

KARYOLOGICAL STUDY OF SOME *GERANIUM* SPECIES (GERANIACEAE) FROM ARMENIA

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The genus *Geranium* is represented by 20 species in Armenian flora. In the present study 9 species of this genus from the territory of Armenia were karyologically investigated for the first time: *G. columbinum*, $2n = 18$ (sect. *Columbinum*); *G. ibericum*, $2n = 28$, *G. sylvaticum*, $2n = 28$ (sect. *Geranium*); *G. lucidum*, $2n = 40$ (sect. *Robertiana*); *G. pyrenaicum*, $2n = 26$; *G. pusillum*, $2n = 26$; *G. molle*, $2n = 26$; *G. rotundifolium*, $2n = 26$; *G. divaricatum*, $2n = 26$ (sect. *Rotundifolia*).

Keywords: chromosome number, karyotype, cytorace, flora of Armenia, *Geranium*

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The species of the genus *Geranium* are common in temperate zones of the Earth and in high mountains of tropical zones. The genus *Geranium* includes about 400 species (Aedo, 2003). Most species are polymorphic. The genus *Geranium* is distributed in Armenia and is represented by 20 species from 8 sections: *Sanguineum* Knuth (1 species), *Columbinum* Koch (2), *Geranium* (5), *Robertiana* Boiss. (2), *Palustra* Knuth (2), *Pyrenaica* Knuth (1), *Rotundifolia* Gams. (5) and *Tuberosa* Boiss. (2) (Table 1). The classification of the genus was carried out according to the system of R. Knuth (Knuth, 1912).

Determination of chromosome numbers is the first step in any karyological study. As karyological data accumulate they can be used in the systematics. The study of chromosome numbers, in some cases, makes it possible to clarify the issues of evolution, speciation and phylogenetic relationships. Available data on chromosome numbers make it possible to better understand a taxon, species, or even family.

Data on the chromosome numbers of species can be found in different books of references, (Fedorov (ed.), 1969; Takhtajan (ed.), 1993; Moore, 1977; Goldblatt, 1981–1988; Goldblatt, Johnson, 1990–1996). Information on the chromosome numbers of species occurring in Armenia is presented in the book “Chromosome numbers of flowering plants of the Armenian flora” (Nazarova, Ghukasyan, 2004), which summarizes the data on about 900 species from more

than 2000 populations, 51 families belonging to 320 genera. Until now, the members of the genus *Geranium* growing in Armenia have not been studied karyologically.

MATERIAL AND METHODS

The determination of the chromosome numbers and the description of the species karyotypes were carried out by light microscopy. The seeds were germinated on wet filter paper in Petri dishes in the laboratory (19–21°C). The karyological studies were made on the mitotic metaphases of the meristematic cells from root tips. The root tips were pretreated in 0.4% colchicine solution for 2 hours and fixed in fluid 3:1 alcohol and glacial acetic acid for at least 2 hours at room temperature. After hydrolysis in HCl 1N for 10–15 minutes at 60°C, the root tips were stained in Schiff reagent for 1.5 hours. Then the root tips were squashed on a glass slide with 45% acetic acid. For all chromosome counts, at least 10 plates were examined for each taxon.

The stained roots were washed in warm water and placed on a glass slide. The colored tip of the rootlet (0.5–1 mm) was crushed in 45° acetic acid under a coverslip. After a preliminary examination of the smears under a microscope, the preparations were placed in buthyl alcohol for 5 minutes, then in xylene for 5 minutes, and were placed in Canadian balsam.

Table 1. Chromosomes numbers of the genus *Geranium* L. species (according to original and literature data)

Section	Species	Chromosomes numbers (2n)
<i>Sanquineum</i> Knuth	<i>G. sanguineum</i> L.	≈56, 80, 82, 84
	<i>Columbinum</i> Koch	<i>G. columbinum</i> L.
	<i>G. dissectum</i> L.	22
<i>Geranium</i>	<i>G. ibericum</i> Cav.	28 , 56
	<i>G. montanum</i> Habl. ex Pall.	—
	<i>G. platypetalum</i> Fisch. et C.A. Mey.	42
	<i>G. sylvaticum</i> L.	24, 28
	<i>G. ruprechtii</i> (Woronow) Grossh.	—
<i>Robertiana</i> Boiss	<i>G. robertianum</i> L.	32, 54, 56, 64
	<i>G. lucidum</i> L.	20, ≈40, 40 –44, 42
<i>Palustra</i> Knuth	<i>G. palustre</i> L.	28, 56
	<i>G. collinum</i> Steph. ex Willd.	28
<i>Pyrenaica</i> Knuth	<i>G. albanum</i> Bieb.	28
<i>Rotundifolia</i> Gams.	<i>G. pyrenaicum</i> Burm. f.	20, 22–24, 26 , 28
	<i>G. pusillum</i> L.	26 , 34
	<i>G. molle</i> L.	26
	<i>G. rotundifolium</i> L.	26
	<i>G. divaricatum</i> Ehrh.	26 , 28
<i>Tuberosa</i> Boiss.	<i>G. tuberosum</i> L.	28
	<i>G. linearilobum</i> DC.	—

Note. * The chromosomes numbers determined on the Armenian material by the authors are highlighted in bold.

The karyological study was based on the samples of the genus *Geranium* (Geraniaceae) species collected by R. Adamyan, K. Tamanyan, G. Fayvush and others, during expeditions in 2003–2010 in different regions of Armenia. Herbarium material of the Institute of Botany of National Academy of Sciences (ERE) and Yerevan State University (EREU) was studied.

RESULTS AND DISCUSSION

There are 20 species of the genus *Geranium* in the flora of Armenia, and following species were studied by us karyologically: *G. columbinum*, $2n = 18$ (sect. *Columbinum*); *G. ibericum*, $2n = 28$, *G. sylvaticum*, $2n = 28$ (sect. *Geranium*); *G. lucidum*, $2n = 40$ (sect. *Robertiana*); *G. pyrenaicum*, $2n = 26$; *G. pusillum*, $2n = 26$; *G. molle*, $2n = 26$; *G. rotundifolium*, $2n = 26$; *G. divaricatum*, $2n = 26$ (sect. *Rotundifolia*) (Table 1).

According to the literature data on the chromosome numbers of the genus *Geranium* species, presented in Table 1, the different basic chromosome numbers $x = 9, 10, 11, 12, 14, 15, 16, 17, 23, 25$ are revealed.

G. columbinum L., $2n = 18$

Examined samples: Lori Province, near the village of Akhtala, 805 m a.s.l., 41°09'26"N 44°45'56"E,

24.06.2009, leg. G. Fayvush, K. Tamanyan, N 09-1804 ERE, W, MA, PE, det. R. Adamyan; Tavush Province, above Yenokavan, a cave in the valley of the river Tanzout. Lastiver, 1260–1360 m a.s.l., 41°54'57" N 44°4'46" E, 06/23/2008, leg. G. Fayvush, K. Tamanyan, N 08-0790 ERE, W, MA, PE, det. R. Adamyan.

The species is well studied karyologically. According to the literature data, only the diploid cytotype is characteristic for *G. columbinum* with $2n = 18$ (Fedorov, 1969; Moore, 1973; Murin, 1974; Alves, Leitao, 1976; Van Loon, 1984b). Our material also revealed a diploid cytotype $2n = 2x = 18$, with a basic chromosome number $x = 9$. The karyotype of *G. columbinum* is asymmetric, consisting of 2 pairs of submetacentric and 7 pairs of metacentric chromosomes. Karyotype formula: $2n = 18 = 4SM+14M$.

G. ibericum Cav., $2n = 28$

Examined samples: Ashotsk Province, climb to the top of Mount Kachal Sar, 2600–2900 m a.s.l., 01.08.2009, leg. E. Gabrielyan, E. Nazarova, M. Hovhannisyan, N 13619 ERCB, det. R. Adamyan; Kotayk Province, Tsakhkadzor, Teghenis 2250 m a.s.l., 40°32'08" N 44°41'02", 05.22.2005, leg. Aedo, Fayvush, Tamanyan et al. No. 17696 MA, det. S. Castroviejo; Kotayk Province, Tsaghkadzor, cableway

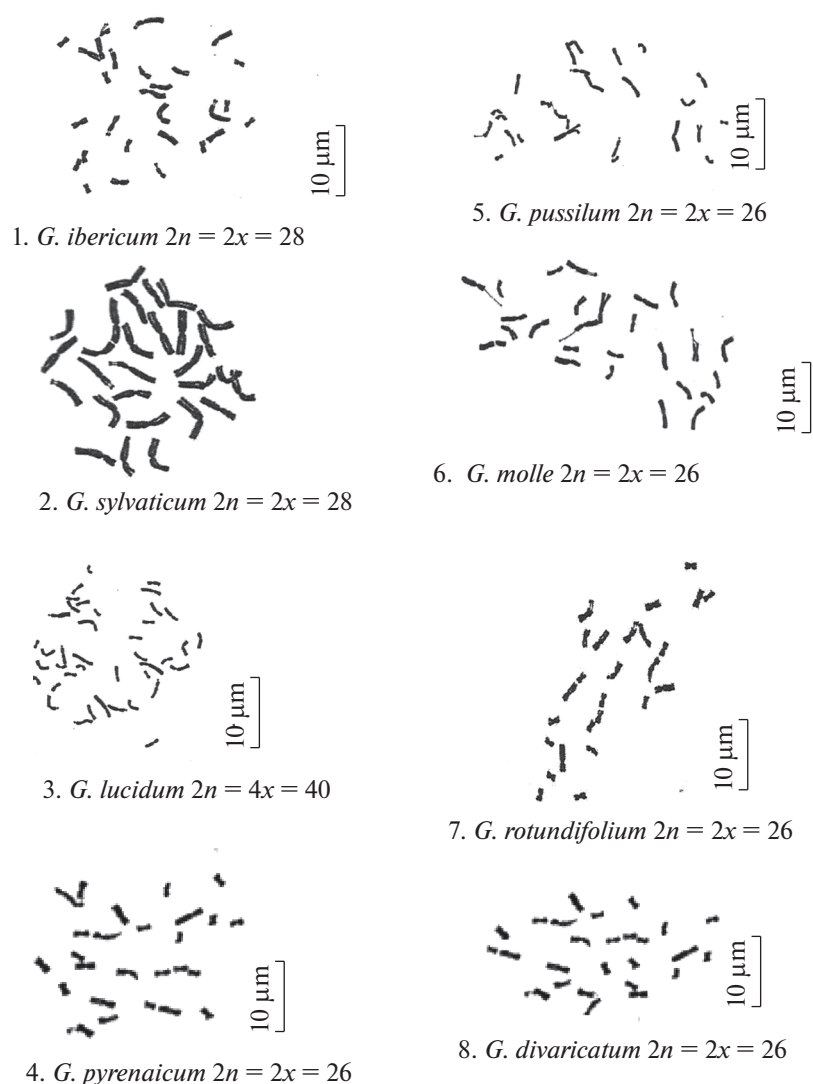


Fig. 1. Metaphase plates of the genus *Geranium* species.

1 – *G. ibericum* ($2n = 2x = 28$); 2 – *G. sylvaticum* ($2n = 2x = 28$); 3 – *G. lucidum* ($2n = 4x = 40$); 4 – *G. pyrenaicum* ($2n = 2x = 26$); 5 – *G. pusillum* ($2n = 2x = 26$); 6 – *G. molle* ($2n = 2x = 26$); 7 – *G. rotundifolium* ($2n = 2x = 26$); 8 – *G. divaricatum* ($2n = 2x = 26$).

2300 m a.s.l., 40°32'08" N 44°41'02", 0.07.2010 leg. R. Adamyan, N 13618 ERCB, det. R. Adamyan.

The species is poorly studied karyologically. According to the literature data, for the European species *G. ibericum*, mainly the tetraploid cytotype was found, $2n = 4x = 56$ (Gauger, 1937; Warburg, 1938), in addition, a diploid cytotype is known for this species, $2n = 28$ (Van Loon, 1984a). On our material the diploid cytotype was also identified for this species $2n = 2x = 28$, with basic chromosome number $x = 14$ (Fig. 1.1). The karyotype of *G. ibericum* is asymmetric, consisting of 7 pairs of metacentric, 4 pairs of submetacentric and 3 pairs of chromosomes with satellites: 2 pairs of metacentric and 1 pair of submetacentric chromosomes with satellites. Karyotype formula: $2n = 28 = 14M + 8SM + 4M^S + 2SM^S$.

G. sylvaticum L., $2n = 28$

Examined samples: Vayots Dzor, Vayk Province, near the village of Kechut, 1200–2050 m a.s.l., 39°49'N 45°38'E, 19.06.2004, leg. K. Tamanyan, G. Fayvush, M. Hovanisyan, N 04-0851, det. R. Adamyan; Kotayk Province, Hankavan, territory of YSU base, 1600 m a.s.l., 20.07.2010, leg. R. Adamyan, N 13617 ERCB, det. R. Adamyan; Kotayk Province, Tsaghkadzor, Teghenis, 2250 m a.s.l., 40°32'08" N 44°41'02", 06.22.2005, leg. K. Aedo et al., No. 17705 MA, det. R. Adamyan.

The species is well studied karyologically. According to the literature data, mainly the diploid cytotype is characteristic for *G. sylvaticum*, $2n = 28$, with basic chromosome number $x = 14$ (Fedorov, 1969; Moore, 1973; Uhrikova, Majovsky, 1980; Strid, Franzen,

1981; Arohonka, 1982; Van Loon, 1984a; Takhtajan, 1990). Only for the Belarusian material, S.A. Dmitrieva gives the chromosome number $2n = 24$ (Dmitrieva, 1986). Our material also revealed a diploid cytotype for this species, $2n = 2x = 28$, with basic chromosome number $x = 14$ (Fig. 1.2). The karyotype of *G. sylvaticum* is asymmetric, consisting of 6 pairs of metacentric, 5 pairs of submetacentric and 3 pairs of chromosomes with satellites: 2 pairs of metacentric and 1 pair of submetacentric chromosomes with satellites. Karyotype formula: $2n = 28 = 12M+10SM+4M^S+2SM^S$.

G. lucidum L., $2n = 40$

Examined samples: Syunik Province, on the road Goris × Kapan, 1370–1600 m a.s.l. 39°20' N 46°23'–24' E, 05.07.2003, leg. G. Fayvush, K. Tamanyan, N 03-0859 ERE, W, MA, PE, det. R. Adamyan; Syunik Province, Nerkin Ande village, 660 m a.s.l., 39°03'47" N 46°31'58" E, 06.25.2005, leg. K. Aedo et al., N 313 MA, det. R. Adamyan.

The species is well studied karyologically. According to the literature data, di- and tetraploid cytotypes were found in most cases for the species, $2n = 20, 40$ (Fedorov, 1969; Alves, Leitao, 1976; Uhrikova, Majovsky, 1980; Strid, Franzen, 1981; Van Loon, 1984b; Galland, 1988; Luque, Díaz Lifante, 1991; Hollingsworth et al., 1992). In addition, a hexaploid cytotype $2n = 60$ (6x) is given for Indian populations of *G. lucidum* (Aryavand, 1983), and for Belarusian populations, an octoploid chromosome number is also known, $2n = 80$ (Petrova, Stanimirova, 2003). For European populations of the species, chromosome numbers $2n = 40–44$ were exhibited (Van Loon, 1984 a, b). In the studied specimens of *G. lucidum*, we found tetraploid cytotype $2n = 4x = 40$, with basic chromosome number $x = 10$ (Fig. 1.3). The karyotype of this species is asymmetric, consisting of 5 pairs of metacentric, 12 pairs of submetacentric and 3 pairs of submetacentric chromosomes with satellites. Karyotype formula: $2n = 40 = 10M+24SM+6SM^S$.

G. pyrenaicum Burm. F., $2n = 26$

Examined samples: Lori Province, northwest of the road from Stepanavan to Spitak, 1965 m a.s.l., 40°52'27"N 43°59'39"E, 06.23.2009, leg. G. Fayvush et al., N 09-1717 ERE, W, MA, PE, det. R. Adamyan; Tavush Province, vicinity of Dilijan, Kurudakh tract, meadow, 1913 m a.s.l., 40°38'47"N 44°29'51"E, 07.10.2005, leg. K. Tamanyan, G. Fayvush, M. Hovhannisyan, N 12616 ERCB, det. R. Adamyan; Kotayk Province, Hankavan, territory of YSU base, forest, 1600 m a.s.l., 07.06.2010, leg. R. Adamyan, N 13615 ERCB, det. R. Adamyan; Armavir Province, Etchmiadzin, Tsiatsan village, 1350 m a.s.l., 40°09'42"N 44°17'28"E, 17.08.2010, leg. R. Adamyan, N 13614 ERCB, det. R. Adamyan.

The species is well studied karyologically. According to the literature data, mainly the diploid cytotype is characteristic for *G. pyrenaicum*, $2n = 26$ (Fedorov, 1969; Moore, 1977; Murin, 1974; Alves, Leitao, 1976; Skalinska et al., 1976, 1978; Strid, 1980; Strid, Franzen, 1981; Mizianty et al., 1983; Van Loon, 1984a; Takhtajan, 1990; Galland, 1988; Baltisberger, 1991), only for Indian populations chromosome number $2n = 2x = 20$ is given, with basic chromosome number $x = 10$ (Sharma, 1970), and for European populations – $2n = 28$ with basic number $x = 14$ (Warburg, 1938). In the studied specimens of the species *G. pyrenaicum* we also revealed a diploid cytotype $2n = 2x = 26$, with basic chromosome number $x = 13$, which confirms the previously presented numerous data (Fig. 1.4). Karyotype of this species is asymmetric, consisting of 8 pairs of metacentric, 3 pairs of submetacentric chromosomes and on 1 pair of meta- and 1 pair of submetacentric chromosomes with satellites. Karyotype formula: $2n = 26 = 16M+6SM+2M^S+2SM^S$.

G. pusillum L., $2n = 26$

Examined samples: Tavush Province, northwest of Ijevan, near Yenokavan village, 1365 m a.s.l., 40°24'54"N 45°18'43"E, 11.06.2008, leg. K. Tamanyan, G. Fayvush, E. Vitek, N 08-0704 ERE, W, MA, PE, det. R. Adamyan; Tavush Province, Dilijan, the territory of the House of Composers, 1200–1500 m a.s.l., 40°44'27"N 44°51'47"E, 07.20.2010, leg. R. Adamyan, N 13613 ERCB, det. R. Adamyan; Yerevan, Khanjyan street, 1020 m a.s.l., 40°18'24"N 44°52'72"E, 05.23.2012, leg. R. Adamyan, N 13612 ERCB, det. R. Adamyan.

The karyology of this species has been fairly well investigated. According to the literature data, mainly the diploid cytotype is found for *G. pusillum*, $2n = 26$, with basic chromosome number $x = 13$ (Fedorov, 1969; Moore, 1977; Murin, 1974; Skalinska et al., 1976; Fernandes Cassas, Pascual, 1978; Arohonka, 1982; Van Loon, 1984b; Buttler, 1989). In the studied specimens of *G. pusillum*, we found the diploid cytotype $2n = 2x = 26$, with basic chromosome number $x = 13$, which confirms numerous previous data (Fig. 1.5). The karyotype of this species is asymmetric. Diploid set of chromosomes consists of 8 pairs of metacentric, 3 pairs of submetacentric chromosomes and 2 pairs of metacentric chromosomes with satellites. Karyotype formula: $2n = 26 = 16M + 6SM + 4M^S$.

G. molle L., $2n = 26$

Examined sample: Syunik Province, not far from the Shikahogh State Reserve, m a.s.l., 06.04.2008, leg. E. Gabrielyan, N 13611 ERCB, det. R. Adamyan.

The karyology of this species has been fairly well investigated. According to the literature data, mainly the diploid cytotype is found for *G. molle*, $2n = 26$ (Fe-

dorov, 1969; Moore, 1977; Alves, Leitao, 1976; Murin, 1978; Franzen, Gustafsson, 1983; Van Loon, 1984b; Hill, 1989). In the studied specimens of the species, we found the diploid cytorace $2n = 2x = 26$, with basic chromosome number $x = 13$, which confirms numerous previous data (Fig. 1.6). The karyotype of this species is asymmetric, consisting of 3 pairs of metacentric, 8 pairs of submetacentric chromosomes, and 1 pair of metacentric and 1 pair of submetacentric chromosomes with satellites. Karyotype formula: $2n = 26 = 6M+16SM+2M^S+2SM^S$.

G. rotundifolium L., $2n = 26$

Examined samples: Lori Province, bank of the river Berd, 1290 m a.s.l., 41°08'0"N 44°26'02"E, 06.28.2003, leg. G. Faivush, K. Tamanyan, A. Ter-Voskanyan, E. Vitek, N 03-0200 ERE, W, MA, det. R. Adamyan; Syunik Province, Meghri district, at the fork of Shvanidzor village, from the side of Nyuvadi village, 500 m a.s.l. 05.09.2004, leg. E. Gabrielyan, M. Hovhannisyanyan, N 13610 ERCB, det. K. Tamanyan; Syunik Province, eastern part of Zangezur, west of Goris-Kapan road, near village Gurdbulakh, 1370–1600 m a.s.l., 40°20'0"N 46°23'24"E, 05.07.2003, leg. G. Faivush, K. Tamanyan, A. Ter-Voskanyan, E. Vitek, N 03-0919 ERE, W, MA, det. R. Adamyan.

The karyology of this species has been fairly well investigated. According to the literature data mainly the diploid cytorace is characteristic for *G. rotundifolium*, $2n = 26$ (Fedorov, 1969; Moore, 1977; Alves, Leitao, 1976; Strid, Franzen, 1981; Franzen, Gustafsson, 1983; Buttler, 1989; Galland, 1988). In the studied specimens we also found the diploid cytorace $2n = 2x = 26$, with basic chromosome number $x = 13$ (Fig. 1.7). The karyotype of this species is asymmetric, consisting of 8 pairs of metacentric, 3 pairs of submetacentric chromosomes and 1 pair of meta-, 1 pair of submetacentric chromosomes with satellites. Karyotype formula: $2n = 26 = 16M+6SM+2M^S+2SM^S$.

G. divaricatum Ehrh., $2n = 26$

Examined samples: Kotayk Province, near Bjni village, 1550 m a.s.l., 40°27'35"N 44°39'34". 06.17.2004, leg. E. Vitek, K. Tamanyan, G. Faivush, M. Hovhannisyanyan, A. Ter-Voskanyan, N 04-0571 ERE, W, MA, det. R. Adamyan; Kotayk Province, Zovuni village, near the monument, 1200 m a.s.l., 05.20.2010, leg. R. Adamyan, N 13609 ERCB, det. R. Adamyan; Vayots Dzor Province, village Ger-Ger, 1780 m a.s.l., 39°47'09"N 45°32'15", 06.24.2005, leg. K. Aedo, G. Faivush, K. Tamanyan, N 2869 MA, det. A. Guerrero.

The species is poorly studied karyologically. According to the literature data, for the Slovakian *G. divaricatum* specimens the chromosome number $2n = 26$ mainly was found, with basic number $x = 13$ (Murin, 1974), for the European specimens the dip-

loid cytorace $2n = 28$ is given, with basic number $x = 14$ (Dersch, 1974; Van Loon, 1984?). In our material, we also revealed the diploid cytorace $2n = 2x = 26$, with basic chromosome number $x = 13$ (Fig. 1.8). The karyotype of this species is asymmetric, consisting of 8 pairs of metacentric, 4 pairs of submetacentric chromosomes and 1 pair of metacentric chromosomes with satellites. Karyotype formula: $2n = 26 = 16M+8SM+2M^S$.

CONCLUSIONS

The karyological research of the genus *Geranium* species of the Armenian flora has revealed the following: we discovered diploid cytoraces for 8 species – *G. columbinum*, $2n = 18$ (sect. *Columbinum*), *G. ibericum*, $2n = 28$, *G. sylvaticum*, $2n = 28$ (sect. *Geranium*), *G. pyrenaicum*, $2n = 26$, *G. pusillum*, $2n = 26$, *G. molle*, $2n = 26$, *G. rotundifolium*, $2n = 26$, *G. divaricatum*, $2n = 26$ (sect. *Rotundifolia*), with different basic chromosome numbers, $x = 9, 13, 14$. For the species *G. lucidum* (sect. *Robertiana*) a tetraploid cytorace $2n = 40$ was discovered with the basic chromosome number $x = 10$. The number of chromosomes for all karyologically studied species of the genus *Geranium* the flora of Armenia is brought up for the first time.

The species of the section *Rotundifolia* occurring in Armenia (*G. pyrenaicum*, $2n = 26$; *G. pusillum*, $2n = 26$; *G. molle*, $2n = 26$; *G. rotundifolium*, $2n = 26$; *G. divaricatum*, $2n = 26$) are characterized with the basic main chromosome number $x = 13$.

The main basic chromosome number $x = 9$ is typical of the Armenian species of the section *Columbinum* (*G. columbinum*, $2n = 18$).

The main basic chromosome number $x = 10$ is typical of the Armenian species of the section *Robertiana* (*G. lucidum*, $2n = 40$).

The main basic chromosome number $x = 14$ is typical of the Armenia species of the section *Geranium* (*G. ibericum*, $2n = 28$; *G. sylvaticum*, $2n = 28$).

Asymmetric karyotype is observed in all the karyologically studied species of the genus *Geranium*.

REFERENCES

- Aedo C. 2003. Taxonomic revision of *Geranium* sect. *Trygonium* (Geraniaceae). – Bot. Zhurn. 88: 124–131.
- Alves M., Leitao M. 1976. Contribucio para o conhecimento citotaxonomico das spermatophyta de Portugal. XIII. Geraniaceae. – Bol. Soc. Brot. 50: 231–245.
- Arohonka T. 1982. Chromosome counts of vascular plants of the island Seili in Nauvo, SW Finland. – Biologian–Laitoksen Julkaisuja. 3: 1–12.
- Aryavand A. 1983. In IOPB Chromosome number reports LXXIV. – Taxon. 32: 321–322.
- Baltisberger M. 1991. Cytological investigations of some Greek plants. – Fl. Medit. 1: 157–173.

- Buttler K.P. 1989. Chromosomenzahlen von Gefäßpflanzen aus Hessen 4. Folge. — Hess. Florist. Briefe. 38: 11–14.
- Dersch G. 1974. Über einige Chromosomenzählungen an mitteleuropäischen Blütenpflanzen. II. — *Philippia*. 2: 75–82.
- Dmitrieva S.A. 1986. Chromosome numbers of some species of vascular plants from Belorussia. — *Bot. Zhurn.* 71 (8): 1145–1147 (In Russ.).
- Fedorov A.A. (ed.). 1969. Chromosome Numbers of Flowering Plants. Leningrad. 926 p. (In Russ.).
- Fernandes Cassas J., Pascual R. 1978. In Numerous cromosómicos para la flora Española. — *Lagascalia*. 7: 105–125.
- Franzen R., Gustafsson L.A. 1983. Chromosome numbers in flowering plants from the high mountains of Sterea Ellas, Grees. — *Willdenowia*. 13: 101–106.
- Galland N. 1988. Recherche sur l'origine de la flore orophile du Maroc étude caryologique et cytogéographique. — *Trav. Inst. Sci. Univ. Mohammed V, Sér. Bot. (Rabat)*. 35: 1–168.
- Gauger W. 1937. Ergebnisse einer zytologischen Untersuchung der Familie der Geraniaceae. I. — *Planta*. 26 (4): 529–531.
- Goldblatt P. 1981. Index to plant chromosome numbers. — *Monogr. Syst. Bot. Missouri Bot. Gard.* 5: 276–277; 1984. 8: 201–202; 1985. 13: 105; 1988. 23: 117.
- Goldblatt P., Johnson D. 1990. Index to plant chromosome numbers. — *Monogr. Syst. Bot. Missouri Bot. Gard.* 30: 98–99; 1991. 40: 113–114; 1994. 51:108–109; 1996. 58: 124–125.
- Hill L.M. 1989. IOPB chromosome data I. — *Int. Organ. Plant Biosyst. Newslett.* 13: 17–19.
- Hollingsworth P., Gornall R., Bailey J. 1992. Contribution to a cytological catalogue of the british and Irish flora, 2. — *Watsonia*. 19: 134–137.
- Knuth R. 1912. Geraniaceae Juss. In: Engler A. *Das Pflanzenreich regni vegetabilis conspectus*. Leipzig, Engelmann. 53: 640 p.
- Luque T., Díaz Lifante. 1991. Chromosome numbers of plants collected during Iter Mediterraneum I in the SE of Spain. — *Bocconea*. 1: 303–364.
- Mizianty M., Mirek Z., Frey L. 1983. Chromosome numbers of Polish vascular plants. Part 4. — *Acta Soc. Bot. Poloniae*. 52: 205–214.
- Moore R.I. 1977. Index to plant chromosome numbers for 1973–1974. *Regnum Vegetabile*. Utrecht. 257 p.
- Murin A. 1974. In Index of chromosome numbers of Slovakian flora. Part 4. — *Acta Fac. Rerum Nat. Univ. Comenianae, Bot.* 23: 1–23.
- Murin A. 1978. In Index of chromosome numbers of Slovakian flora. Part 6. — *Acta Fac. Rerum Nat. Univ. Comenianae, Bot.* 26: 1–42.
- Nazarova E.A., Gukasyan A.G. 2004. Chromosome numbers of flowering plants of Armenia flora, Yerevan. Institute of Botany NAS RA. 171 p. (In Russ.).
- Petrova A., Stanimirova P. 2003. Karyological study of some *Geranium* (Geraniaceae) species growing in Bulgaria. — *Bocconea*. 16 (2): 675–682.
- Sharma A.K., 1970. Annual report, 1967–1968. — *Res. Bull. Univ. Calcutta Cytogenetics Lab.* 2: 1–50.
- Skalinska M., Pogan E., Weislo H. 1976. Further studies in chromosome numbers of Polish angiosperm. XI. — *Acta. Biol. Cracov.* 19: 107–148.
- Skalinska M., Pogan E., Czapiak R. 1978. Further studies in chromosome numbers of Polish angiosperm. XII. — *Acta. Biol. Cracov.* 21: 31–63.
- Strid A. 1980. In chromosome number reports LXIX. — *Taxon*. 29: 709–710.
- Strid A., Franzen R. 1981. In chromosome number reports LXXIII. — *Taxon*. 30: 829–842.
- Takhtajan A.L. (ed.) 1993. Chromosome Numbers of flowering plants of the Flora of the USSR. St. Petersburg. Vol. 1. 508 p. (In Russ.).
- Uhrikova A., Majovsky J. 1980. In chromosome number reports LXIX. — *Taxon*. 29: 725–725.
- Van Loon, J.C. 1984a. Chromosome numbers in *Geranium* from Europe, I. The perennial species. — *Proceedings Koninklijke Nederlandse Akademie van Wetenschappen. Series C, Biological and Medical Sciences.* 87: 263–277.
- Van Loon, J.C. 1984b. Chromosome numbers in *Geranium* from Europe, II. The annual species. — *Proceedings Koninklijke Nederlandse Akademie van Wetenschappen. Series C, Biological and Medical Sciences.* 87: 279–296.
- Warburg E.F. 1938. Taxonomy and relationship in the Geraniales in the light of their cytology. — *New Phytol.* 37 (2): 130–159.