n* = 3x = 24 (ISTE 101811) & 2*n* = 4x = 32 (ISTE 102330); **M**, *T. scaturiginosum*, 2*n* = 3x = 24 (ISTE 102400).

class and considered as primitive. Mártonfiová (2013) reported different TCL (total chromosome length) values for different c-metaphases coming from one meristem of *T. linearisquameum* Soest.

In this study, the detailed karyotypes of all studied species are provided for the first time. The previously reported chromosome numbers of *T. buttleri*, *T. turcicum* and *T. waltheri* (sect. *Erythrosperma*) correspond with our results of $2n = 24$. In this study, the chromosome numbers of the other three members of section *Erythrosperma* that are *T. aznavourii*, *T. gracilens* and *T. pseudobrachyglossum* are reported for the first time. Similar to other members of section *Erythrosperma*, *T. aznavourii*, *T. gracilens* and *T. pseudobrachyglossum* have a chromosome number as $2n = 24$. As previously reported in the literature, we found that the chromosome number of *T. scaturiginosum* (sect. *Palustria*), is $2n = 24$; however, the chromosome number of this species has also been reported as $2n = 32$ (Rice & al. 2014; Richards, 1969). We found that the chromosome number of *T. aleppicum* and *T. hellenicum* (sect. *Scariosa*), is $2n = 32$, as previously reported by Doll (1976a). The chromosome number of *T. hybernum* was formerly reported as $2n = 24$ and 32 (Doll, 1975). In this study, however, the chromosome number of this species is $2n = 32$. The chromosome number of *T. minimum* has been reported as $2n = 16$ and $2n = 32$ (Richards 1969; Brullo & al. 1997). The first record ($2n = 16$) indicated that the species is sexual. However, given that one species cannot simultaneously contain sexual and apomictic individuals; this result was likely caused by misidentification. In this study, we found that the chromosome numbers of these species are $2n = 24$ and $2n = 32$.

Recent studies have reported M_{CA} (mean centromeric asymmetry) values in addition to CV_{CL}, CV_{CI}. The CV_{CL} values found in this study ranged from 15.365 to 30.667. Based on M_{CA} and CV_{CL} values, *T. pseudobrachyglossum* has the most symmetric karyotype, whereas *T. turcicum* has the most asymmetric karyotype. M_{CA} and CV_{CL} are positively correlated.

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