Taylor & Francis
Taylor & Francis Group



Caryologia

International Journal of Cytology, Cytosystematics and Cytogenetics

ISSN: 0008-7114 (Print) 2165-5391 (Online) Journal homepage: https://www.tandfonline.com/loi/tcar20

Karyotype analysis of four species of *Dianthus* section *Fimbriati* (Caryophyllaceae, Sileneae)

Emine Şahin, Halil Erhan Eroğlu, Ergin Hamzaoğlu & Murat Koç

To cite this article: Emine Şahin, Halil Erhan Eroğlu, Ergin Hamzaoğlu & Murat Koç (2016) Karyotype analysis of four species of *Dianthus* section *Fimbriati* (Caryophyllaceae, Sileneae), Caryologia, 69:3, 267-272, DOI: 10.1080/00087114.2016.1179527

To link to this article: https://doi.org/10.1080/00087114.2016.1179527

Published online: 06 Jun 2016.

Submit your article to this journal

Article views: 283

View related articles

View Crossmark data

Citing articles: 2 View citing articles

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=tcar20

CARYOLOGIA: INTERNATIONAL JOURNAL OF CYTOLOGY, CYTOSYSTEMATICS AND CYTOGENETICS, 2016
VOL. 69, NO. 3, 267–272
http://dx.doi.org/10.1080/00087114.2016.1179527

Taylor & Francis
Taylor & Francis Group

Karyotype analysis of four species of *Dianthus* section *Fimbriati* (Caryophyllaceae, Sileneae)

Emine Şahin[a], Halil Erhan Eroğlu[b], Ergin Hamzaoğlu[c] and Murat Koç[d]

[a]Department of Biology, Graduate School of Natural and Applied Sciences, Bozok University, Yozgat, Turkey; [b]Department of Biology, Faculty of Science and Art, Bozok University, Yozgat, Turkey; [c]Department of Elementary Education, Gazi Faculty of Education, Gazi University, Ankara, Turkey; [d]Animal Production High School, Bozok University, Yozgat, Turkey

ABSTRACT

Karyotypic characters, mitotic metaphase chromosomes, monoploid ideograms and karyograms of *Dianthus* L. section *Fimbriati* Boiss., *D. tabrisianus* Bien.ex Boiss., *D. sessiliflorus* Boiss., *D. stramineus* Boiss. & Heldr., and *D. erythrocoleus* Boiss. were investigated for the first time. Analysis of somatic metaphases showed that the chromosome numbers and the karyotype formula of these taxa were $2n = 30 = 22m + 6sm + 2st$ for *D. tabrisianus*, $2n = 30 = 14m + 8sm + 8st$ for *D. sessiliflorus*, $2n = 30 = 20m + 4sm + 6st$ for *D. stramineus* and $2n = 30 = 18m + 8sm + 4st$ *D. erythrocoleus*. No satellites were observed in the karyotypes of these species. The interchromosomal and intrachromosomal karyotype asymmetries were estimated with coefficient of variation of chromosome length (CV_{CL}) and mean centromeric asymmetry (M_{CA}).

ARTICLE HISTORY
Received 3 June 2015
Accepted 14 April 2016

KEYWORDS
Dianthus; ideogram; karyotype; symmetry/asymmetry index

Introduction

Dianthus L. is placed in the subfamily Sileneae DC. in the family Caryophyllaceae. It is a large genus, consisting of approximately 300 species found in Europe, Asia, Africa and North America (Bittrich 1993; Vaezi et al. 2014). The genus was represented by 121 species in *Flora Europaea* (Tutin 1964), 78 species in *Flora of the USRR* (Shishkin 1995), 49 species in *Flora Iranica* (Rechinger 1988), 19 species in *Flora of Syria, Palestine and Sinai* (Post 1932), eight species in *Flora Palestina* (Zohary 1966), three species in *Flora of Iraq* (Rechinger 1964), and three species in *Flora of Cyprus* (Meikle 1977). The most comprehensive taxonomic study of Turkish *Dianthus* was carried out by Reeve (1967). In the light of the latest data, the genus includes 74 species, two subspecies and 12 varieties found in five sections in the flora of Turkey (Davis et al. 1988; Güner 2000; Menemen and Hamzaoğlu 2000; Aytaç and Duman 2004; Vural 2008; Yılmaz et al. 2011; İlçim et al. 2013). The taxa of section *Fimbriati* are distinguished from other taxa with fimbriate petals (Boissier 1867; Reeve 1967). The section *Fimbriati* includes nine species in the Flora of Turkey (Reeve 1967). Petal surface with glabrous or barbulate is one of the most important distinctive characters among species. *D. tabrisianus*, *D. sessiliflorus*, *D. stramineus*, *D. erythrocoleus* and *D. crinitus* Sm. have glabrous petals (Reeve 1967).

The chromosomal measurements and karyotype symmetry/asymmetry are the most important taxonomic characters, together with morphological characters (Eroğlu et al. 2013; Peruzzi and Eroğlu 2013), as the chromosome numbers of organisms are highly variable (Peruzzi and Bedini 2014). There are different karyotype symmetry/asymmetry formulae in higher plants (Paszko 2006; Peruzzi and Eroğlu 2013), animals and humans (Eroğlu 2015). Different chromosome counts have been reported in the genus *Dianthus*. However, the most frequent chromosome number in the genus *Dianthus* is diploid $2n = 30$. Other counts such as $2n = 60$, 90 and 120 are also known (Güner 2000).

Although there are several chromosome reports on *Dianthus* (Güner 2000), no information on chromosome numbers and karyotype analysis of the investigated species was found in the literature. The aim of this study is to investigate the chromosome number, karyotype, idiogram and other detailed measurements within four species of *Dianthus* section *Fimbriati*. *D. sessiliflorus* and *D. stramineus* of these species are narrow endemic in Turkey. *D. tabrisianus* and *D. erythrocoleus* grow wild in Turkey and Iran (Reeve 1967; Rechinger 1988).

Material and methods

The plant materials were collected from natural habitats in different localities (Table 1). Ergin Hamzaoğlu and Murat Koç authenticated the plant material. The voucher specimens have been deposited in the Herbarium of Gazi University (GAZI). The seeds were germinated between moist Whatman papers in Petri dishes. The root tips

CONTACT Halil Erhan Eroğlu herhan.eroglu@bozok.edu.tr

© 2016 Dipartimento di Biologia Evoluzionistica, Università di Firenze

Table 1. Localities, coordinates, collector name and numbers of studied species.

Species	Locality	Coordinate	Collectors and herbarium
D. tabrisianus	Kars: Digor, between Digor and Iğdır, 27 August 2012, 1375 m	40° 10' N 43° 30' E	Hamzaoğlu 6657 & Koç (GAZI)
D. sessiliflorus	Muş: Varto, Bingöl Mountain, 25 July 2013, 3120 m	39° 20' N 41° 20' E	Hamzaoğlu 6935 & Koç (GAZI)
D. stramineus	Konya: Akören, between Belkuyu and Dutlu, 18 June 2013, 1200 m	40° 40' N 42° 10' E	Hamzaoğlu 6767 & Koç (GAZI)
D. erythrocoleus	Van: Bahçesaray, around Karapet Pass, 24 July 2013, 3100 m	38° 00' N 42° 50' E	Hamzaoğlu 6911 & Koç (GAZI)

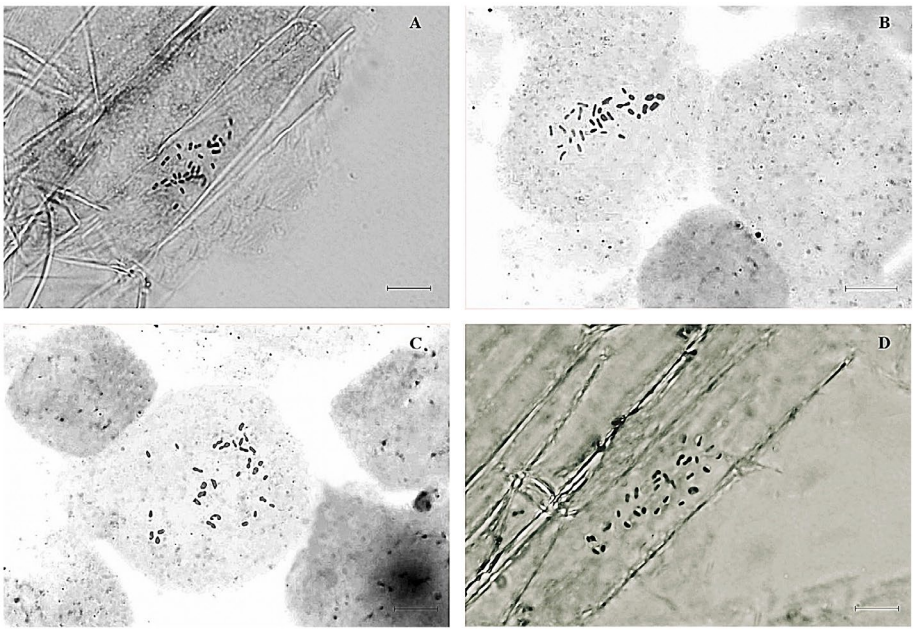

Figure 1. Somatic metaphase chromosomes of four species of *Dianthus* section *Fimbriati*. A: *D. tabrisianus*; B: *D. sessiliflorus*; C: *D. stramineus*; D: *D. erythrocoleus*. All scale bars = 10 µm.

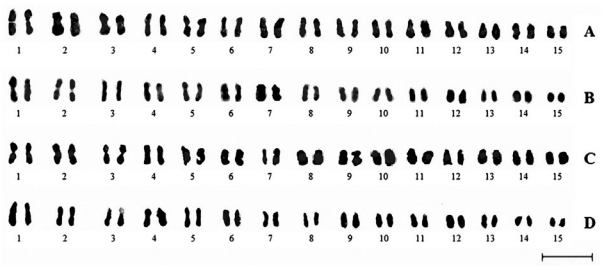

Figure 2. Karyograms of four species of *Dianthus* section *Fimbriati*. A: *D. tabrisianus*; B: *D. sessiliflorus*; C: *D. stramineus*; D: *D. erythrocoleus*. Scale bar = 5 µm.

were fixed in Carnoy's fixative (3:1 absolute alcohol: glacial acetic acid) at +4°C overnight after pre-treatment in colchicine (0.2% w/v) for 2 h. Root tips were stained with acetocarmine. Preparations were made using the squash method. At least 10 metaphase cells were used to determine chromosome numbers. The metaphase chromosomes were photographed by Olympus BX53 digital camera (Olympus Corporation, Tokyo, Japan) and measured using the Bs200ProP image processing and analysis system (BAB Image Analysing Systems, Ankara, Turkey).

Karyotype formula was determined by chromosome morphology based on centromere position according to the classification of Levan et al. (1964). The following parameters were estimated to characterize the karyotypes numerically: long arm length (LAL), short arm length (SAL), total chromosome length (TCL) = [LAL + SAL], arm ratio (AR) = [LAL/SAL] and centromeric index (CI) = [SAL / (LAL + SAL) × 100]. For each species, karyograms were drawn based on length of chromosome size (arranged large to small).

The interchromosomal and intrachromosomal karyotype asymmetries were estimated with coefficient of variation of chromosome length (CV_{CL}) (Paszko 2006) and mean centromeric asymmetry (M_{CA}) (Peruzzi and Eroğlu 2013). Asymmetry indexes were compared with Pearson correlation.

Results

Dianthus tabrisianus

Mitotic metaphase chromosomes, karyotype and monoploid ideogram of *D. tabrisianus* are given in Figures 1–3, respectively. The measurement data of these chromosomes are given in Table 2. Analysis of somatic metaphases showed that the chromosome number of the species is $2n = 30$. The formula is 22m + 6sm +2st. No satellite was observed in the chromosomes. The length of chromosomes varied from 1.09 to 2.68 µm, and the total haploid length was 28.36 µm. The average length of chromosomes was 1.89 µm. The CI varied from 25.00 to 50.00 µm. The analysis of the interchromosomal

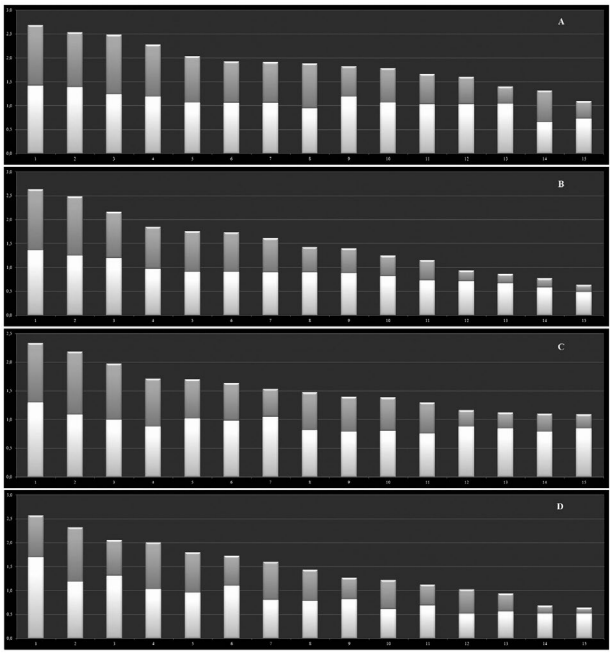

Figure 3. Ideograms of four species of *Dianthus* section *Fimbriati*. A: *D. tabrisianus*; B: *D. sessiliflorus*; C: *D. stramineus*; D: *D. erythrocoleus*.

and intrachromosomal karyotype asymmetry indexes showed values of 24.17 and 15.81 for CV_{CL} and M_{CA}, respectively.

Dianthus sessiliflorus

Mitotic metaphase chromosomes, karyotype and monoploid ideogram of *D. sessiliflorus* are given in Figures 1–3, respectively. The measurement data of these chromosomes are given in Table 2. Analysis of somatic metaphases showed that the chromosome number of the species is $2n = 30$. The formula is 14m + 8sm + 8st. No satellite was observed in the chromosomes. The length of chromosomes varied from 0.63 to 2.63 µm, and the total haploid length was 22.59 µm. The average length of chromosomes was 1.51 µm. The CI varied from 22.09 to 49.60 µm. The analysis of the interchromosomal and intrachromosomal karyotype asymmetry indexes showed values of 40.24 and 24.61 for CV_{CL} and M_{CA}, respectively.

Dianthus stramineus

Mitotic metaphase chromosomes, karyotype and monoploid ideogram of *D. stramineus* are given in Figures 1–3, respectively. The measurement data of these chromosomes are given in Table 2. Analysis of somatic metaphases showed that the chromosome number of the species is $2n = 30$. The formula is 20m + 4sm + 6st. No satellite was observed in the chromosomes. The length of chromosomes varied from 1.09 to 2.33 µm, and the total haploid length was 23.05 µm. The average length of chromosomes was 1.54 µm. The CI varied from 22.02 to 50.00 µm. The analysis of the interchromosomal and intrachromosomal karyotype asymmetry indexes showed values of 25.31 and 23.81 for CV_{CL} and M_{CA}, respectively.

Dianthus erythrocoleus

Mitotic metaphase chromosomes, karyotype and monoploid ideogram of *D. erythrocoleus* are given in Figures 1–3, respectively. The measurement data of these chromosomes are given in Table 2. Analysis of somatic metaphases showed that the chromosome number of the species is $2n = 30$. The formula is 18m + 8sm + 4st. No satellite was observed in the chromosomes. The length of chromosomes varied from 0.64 to 2.57 µm, and the total haploid length was 22.33 µm. The average length of chromosomes was 1.49 µm. The CI varied from 18.75 to 49.59 µm. The analysis of the interchromosomal and intrachromosomal karyotype asymmetry indexes showed values of 39.22 and 20.26 for CV_{CL} and M_{CA}, respectively.

Discussion

Cytogenetic characters, especially chromosome number, chromosome size and chromosome asymmetry, are preferred characters in plant taxonomy. These data are also important to elucidate the origin, speciation and phylogenetic relationships of plants (Eroğlu et al. 2013). The chromosome numbers of *Dianthus tabrisianus*, *D. sessiliflorus*, *D. stramineus* and *D. erythrocoleus* are $2n = 30$. All species have small chromosomes between 0.63 and 2.68 µm. The chromosomes were showed little variation in size within the complement (Table 2).

There are nine species and 12 taxa in section *Fimbriati* (Reeve 1967). In section *Fimbriati* it is reported that the chromosome numbers of *Dianthus crinitus* var. *crinitus* (Khatoon and Ali 1993), *D. orientalis* Donn subsp. *orientalis* (Gadnidze et al. 1998) and *D. orientalis* Donn subsp. *nassireddini* (Stapf) Rech.f. (Ghaffari 2006) were $2n = 30$. The chromosome numbers of three populations of *D. crinitus* were $2n = 60$ (Jafari and Behroozian 2010). The predominant diploid number of chromosomes in *Dianthus* is $2n = 30$. Other common chromosome numbers are $2n = 60$, 90 and 120 (Khatoon and Ali 1993; Gadnidze et al. 1998; Ghaffari 2006; Güner 2000). In section *Fimbriati* the diploid number of chromosomes is $2n = 30$.

The CV_{CL} value is perfectly suited for the measure of interchromosomal asymmetry (Paszko 2006). It varies between 0 (no variation) and 100. The CV_{CL} values of *Dianthus tabrisianus*, *D. sessiliflorus*, *D. stramineus* and *D. erythrocoleus* are 24.17, 40.24, 25.31 and 39.22, respectively. The M_{CA} value is perfectly suited for the measure of intrachromosomal asymmetry (Peruzzi and Eroğlu 2013). It varies between 0 (perfectly symmetric) and 100 (perfectly asymmetric). The M_{CA} values of

Table 2. The measurement data of chromosomes of species of *Dianthus* section *Fimbriati*.

Species	Chromosome pair	TCL(μm)	LAL(μm)	SAL(μm)	AR	Chromosome type	CI
D. tabrisianus	1	2.68	1.42	1.26	1.127	m	47.01
D. sessiliflorus	1	2.63	1.36	1.27	1.071	m	48.29
D. stramineus	1	2.33	1.30	1.03	1.262	m	44.21
D. erythrocoleus	1	2.57	1.70	0.87	1.954	sm	33.85
D. tabrisianus	2	2.53	1.39	1.14	1.219	m	45.06
D. sessiliflorus	2	2.48	1.25	1.23	1.016	m	49.60
D. stramineus	2	2.18	1.09	1.09	1.000	m	50.00
D. erythrocoleus	2	2.32	1.19	1.13	1.053	m	48.71
D. tabrisianus	3	2.48	1.24	1.24	1.000	m	50.00
D. sessiliflorus	3	2.16	1.20	0.96	1.250	m	44.44
D. stramineus	3	1.97	1.00	0.97	1.031	m	49.24
D. erythrocoleus	3	2.05	1.31	0.74	1.770	sm	36.10
D. tabrisianus	4	2.27	1.19	1.08	1.102	m	47.58
D. sessiliflorus	4	1.84	0.97	0.87	1.115	m	47.28
D. stramineus	4	1.71	0.88	0.83	1.060	m	48.54
D. erythrocoleus	4	2.00	1.03	0.97	1.062	m	48.50
D. tabrisianus	5	2.03	1.07	0.96	1.115	m	47.29
D. sessiliflorus	5	1.75	0.91	0.84	1.083	m	48.00
D. stramineus	5	1.70	1.02	0.68	1.500	m	40.00
D. erythrocoleus	5	1.79	0.96	0.83	1.157	m	46.37
D. tabrisianus	6	1.92	1.06	0.86	1.233	m	44.79
D. sessiliflorus	6	1.73	0.91	0.82	1.110	m	47.40
D. stramineus	6	1.63	0.98	0.65	1.508	m	39.88
D. erythrocoleus	6	1.72	1.10	0.62	1.774	sm	36.05
D. tabrisianus	7	1.91	1.06	0.85	1.247	m	44.50
D. sessiliflorus	7	1.61	0.90	0.71	1.268	m	44.10
D. stramineus	7	1.53	1.05	0.48	2.188	sm	31.37
D. erythrocoleus	7	1.59	0.81	0.78	1.038	m	49.06
D. tabrisianus	8	1.88	0.95	0.93	1.022	m	49.47
D. sessiliflorus	8	1.42	0.90	0.52	1.731	sm	36.62
D. stramineus	8	1.47	0.82	0.65	1.262	m	44.22
D. erythrocoleus	8	1.43	0.78	0.65	1.200	m	45.45
D. tabrisianus	9	1.82	1.19	0.63	1.889	sm	34.62
D. sessiliflorus	9	1.39	0.88	0.51	1.725	sm	36.69
D. stramineus	9	1.39	0.79	0.60	1.317	m	43.17
D. erythrocoleus	9	1.26	0.82	0.44	1.864	sm	34.92
D. tabrisianus	10	1.78	1.07	0.71	1.507	m	39.89
D. sessiliflorus	10	1.24	0.82	0.42	1.952	sm	33.87
D. stramineus	10	1.38	0.81	0.57	1.421	m	41.30
D. erythrocoleus	10	1.21	0.61	0.60	1.017	m	49.59
D. tabrisianus	11	1.66	1.03	0.63	1.635	m	37.95
D. sessiliflorus	11	1.15	0.73	0.42	1.738	sm	36.52
D. stramineus	11	1.29	0.76	0.53	1.434	m	41.09
D. erythrocoleus	11	1.12	0.69	0.43	1.605	m	38.39
D. tabrisianus	12	1.60	1.03	0.57	1.807	sm	35.63
D. sessiliflorus	12	0.93	0.71	0.22	3.227	st	23.66
D. stramineus	12	1.16	0.88	0.28	3.143	st	24.14
D. erythrocoleus	12	1.02	0.52	0.50	1.040	m	49.02
D. tabrisianus	13	1.40	1.05	0.35	3.000	st	25.00
D. sessiliflorus	13	0.86	0.67	0.19	3.526	st	22.09
D. stramineus	13	1.12	0.85	0.27	3.148	st	24.11
D. erythrocoleus	13	0.93	0.56	0.37	1.514	m	39.78
D. tabrisianus	14	1.31	0.66	0.65	1.015	m	49.62
D. sessiliflorus	14	0.77	0.58	0.19	3.053	st	24.68
D. stramineus	14	1.10	0.79	0.31	2.548	sm	28.18
D. erythrocoleus	14	0.68	0.52	0.16	3.250	st	23.53
D. tabrisianus	15	1.09	0.73	0.36	2.028	sm	33.03
D. sessiliflorus	15	0.63	0.49	0.14	3.500	st	22.22
D. stramineus	15	1.09	0.85	0.24	3.542	st	22.02
D. erythrocoleus	15	0.64	0.52	0.12	4.333	st	18.75

Abbreviations: TCL: total chromosome length; LAL: long arm length; SAL: short arm length; AR: arm ratio; CI: centromeric index; m: median; sm: sub-median; st: sub-terminal.

D. tabrisianus, *D. sessiliflorus*, *D. stramineus* and *D. erythrocoleus* are 15.81, 24.61, 23.81 and 20.26, respectively. The values of CV_{CL} and M_{CA} increase with increasing asymmetry. The symmetrical karyotype is defined with median and sub-median chromosomes. The location of centromere position changes in intrachromosomal karyotype asymmetry. In addition, the sizes of large and small chromosomes are quite different in interchromosomal karyotype asymmetry (Peruzzi et al. 2009). According to the CV_{CL} and M_{CA} values, *D. tabrisianus* is the most symmetrical karyotype, while *D. sessiliflorus* is the most asymmetrical karyotype. According to the CV_{CL} value, *D. stramineus* is more symmetrical than *D. erythrocoleus*, but *D. erythrocoleus* is more symmetrical than *D. stramineus* in M_{CA} value. Weak positive correlation was observed between CV_{CL} and M_{CA} (r = 0.441) (Figure 4). The weak positive correlation is a result of a change in place of symmetry/

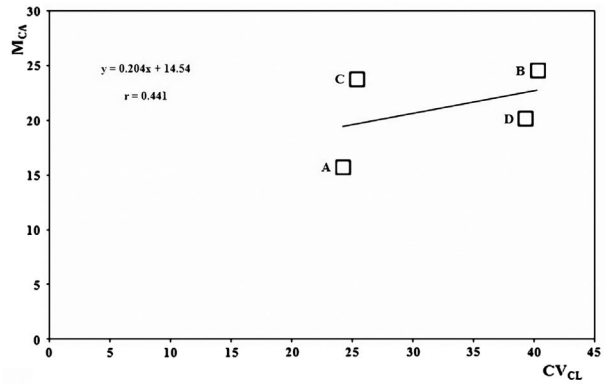

Figure 4. Scatter diagram between CV_{CL} and M_{CA}: A: *D. tabrisianus*; B: *D. sessiliflorus*; C: *D. stramineus*; D: *D. erythrocoleus*.

asymmetry position between *D. stramineus* and *D. erythrocoleus*. This is due to the CV_{CL} parameters. The CV_{CL} provides the most reliable data when used together with M_{CA}. For instance, the karyotype could not be discriminated by CV_{CL}, if there is not variation in chromosome size (Peruzzi and Eroğlu 2013).

Dianthus tabrisianus, *D. sessiliflorus*, *D. stramineus* and *D. erythrocoleus* are quite different species morphologically. A key to closely relate to the taxonomic status of these species is given below. The key was made from plant samples collected for cytogenetic analysis.

1. Stems 2–12 cm, 1–3-noded; epicalyx scales 4(–6), indistinctly 1-3-veined at apex **2**
– Stems 15–45 cm, 5–11-noded; epicalyx scales (4–)6–10(–12), distinctly 3-5-veined or indistinctly 5–9-veined at apex **3**
2. Calyx 20–26(–30) mm; teeth 5–7.5 mm long; petal 23–28(–32) mm, limb 9–15-toothed .....***D. erythrocoleus***
– Calyx 14–18 mm; teeth 3–5 mm long; petal 18–21 mm, limb 5–9-toothed .....***D. sessiliflorus***
3. Calyx teeth narrowly triangular, 2.2–5 mm long; inner epicalyx scales 1/2–3/5 as long as calyx, with scarious (0.4–0.6 mm) margins; petal limb 7–9-toothed, claw 14–19 mm long, collar as wide as claw.....***D. tabrisianus***
– Calyx teeth linear-oblong, 6.5–8.5 mm long; inner epicalyx scales 1/3–2/5 as long as calyx, with scarious (0.2–0.3 mm) margins; petal limb 11–15-toothed, claw 20–26 mm long, collar 1/2 as wide as claw .....***D. stramineus***

There are differences among species in karyotype formulae and karyotype asymmetry indexes. These differences seemed to support morphological differences. Although karyotype formula and karyotype asymmetry are not distinctive characters for all *Dianthus* taxa, there are similarities between morphological differences and cytogenetic differences of studied species. Seijo and Fernandez (2003) reported that the differences found among species in asymmetry indexes and karyotype formulae may contribute to the diversification of the genus. For example, *D. sessiliflorus* and *D. erythrocoleus* are different from *D. tabrisianus* and *D. stramineus* morphologically and grow in alpine regions and high altitudes (Table 1). Also, *D. sessiliflorus* and *D. erythrocoleus* are different from *D. tabrisianus* and *D. stramineus* in the following ways: (i) lower number of median chromosomes; and (ii) more asymmetric karyotype. *D. sessiliflorus* and *D. erythrocoleus* show different locations in Figure 4.

In this study, the chromosome numbers, karyotypes, ideograms and karyotype asymmetry degrees of four species of section *Fimbriati* were determined. The chromosome numbers of the studied species were firstly reported. In all species the same chromosome number ($2n=30$) was found. The karyotypes of *Dianthus tabrisianus*, *D. sessiliflorus*, *D. stramineus* and *D. erythrocoleus* were quite symmetric, because they have a large number of median chromosomes, a small number of sub-median chromosomes and several sub-terminal chromosomes.

Disclosure statement

No potential conflict of interest was reported by the author.

Funding information

This work was financially supported by TUBITAK [project number: KBAG–111T873] and Scientific Research Projects Fund of Bozok University [project number: 2015FBE/T183 and 184].

ORCID details

Halil Erhan Eroğlu http://orcid.org/0000-0002-4509-4712
Murat Koç http://orcid.org/0000-0002-1156-0068

References

Aytaç Z, Duman H. 2004. Six new taxa (Caryophyllaceae) from Turkey. Ann Bot Fenn. 41(3):213–223.
Bittrich V. 1993. Caryophyllaceae. In: Kubitzki K, Rohwer JG, Bittrich V, editors. The families and genera of vascular plants, Magnoliid, Hamamelid, and Caryophyllid families. vol 2. Berlin: Springer Verlag; p. 232.
Boissier E. 1867. Flora Orientalis. Vol. 1. Geneva & Basel: H. Georg; p. 479–516.
Davis PH, Mill RR, Tan K. 1988. Flora of Turkey and the East Aegean Islands. Vol. 10. Edinburgh: Edinburgh University Press; p. 71–72.
Eroğlu HE. 2015. Which chromosomes are subtelocentric or acrocentric? A new karyotype symmetry/asymmetry index. Caryologia. 68(3):239–245.
Eroğlu HE, Şimşek N, Koç M, Hamzaoğlu E. 2013. Karyotype analysis of some *Minuartia* L. (Caryophyllaceae) taxa. Plant Syst Evol. 299(1):67–73.
Gadnidze RI, Gviniashvili TN, Danelia IM, Churadze MV. 1998. Chromosome numbers of the species of the Georgian flora. Bot Žh (Moscow & Leningrad). 83(10):143–147.

Ghaffari SM. 2006. New or rare chromosome counts of some angiosperm species from Iran. Iran J Bot. 11(2):185–192.
Güner A. 2000. *Dianthus* L. In: Güner A, Özhatay N, Ekim T, Başer KHC, editors. Flora of Turkey and the East Aegean Islands. vol 11. Edinburgh: Edinburgh University Press; p. 48–49.
İlçim A, Behçet L, Mükemre M. 2013. *Dianthus vanensis* (Caryophyllaceae), a new species from Turkey. Turk J Bot. 37(2):219–224.
Jafari A, Behroozian M. 2010. A cytotaxonomic study on *Dianthus* L. species in North Eastern Iran. Asian J Plant Sci. 9(1):58–62.
Khatoon S, Ali SI. 1993. Chromosome atlas of the Angiosperms of Pakistan. Karachi: Department of Botany, University of Karachi.
Levan AK, Fredga K, Sandberg AA. 1964. Nomenclature for centromeric position on chromosomes. Hereditas. 52(2):201–220.
Meikle RD. 1977. Flora of Cyprus. Vol. 1. Kew: Bentham–Moxon Trust, Royal Botanic Gardens; p. 214–218.
Menemen Y, Hamzaoğlu E. 2000. A new species of *Dianthus* (Caryophyllaceae) from Salt Lake, Central Anatolia. Turkey. Ann Bot Fenn. 37(4):285–287.
Paszko B. 2006. A critical review and a new proposal of karyotype asymmetry indices. Plant Syst Evol. 258 (1–2):39–48.
Peruzzi L, Bedini G. 2014. Online resources for chromosome number databases. Caryologia. 67(4):292–295.
Peruzzi L, Eroğlu HE. 2013. Karyotype asymmetry: again, how to measure and what to measure? Comp Cytogen. 7(1):1–9.
Peruzzi L, Leitch IJ, Caparelli KF. 2009. Chromosome diversity and evolution in Liliaceae. Ann Bot London. 103(3):459–475.
Post GE. 1932. Flora of Syria, Palestina and Sinai. Vol. 1. Beirut: Syrian Protestant College; p. 154–160.
Rechinger KH. 1964. *Dianthus* L. In: Rechinger KH, editor. Flora of Lowland Iraq. Weinheim: J. Cramer; p. 245–246.
Rechinger KH. 1988. Caryophyllaceae II, *Dianthus* L. In: Rechinger KH, editor. Flora Iranica. vol 163. Graz: Akademische Druck-u Verlagsanstalt; p. 128–188.
Reeve H. 1967. *Dianthus* L. In: Davis PH, editor. Flora of Turkey and the East Aegean Islands. vol 2. Edinburgh: Edinburgh University Press; p. 99–131.
Seijo GS, Fernandez A. 2003. Karyotype analysis and chromosome evolution in South American species of *Lathyrus* (Leguminosae). Am J Bot. 90(7):980–987.
Shishkin BK. 1995. *Dianthus* L. In: Shishkin BK, editor. Flora of the USRR. Vol. 26. Moscow–Leningrad: Bishen Singh Mahendra Pal Singh and Koeltz Scientific Books (English version); p. 611–654.
Tutin GT. 1964. *Dianthus* L. In: Tutin TG, Heywood VH, Burges NA, Valentine DH, Walters SM, Webb DA, editors. Flora Europaea. vol 1. Cambridge: Cambridge University Press; p. 227–246.
Vaezi J, Behroozian M, Memariani F, Joharchi MR. 2014. *Dianthus pseudocrinitus* (Caryophyllaceae), a new species from Northeast of Iran identified by morphological and molecular data. Phytotaxa. 156(2):59–73.
Vural C. 2008. A new species of *Dianthus* (Caryophyllaceae) from Mount Erciyes, Central Anatolia. Turkey. Bot J Linn Soc. 158(1):55–61.
Yılmaz Ö, Kaynak G, Daşkın R, Meriçlioğlu A. 2011. *Dianthus goekayi* (Caryophyllaceae), a new species from Turkey. Ann Bot Fenn. 48(1):74–78.
Zohary M. 1966. *Dianthus* L. In: Zohary M, editor. Flora Palestina. Vol 1. Jerusalem: Israel Academy of Sciences and Humanities; p. 106–111.