Arch. Biol. Sci., Belgrade, 65 (1), 23-32, 2013 DOI:10.2298/ABS1301023V

POLYPLOIDY AND B CHROMOSOMES IN *ALLIUM FLAVUM* FROM SERBIA

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Abstract - The most intriguing karyological features of the genus *Allium* are polyploidy and the frequent appearance of supernumerary or B chromosomes (Bs). Specimens of *Allium flavum* from natural populations at the Gornjačka Gorge in the vicinity of Gornjak Monastery, Serbia, were analyzed karyologically. All studied plants were tetraploid (2n = 32). One submetacentric B chromosome representing 1% of the genome, smaller than the smallest chromosomes of the standard set, was present in some plants. This is the first finding of Bs in tetraploid *A. flavum*.

Key words: Allium flavum, B chromosomes, tetraploids

INTRODUCTION

Being the largest in the family Amaryllidaceae, the genus *Allium* comprises more than 800 species of perennial, mostly bulbous plants (Fritsch et al., 2010). These are mainly distributed in subtropical and temperate regions of the Northern Hemisphere, particularly around the Mediterranean region and in Central Asia. Although favourable cytological characteristics make species from the genus *Allium* attractive subjects for study, chromosome numbers are known for only about one-third of them and detailed cytological data are very limited. The most intriguing karyological features of the genus *Allium* are polyploidy and the frequent appearance of B chromosomes (Bs). Up to now, Bs have been found in 97 species (Table 1). Different levels of ploidy are also frequent, and in ten species Bs are present in polyploids as well.

Bs are supernumerary components of the genomes of numerous species of plants, fungi and animals. The term B chromosome was first used by Randolph (1928) to describe supernumerary or extra chromosomes in maize, and since that time it has been applied to such chromosomes in a variety of species from all the major taxa (Jones 1995), apart from birds (Vujošević and Blagojević, 2004). It is assumed that, in general, Bs occur in about 15% of species, but the heterogeneity of different Bs poses a problem of definition, since the number of characteristics shared by all Bs is very limited. Therefore, their dispensable nature describes them the best, while the absence of recombination with any member of the basic A chromosome set and irregular, non-Mendelian modes of inheritance serve for recognising that the supernumerary chromosome is in fact a B chromosome. In general, B chromosomes are found in some members of a population, but not in others (Jones and Rees 1982). In addition, some features are common to Bs, but never shared by all of them. For instance, Bs are often smaller than chromosomes of the standard set and in plants this is true for more than half the species possessing Bs. However, Bs as large as the largest chromosomes of the set also exist. Completely heterochromatic Bs are more characteristic for animals than for plants, yet half of all Bs in plants are heterochromatic (Jones, 1975, 1995). There is a large amount of variability between families regarding the presence of species with Bs, but part of this may be explained by differences in study intensity, as is the case with bulbous monocots being amenable to chromosome analysis.

B chromosomes were repeatedly found in *Allium flavum* (Chesmedzhiev, 1971; Šopova, 1971; Vosa, 1973; Capineri et al. 1978; Baltisberger and Baltisberger, 1995; Krahulcová, 2003) but always in diploid specimens. Here, for the first time, we present the appearance of Bs in tetraploid specimens of *Allium flavum*.

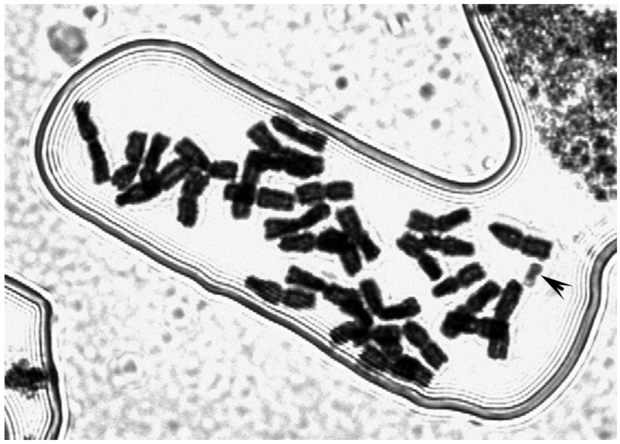

Fig. 1. Tetraploid mitosis in *Allium flavum* with one B chromosome (arrow).

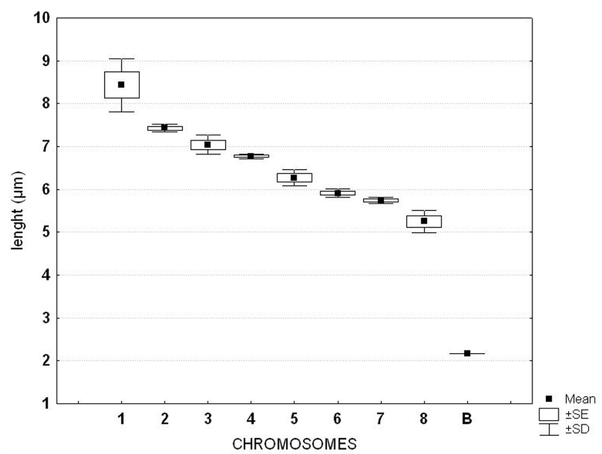

Fig. 2. Average length of chromosomes in tetraploid *Allium flavum* determined by MicroMeasure 3.3.

MATERIALS AND METHODS

Specimens of *Allium flavum* were collected from natural populations at Gornjačka Gorge near the Gornjak Monastery (East Serbia). Actively growing roots of about 1-1.5 cm in length were excised, treated with 0.02% colchicine for 5 h, kept in Carnoy's fixative overnight, hydrolyzed in 1 N HCl at 60°C for 12 min, stained with aceto-orcein, and squashed. Slides were analyzed using a Zeiss Axio Observer.Z1 light microscope (1600x), and the number of chromosomes was counted. Chromosome counts were made from at least five root tips of each plant.

The length of the chromosomes was measured in micrometers (µm) from images, using MicroMeasure 3.3 (http://www.colostate.edu/Depts/Biology/MicroMeasure/). Centromere positions were recorded. In addition, the relative size (percentage of each chromosome within the total length of the complement) and centromere index (ratio between the length of the short arm and the total chromosome length) were scored for each chromosome. The nomenclature of chromosomes in the basic set was followed according to Levan et al. (1964), and chromosomes were named as 1, 2, 3, 4, 5, 6, 7 and 8 in descending order of length.

RESULTS AND DISCUSSION

The karyotype of *Allium flavum* contained four haploid chromosome sets (2n = 32, FN = 64). B chromosomes were detected in some plants (Fig. 1). Most chromosomes were large, and the karyotype analysis revealed a dominance of metacentrics. Centromeric indexes varied from 0.459 to 0.474. Chromosome length ranged from 8.44 µm for chromosome 1 to 5.25 µm for chromosome 8 (Fig. 2). B chromosomes represented approximately 1% of the tetraploid genome and were less than half the size of the smallest chromosome in the karyotype. They were sub-metacentric with centromeric index 0.395.

Allium flavum occurs in Europe in both diploid and tetraploid forms. Besides a constant dip-

Table 1. Species with B chromosomes in the genus *Allium*.

	Species	Ploidy	2n	Number of Bs	Reference
1.	*A. albidum*	2x	16	4	Cheshmedzhiev (1975)
2.	*A. alexeianum*	2x	16	2, 4	Pogosian & Seisums (1992)
3.	*A. allegheniense*	2x	14	0-4	Levan (1932)
4.	*A. ameloprasum*	3x	24	1-2	Kollman (1971, 1972)
		4x	32	1	Kollman (1972)
	ameloprasum group	4x	32	2-4	Bohanec et al. (2005)
5.	*A. angulosum*	2x	16	0-3	Levan (1934), Šopova (1966), Měsíček (1992)
		4x	32	2	Dmitrieva (2000)
		4x	32	0-1	Šopova (1966)
6.	*A. anisopodium*	2x	16	0-1	Frizen (1983), Tolgor et al (1994)
7.	*A. arvense*	2x	16	0-2	Marcucci & Tornadore (1997)
8.	*A. ascalonicum*	2x	16	1	Bartolo et al. (1984)
9.	*A. barsczewskii*	4x	32	1	De Sarker et al (1997)
10.	*A. barthianum*	2x	16	3	Hamoud et al (1990)
11.	*A. bidentatum*	4x	32	1	Tolgor et al (1994)
12.	*A. bimetrale*	2x	16	0-4	Bothmer (1970)
13.	*A. bourgeaui*	2x	16	0-1	Bothmer (1975)
14.	*A. brulloi*	2x	16	1	Salmeri (1998)
15.	*A. calabrum*	2x	16	2	Brullo et al. (1994)
16.	*A. carinatum*	3x	24	0-3	Šopova (1971)
17.	*A. cappadocicum*	2x	16	1	De Sarker et al (1997), Özhatay (2002)
18.	*A. cardiostemon*	2x	16	1	Pogosain (1983), Hosseini & Go (2010)
19.	*A. caspium*	2x	16	1	Zakirova & Nafanailova (1990)
20.	*A. cepa*	2x	16	1	Noda (1953)
21.	*A. cernuum*	2x	14	0-11, 13	Grun (1959), Chinnapa & Basappa (1986)
22.	*A. chrysantherum*	2x	16	1	Koyuncu & Özhatay (1983)
23.	*A. cirrhosum*	2x	16	1	Cheshmedzhiev (1975)
24.	*A. commutatum*	2x	16	1-2	Bothmer (1982)
25.	*A. condensatum*	2x	16	1	Tolgor et al (1994)
26.	*A.consanguineum*	2x	16	0-1	Mehra & Pandita (1978)
27.	*A. curtum*	2x	16	4	Özhatay & Johnson (1996)
28.	*A. dalmaticum*	2x	16	0-2	Feinbrun (1950), Lovka (1995) Brullo et al. (1996)
29.	*A. dasyphyllum*	2x	16	0-1	Pogosian & Seisums (1992)
30.	*A. derderanum*	2x	16	1	Pogosian (1983)
31.	*A. dictyoprasum*	2x	16	0-1	Özhatay & Johnson (1996)
32.	*A. dictyoscordum*	2x	16	1	Hosseini & Go (2010)
33.	*A. dodecadontum*	2x	16	0-1	Pogosian & Seisums (1992)
34.	*A. ericetorum*	2x	16	1	Wetschnig (1995), Marcucci & Tornadore (1999)
35.	*A. fibrosum*	2x	16	0-2	Vakhtina (1989)

Table 1. *Continued*

	Species	Ploidy	2n	Number of Bs	Reference
36.	*A. flavum*	2x	16	1, 2	Cheshmedzhirev (1971), Baltisberger & Baltisberger (1995), Krahulcová (2003)
		4x	32	0-1	This paper
37.	*A. flavens*	2x	16	+ Bs	Loidl (1982a)
38.	*A. fominianum*	2x	16	2	Pogosian (1983)
39.	*A. funckiaefolium*	2x	16	0-5	Jing et al. (1999)
40.	*A. fuscoviolaceum*	2x	16	1	Özhatay (1993)
41.	*A. fuscum*	2x	16	0-1	Cheshmedzhiev (1975)
42.	*A. globosum*	2x	16	2	Kudryashova (1988)
43.	*A. gramineum*	2x	16	2	Pogosian (1991)
44.	*A. guttatum*	2x	16	+ Bs	Tzanoudakis (1992)
45.	*A. iranicum*	2x	32	0-1	Ghaffari (2006)
46.	*A. jodanthum*	2x	16	0-1	Ohle (1992)
47.	*A. kuramense*	2x	16	1	Fritsch et al. (1998)
48.	*A. laeve*	4x	32	2	Miryeganeh & Movafeghi (2011)
49.	*A. macrostemon*	3x	24	1	Wang et al. (2009)
50.	*A. mairei*	2x		+Bs	Chen et al. (2005)
		4x		+Bs	Chen et al. (2005)
51.	*A. margaritaceum*	2x	16	0-2	Šopova (1970), Lovka (1995)
		3x	24	0-1	Šopova (1970)
52.	*A. melantherum*	3x	24	1	Cheshmedzhiev (1979)
53.	*A. montanum*	4x	32	3	Wetschnig (1992)
54.	*A. moschatum*	2x	16	0-1	Tzanoudakis (1992)
55.	*A. nanodes*	2x	16	0-3	Jing et al. (1999)
56.	*A. nanum*	2x	16	0-1	Cheshmedzhiev (1976)
57.	*A. neriniflorum*	2x	16	0-1	Li et al. (1996)
58.	*A. nutans*	2-5x	16-40	0-1	Šopova (1966)
		?	42, 44, 68	+B	Levan (1932)
59.	*A. ochroleucum*	2x	16	0-1	Holub et al. (1970)
60.	*A. ovalifolium*	2x	16	1-6	Jing et al. (1999)
61.	*A. paepalanthoides*	2x	16	3	Zhang et al. (1993)
62.	*A. palestinum*	4x	28	1	Kollman (1973)
63.	*A. pallens*	2x	16	0-1	Loidl (1982b), Özhatay (1993), Puizina et al. (1995)
64.	*A. paniculatum*	2x	16	0-3	Ved Brat (1965), Ruiz Rejon et al. (1986)
65.	*A. plurifoliatum*	2x	16	1	Zhang et al. (1993)
66.	*A. polyanthum*	4x	32	1	Guern et al. (1991)
67.	*A. porrum*	2x	16	6	Nybom (1974)
		4x	32	0-3	Vosa (1966)
68.	*A. prattii*	2x	16	0-5	Jing et al. (1999), Xue et al. (2000)
69.	*A. przewalskianum*	2x	16	0-2	Ao (2008)

Table 1. *Continued*

	Species	Ploidy	2n	Number of Bs	Reference
70.	*A. pseudoflavum*	2x	16	2	Кудряшова (1988)
71.	*A. pulchellum*	2x	16	0-3	Tschermak-Woes and Schiman (1960)
72.	*A. ramosum*	2x	16	0-1	Zou & Jia (1985), Yang (2001)
73.	*A. rotundum*	2x	16	0-2	Löve (1976), De Sarker et al (1997)
		?	36-38	1	Löve (1976)
		5x	40	4	Löve (1976)
		6x	48	1	Löve (1976)
74.	*A. rubellum*	2x	16	0-1	Pogosian (1991)
75.	*A. rubens*	2x	16	0-1	Ohle (1992)
76.	*A. rupicola*	2x	16	1	Tanker & Kurucu (1979), Özhatay (2002)
77.	*A. schoenoprasum*	2x	16	0-18	Bougourd (1976)
78.	*A. schugnanicum*	2x	16	0-1	Pogosian & Seisums (1992)
79.	*A. scorodoprasum*	2x	16	0-2	Lövkvist & Hultgård (1999)
		4x	32	1	Karabokiroy (1995)
80.	*A. senescens (=A. lusitanicum)*	2x	16	0-5	Fernandez-Casas et al. (1978)
		4x	32	0-4	Holub et al. (1970)
81.	*A. sieheneanum*	3x	24	1	Özhatay (2002)
82.	*A. sphaerocephalon*	2x	16	0-2	Bothmer (1970), Viegi & Renzoni (1981), Pastor (1982), Guillén & Rejón (1984)
83.	*A. stamineum*	2x	16	0-1	Loidl (1982a)
84.	*A. stracheyi*	2x	14	2-10	Sharma and Aiyanger (1961)
		2x	16	1	Pandita (1981)
85.	*A. suaveolens*	2x	16	0-3	Fernandes (1950)
86.	*A. taeniopetalum*	2x	16	1	Fritsch & Astanova (1998)
87.	*A. tardans*	2x	16	1	Tzanoudakis (1986)
88.	*A. textile*	2x	14	0-1	Cai and Chinnappa (1987)
89.	*A. thracium*	3x	24	0-1	Ceschmedziev (1992)
90.	*A. thunbergii*	2x	16	0-4	Noda and Watanabe (1968)
		4x	32	0-6	Noda and Watanabe (1968), Noda & Li (1980)
		6x	48	0-4	Noda and Watanabe (1968)
91.	*A. tulipifolium*	2x	16	0-1	Frizen (1986), Frizen (1988)
92.	*A. ursinum*	2x	14	0-1	Vujošević and Blagojević (2002)
93.	*A. victorialis*	2x	16	0-5	Jing et al. (1999)
94.	*A. vineale*	2x	16	0-2	Lövkvist and Hultgård (1999)
		4x	32	1-4	Měšíček & Javůrková-Jarolímová (1992)
95.	*A. vodopjanovae*	2x	16	0-2	Frizen (1988)
96.	*A. wallichii*	2x	14	1-2	Chang et al. (2006)
97.	*A. webbii*	2x	16	4	Cheshmedzhiev (1975)

loid number 2n = 16, the tetraploid cytotype (2n = 32) was found in Poland (Mizianty and Frey, 1973), Spain (Ruiz Rejón and Sañudo, 1976), Italy (Bartolo et al., 1978), Austria (Loidl, 1979), Greece (Tzanoudakis and Vosa, 1988) and Bulgaria (van Loon and van Setten, 1982). Both diploids and tetraploids have been recorded in Austria, Greece and Bulgaria. Entirely new distributions of cytotypes were noted for many plant species after wide use of flow cytometry techniques. For instance, Šafářová et al. (2011) found four cytotypes with different levels of ploidy (3x, 4x, 5x and 6x) in *Allium oleraceum*. Therefore, it would not be surprising if more cytotypes for *A. flavum* are discovered in the future, assuming that many more populations are studied.

In all earlier reports Bs were found only in diploid specimens of *A. flavum*. Thus, Šopova (1971) noted that a single B chromosome was constantly present in the frequency of 0.54 in a diploid population of *A. flavum* from mountain Galičica (FRG Macedonia). This B chromosome was easily distinguished from A chromosomes both by its morphology and size, i.e. it was shorter than the smallest chromosome of the standard set, with the centromere positioned subterminally. Moreover, the B chromosome was almost completely heterochromatic. It was also found that chiasma frequency increased in the presence of B chromosomes and that the flowering time of plants with Bs was delayed in both the natural habitat and in a botanical garden. Loidl (1982a) showed that in this species Bs have less heterochromatin than A chromosomes, but a similar C-band location. In one case, he noticed a nucleolus organizing region in a B chromosome. In the diploid *A. flavum* from Austria, Bs differ within and between populations to a great extent in both size and shape. Thus, three different types of Bs were distinguished in one population, all being submetacentrics. In the Czech Republic, Krahulcová (2003) found diploid plants with two B chromosomes, which were smaller than the other chromosomes of the set. One B chromosome was discovered in diploid plants in Albania (Baltisberger and Baltisberger 1995).

As a rule, Bs are less frequent in species with lower ploidy level. In the genus *Allium*, about 20% of species with Bs are polyploid, one third of them are triploids and the others are tetraploids. Rarely, Bs appear in penta- and hexaploids. Thus, the occurrence of Bs in tetraploid *Allium flavum* is a rare but not unexpected event.

Acknowledgments - This study was supported by the Serbian Ministry of Education and Science (Grant No. 173003).

REFERENCES

Ao, C. (2008). Chromosome Numbers and Karyotypes of *Allium przewalskianum* Populations. *Acta biologica Cracoviensia Series Botanica* **50(1),** 43-49.

Baltisberger, M. and *E. Baltisberger* (1995). Cytological data of Albanian plants. *Candollea* **50(2)**, 457-493.

Bartolo, G., Brullo, S. and *P. Pavone* (1978). Numeri cromosomici per la flora Italiana: 484-493. *Informatore Botanico Italiano* **10,** 267-277.

Bartolo, G., Brullo, S., Pavone, P. and *M.C. Terrasi* (1984). Cytotaxonomical notes on some Liliaceae of N. Cyrenaica. *Webbia* **38**, 601-622.

Bohanec, B., Jakše, M. and *P. Šesek* (2005). Genetic characterization of an unknown Chinese bulbous leek-like accession and its relationship to similar *Allium* species. *Hort. Science* **40(6)**, 1690-1694.

Bougourd, S.M. (1976). The B chromosome system of *Allium schoenoprasum* L. Current Chromosome Res. (Eds. K. Jones and P. E. Brandham), 206-207. Elsevier/North Holland Biomedical Press, Amsterdam.

Brullo, S., Pavone, P. and *C. Salmeri* (1996). *Allium daninianum* (Alliaceae), a new species from the Middle East. *Willdenowia* **26(1/2)**, 237-244.

Brullo, S., Pavone, P. and *C. Salmeri* (1994). Considerazioni citotassonomiche su *Allium calabrum* (Alliaceae), raro endemismo dell Italia meridionale. *Giorn. Bot. Ital.* **128(1)**, 246.

Cai, Q. and *C.C. Chinnappa* (1987). Giemsa C-banded karyotypes of seven North American species of *Allium*. *Am. J. Bot.* **74**, 1087-1092.

Capineri, R., D'Amato, G. and *P. Marchi* (1978). Numeri cromosomici per la Flora Italiana: 534-583. *Inform. Bot. Ital.* **10(3)**, 421-465.

Chang, L., Ding, K., Yu, H., Shang, C., and *Gai, J.* (2006). The variance of B chromosome frequency in *Allium wallichii*

Kunth with altitude and the effect on vegetative and reproductive growth. *Journal Yunnan University Natural Science* **28(2)**, 178-183.

Chen, X., Shi, D., Deng, G., and *S. Chen* (2005). A preliminary study of B-chromosome and physiological resistance characteristics of *Allium mairei*. *Xibei Zhiwu Xuebao* **25**, 1238-41.

Cheshmedzhiev, I.V. (1971). A contribution to the cytotaxonomy of certain species of *Allium L. Bot. J.* **56**, 662-670.

Cheschmedzhiev, I. 1975. The genus *Allium* L. in Bulgaria. *Tez. dokl. XII mezdun. botan. congr. L. Nauka*, 2.

Cheshmedzhiev, I.V. (1975). On chromosome polymorphism in some *Allium* species. *Genet. and Plant Breeding* **8**, 184-191.

Cheshmedzhiev, I.V. (1976). In IOPB chromosome number reports LIV. *Taxon* **25**, 631 -649.

Cheshmedzhiev, I.V. (1979). Karyosystematic investigations on species of the genus *Allium* L. in Bulgaria. *Fitologija* (Sofia) **11**, 40-46.

Chinnappa, C.C and *G.P. Basappa (*1986). Cytology of Some Western Canadian *Allium*-Spp. *American Journal of Botany* **73**, 529-34.

De Sarker, D., Johnson, M.A.T., Reynolds, A. and *P.E. Brandham* (1997). Cytology of the highly polyploid disjunct species, *Allium dregeanum* (Alliaceae), and of some Eurasian relatives. *Bot. J. Linn. Soc.* **124**, 361-373.

Dmitrieva, S.A. (2000). Karyology of the flora of Byelarus. pp. 42, Thesis of the Diss. Doc. Biol. Sci. Minsk (In Russian).

Fernandes, A. (1950). Sobre a cariologia de algumas plantas da serra de gerês. *Agronomia Lusit.* **12**, 551-600.

Fernández-Casas J., Pojarón S. and *M.L., Rodriguez* (1978). Numeros cromosomicos para la flora Espanola: 45-83. *Lagascalia* **7**, 105-125.

Friesen, N.V. (1986). Chromosome numbers of the representatives of the family Alliaceae from Siberia. *Bot. Zhurn.* **71(1)**, 113-115.

Fritsch R.M. and *S.B. Astanova* (1998). Uniform karyotypes in different sections of *Allium* L. subgen. *Melanocrommyum* (Webb & Berth) Rouy from Central Asia. *Feddes Repertorium* **109(7-8)**, 539-549.

Fritsch, R.M., Khassanov, F.O. and *N.W. Friesen* (1998). New taxa, new cmbinations, and taxonomic remarks on *Allium* L. from Fergan depression, Middle Asia. *Linzer biol. Beitr.* **30(1)**, 281-292.

Fritsch RM, Blattner F.R. and *M. Gurushidze (2010).* New classification of *Allium* L. subg. Melanocrommyum (Webb & Berthel) Rouy (Alliaceae) based on molecular and morphological characters. *Phyton* **49**, 145-220.

Frizen, N.W. 1983. Cytotaxonomical study of some species of *Allium* L. in Siberia. Izv. Sibirsk. *Otd. Akad. Nauk SSSR, Ser. Biol. Nauk* **5(1),** 48-53. (In Russian).

Frizen, N.V. (1988). *Alliaceae* from Siberia: taxonomy, karyology, chorology. Akademia Nauk SSSR, Sibirskoe Otdelenie, Novosibirsk. (In Russian).

Ghaffari, S.M. (2006). New cytogenetic information on *Allium iranicum* (Alliaceae) from Iran. *Biologia*, **61(4)**, 375-379.

Grun, P. (1959). Variability of accessory chromosomes in native populations of *Allium cernuum*. *Am. J. Bot*. **46**, 218-224.

Guern, M., LeCorff, J. and *J. Boscher* (1991). Comparative karyology of the *Allium ampeloprasum* complex in France. *Bul. Soc. Bot. Fr.-Lett. Bot.* **138**, 303-313.

Guillén, A. and *M.R. Rejón* (1984). The B-chromosome system of *Allium sphaerocephalon* L. (Liliaceae): types, effects and origin. *Caryologia* **37**, 259-267.

Hamoud, M.A., Badr A. and *Z. Turki*. 1990. Cytotaxonomic relationships of some taxa of Egyptian *Allium* L. *Cytologia* **55**, 161-167.

Holub, J., Měsiček, J. and *V. Javůrkova* (1970). Annotated chromosome counts of Czechoslovak plants (1-15) (Material for "Flora ČSSR" -1). *Folia Geobot. Phytotax.* **5**, 339-368.

Hosseini, S. and *R. Go* (2010). Cytogenetic Study of Some *Allium* Species (Subgenus *Allium* and *Melanocrommyum*) in Iran. *Cytologia* **75**, 99-108.

Jing, W., Xu, J. and *L. Yang* (1999). A study on cytotaxonomy of Sect. *Anguinum* of *Allium*. *Acta Phytotaxonomica Sinica* **37(1),** 20-34.

Jones, R.N. (1975). B chromosome system in flowering plants and animal species. *Int. Rev. Cytol.* 40, 1-100.

Jones, R.N. (1995). Tansley review no. 85: B chromosomes in plants. *New Phytol.* **131***, 411-434.*

Jones, R.N. and *H. Rees* (1982). B chromosomes. Academic Press, New York.

Karabokypoy, E. (1995). Study of the plant genus *Allium* in Eastern Greece. *PhD. Thesis, University of Patras.*

Kollman, F. (1971). *Allium ameloprasum* - polyploidy complex I. Ploidy levels. *Isr. J. Bot.* **20**, 13-20.

Kollman, F. (1972). *Allium ameloprasum* - polyploidy complex II. Meiosis and relationships between ploidy types. *Caryologia* **25**, 295-312.

Kollman, F. (1973). Karyology of some species of *Allium* section *Molium* in Israel. *Isr. J. Bot*. **22**, 92-112.

Koyuncu, M., and *N. Özhatay* (1983). Cytotaxonomic studies on some *Allium* species (Sect. *Melanocrommyum*) of south Anatolia. *J. Fac. Pharm. Ankara Univ.* **13**, 159-169.

Krahulcová, A. (2003). Chromosome numbers in selected monocotyledons (Czech Republic, Hungary, and Slovakia). *Preslia* **75**, 97-113.

Kudryashova, G.L. (1988). Cytotaxonomical study of *Allium saxatile* (Alliaceae) and closely related species from the Caucasus and the European part of USSR. *Bot. Žurn.* (Moscow & Leningrad) **73(5),** 665-669.

Levan, A. (1932). Cytological studies in *Allium*. II. Chromosome morphological contributions. *Hereditas* **16**, 257-294.

Levan, A. (1934). Cytological studies in *Allium*. VI. The chromosome morphology of some diploid species of *Allium*. *Hereditas* **20**, 289-330.

Levan, A., Fredga, K. and *A. Sandberg* (1964). Nomenclature for centromeric position on chromosomes. *Hereditas* **52,** 201-20

Li, R., Shang, Z., and *T. Cui* (1996). Studies on karyotypes and phylogenetic relationship of *Allium* Sect. *Caloscordum* (Liliaceae) from China. *Acta Phytotaxonomica Sinica* **34(3)**, 288-295.

Loidl, J. (1979). C-band proximity of chiasmata and absence of terminalisation in *Allium flavum* (Liliaceae). *Chromosoma* **73**, 45-51.

Loidl, J. (1982a). B-chromosomes in *Allium flavum* (Liliaceae) and some related species. *Pl. Syst. Evil.*, **139**, 197-207.

Loidl, J. (1982b). Fluoreszenzmikroskopische Untersuchungen an B-ehromosomen von *Allium flavum* und *Allium pallens* (Liliaceae). *Stapfia* **10**, 5-10.

Löve, A. (1976). IOPB chromosome number reports LIV. *Taxon* **25**, 631-649.

Lovka, M. 1995. IOPB chromosome data 9. *Int. Organ. Pl. Biosyst. Newslett. (Zurich)* **24**, 21-23.

Lövkvist, B. and *U.M., Hultgård* (1999). Chromosome numbers in south Swedish vascular plants. *Opera Bot.* **137**, 1-42.

Marcucci, R. and *N., Tornadore* (1997). Cytological and taxonomical notes on *Allium arvense* Guss. (Alliaceae) in Italy. *Webbia* **51(2)**, 189-199.

Marcucci, R. and *N., Tornadore* (1999). Mediterranean chromosome number reports 9 (1089-1098). *Fl. Medit.* **9**, 372-378.

Mehra, P.N., and *Pandita, T.K.* (1978). In IOPB chromosome number reports LXI. *Taxon* **27,** 375-392.

Měsíček, J. and *V. Javůrková-Jarolímová* (1992). List of Chromosome Numbers of the Czech Vascular Plants. Academia, Praha.

Miryeganeh, M. and *A. Movafeghi* (2011). Karyotype analysis in some species of *Allium* section *Allium* (Alliaceae). *Rom. J. Biol. - Plant Biol.* **56(1),** 17-27.

Mizianty, M. and *L. Frey.* (1973). Chromosome numbers of some vascular plants in the Western Bieszczady Mts. (Southeastern Poland). *Fragm. Florist. Geobot.* **19**, 265-270.

Noda, S. (1953). A new type of nucleolar chromosome and supernumerary fragment chromosome in *Allium cepa* L. Mem. Fac. Sci. Kyushu Univ., Ser. E **1**, 139-146.

Noda, S. and *H. Watanabe* (1968). Chromosome constitutions and polymorphic B-chromosomes in *Allium thunbergii* (A preliminary note). *Bull. Osaka Gakun Univ.* **11**, 105-128.

Noda, S. and *K. Li* (1980). Relationships of chromosome constitution for human activity as observed in the three species of Liliaceae. Monbu-sho Kaigai Gakujutsuchyosa chyukanhokoku, Kankoku ni okeru Kankyo Hensenshi, 33-55.

Nybom, N. (1974). Accessory chromosomes in *Allium*. *Hereditas* **33**, 571-572.

Ohle, H. (1992). Karyotype analysis using Giemsa C-banding technique in *Allium* species of six sections of the subgenus *Rhiziridium*, In: *The Genus Allium-Taxonomic Problems and Genetic Resources*. (Eds. P. Hanelt, K. Hammer and H. Knupffer), 21-26. Proc. Int. Symp., Gatersleben 1991, Germany.

Özhatay, N. (1993). *Allium* in Turkey: distribution, diversity, endemism and chromosome number. In: *5th OPTIMA Meeting* (Eds. H. Demiriz and N. Özhatay), 247-271. Istanbul Univ. Press, Turky.

Özhatay, N. (2002). Diversity of bulbous monocots in Turkey with special reference. Chromosome numbers. *Pure Appl. Chem.* **74(4)**, 547-555.

Özhatay, N. and *M.A.T. Johnson,* (1996). Some karyological remarks on Turkish *Allium* sect. *Allium*, *Bellevalia*, *Muscari*, and *Ornithogalum* subgen. *Ornithogalum*. *Bocconea* **5**, 239-249.

Pandita, T. K. and *P.N. Mehra.* (1981). Cytology of Alliums of Kashmir Himalayas, III. Male meiosis. *Nucleus* (Calcutta) **24**, 147-151.

Pastor, J. (1982). Karyology of *Allium* species from the Iberian Peninsula. *Phyton* (Horn). **22**, 171-200.

Pogosian, A.I. (1983). Chromosome numbers of some species of the *Allium* (Alliaceae) distributed in Armenia and Iran. *Bot. Žurn.* **68(5),** 652-660. (In Russian).

Pogosian, A.I. (1991). Cytotaxonomical investigation of the Caucasian representatives of the subgenus *Allium* (Alliaceae). Fl. Rastitel'n. Rastitel'n. *Resursy Armenii* **13**, 116-134.

Pogosian, A.I. and *A.G.. Seisums* (1992). Chromosome numbers in some species of *Allium* (Alliaceae) from the Afghanistan, Turkey and states of Middle Asia. *Bot. Žurn.* (Moscow & Leningrad) **77(9)**, 103-104.

Puizina, J., Šolić, M., Jelisavac, M. and *D. Papeš* (1995). B-kromosomi u populaciji blijedog luka (*Allium pallens* ssp. *tenuiflorum*) s Makarskog područja. Zbornik sažetaka priopćenja Simpozija u čast Zdravka Lorkovića, Zagreb, Hrvatska.

Randolph, L.F. (1928). Chromosome numbers in *Zea Mays* L. - Mem. *Cornell Agric. Exp. Sta. No.* 117.

Reeves, A. and *J. Tear* (2000). MicroMeasure for Windows, version 3.3. Free program distributed by the authors over the Internet from http://www.colostate.edu/Depts/Biology/MicroMeasure.

Ruiz Rejon, C., Lozano, R. and *M.R. Rejon* (1986). Numeros cromosomicos para la flora Espanola, 479-484. *Lagascalia* **14**, 292-296.

Ruiz Rejón, M. and *A. Sañudo* (1976). Estudios cariologicos en especies espanolas del orden Liliales. 1. Allium, Lapiedra, Narcissus. *Lagascalia* **6**, 225-238.

Šafářová, L., Duchoslav, M., Jandová, M. and *F. Krahulec* (2011). *Allium oleraceum* in Slovakia: cytotype distribution and ecology. *Preslia* **83**, 513-527.

Salmeri, C. (1998). *Allium brulloi* (Alliaceae), a New Species from Astypalea (Aegean Islands, Greece). *Willdenowia*, **28(1/2)**, 69-75.

Sharma, A.K. and *H.R. Aiyanger* (1961). Occurrence of B chromosomes in diploid *Allium stracheyi* Baker and their elimination in polyploids. *Chromosoma* **12**, 310-317.

Šopova, M. (1966). The nature and behaviour of supernumerary chromosomes in the Rhiyrideum group of the genus *Allium*. *Chromosoma* **19**, 149-158.

Šopova, M. (1970). The occurenec and nature of B chromosomes in a population of *Allium margaritaceum*. *God. Zborn. Prir.-Mat. Fak. Univ. Skopje* **22**, 179-187.

Šopova, M. (1971). Behaviour and transmission of B chromosomes in the population of *Allium flavum* L. and *Allium carinatum* L. from Macedonia. *Genetika* **3**, 249-259.

Tanker, N. and *S. Kurucu* (1979). Cytotaxonomical researches on some species of *Allium* naturally growing in Turkey. *J. Fac. Pharm.* Ankara Univ. **9**, 64-80.

Tolgor, Zhao, Y. and *J. Xu* (1994). A chromosomal study of eight species in *Allium* Sect. *Rhiziridium* G.. Don in China. *Acta Phytotaxonomica Sinica* **32(2)**, 165-172.

Tschermak-Woes, E. and *H. Schiman* (1960). Strukturelle hybridität und akzessorische chromosomen bei *Allium pulchellum*. *Öst. Bot. Z.* **107**, 212-227.

Tzanoudakis, D. (1986). Chromosome Studies in the Greek Flora. II. Karyotypes of four Aegean endemics of *Allium* sect. *Codonoprasum* (Liliaceae). *Willdenowia* **16(1)**, 203-211.

Tzanoudakis, D. (1992). Karyotype variation and evolution in the Greek *Allium,* In: *The genus Allium. Taxonomic problems and genetic resources,* (Eds. P.Hanelt, K.Hammer and H. Knupffer), 305-320. Proc. Int. Symp., Gatersleben 1991, Germany.

Tzanoudakis, D. and *C.G. Vosa* (1988). The cytogeographical distribution pattern of *Allium* (Alliaceae) in the Greek peninsula and islands. *Plant Systematics and Evolution* **159**, 193-215.

Vakhtina, L.I. (1989). Issledovanie karyotipa *Allium fibrosum* Regel s pomoshchju differencialnoj okraski. Tesizy II Symp. Plant Karyology, pp. 53-54.

van Loon J. C. & *van Setten A. K.* (1982): In: Löve Á. (ed.), IOPB chromosome number reports LXXVI, Taxon, Utrecht, **31**, 574-598.

Ved Brat, S. (1965). Genetic systems in *Alliums*. I. Chromosome variation. *Chromosoma* **16**, 486-499.

Viegi, L. and *G. Renzoni* (1981). Numeri cromosomici per la Flora Italiana: 831-835. *Inform. Bot. Ital.* **13**, 168-171.

von Bothmer, R. (1970). Cytological studies in *Allium* I. Chromosome numbers and morphology in sect *Allium* from Greece. *Bot. Notiser* **123**, 519-551.

von Bothmer, R. (1975). Karyotype variation in *Allium bourgeaui*. *Hereditas* **79**, 125-132.

von Bothmer, R.. (1982). Karyotype variation in *Allium commutatum* (Liliaceae s. lato). *Pl. Syst. Evol.* **140**, 179-189.

Vosa, C.G. (1966). Seed germination and B chromosomes in the leek (*Allium porrum*). *Chromosomes Today* **1**, 24-27.

Vosa, C.G. (1973). The enhanced and reduced quinacrine fluorescence bands and their relationship to the Giemsa patterns in *Allium flavum*. In: *Chromosome identification*, (Eds. Caspersson T. and Zech, L.), 156-158. Nobel Symp. 23 (Med. Nat. Sci).

Vujošević M. and *J. Blagojević* (2004). B chromosomes in populations of mammals. *Cytogenet Gen Res* **106**, 247-256.

Vujošević, M. and *J. Blagojević* (2002). B chromosomes in wild garlic, *Allium ursinum*. *Arch Biol. Sci.*, Belgrade, **54(1-2)**, 19P-20P.

Wang, A., Wang, Y., Ren, X. and *L. Zhang* (2009). Discovery of triploid *Allium macrostemon* in Laizhou city in Shandong province. *Journal of Anhui Agricultural Sciences* **1009-4229(1)**, 124-126.

Wetschnig, W. (1992). Chromosomenzahlen Kärntner Gefässpflanzen (Teil 3): Karyologie und Verbreitung der *Allium*-Arten (Alliaceae) in Kárnten. *Carinthia II* **182**, 497-533.

Wetschnig, W. (1995). Giemsa C-banded karyotypes of *Allium ericetorum* and *A. kermesinum* (Alliaceae). *Pl. Sys. Ev.* **195(1-2)**, 45-59.

Xue, C.Y., Xu, J.M. and *J.Q., Liu* (2000). Karyotype studies of *Allium prattii* among 4 populations in Southern Qinghai. *Acta Botanica Boreali-Occidentalia Sinica* **20**, 288-293.

Yang, D. (2001). Chromosome studies of six species of plants from Shandong. J. *Shandong Norm. Univ., Nat. Sci. Ed.* **16(3)**, 305-312.

Zakirova, R.O. and *I.I. Nafanailova.* (1990). Chromosome numbers in the members of some families of vascular plants in the flora of Kazakhstan. *Bot. Žurn.* (Moscow & Leningrad) **75**, 438-439.

Zhang, Y., Zhang, X., and *Xu., J.* (1993). Biosystematic studies on *Allium* L. A study on karyotypes of 6 samples of *Allium* L. *Journal of Wuhan Botanical Research* **11**, 193-198.

Zou, D.Q. and *Q.Y. Jia* (1985). Cytological study on Chinese chive (*Allium tuberosum* Rottl.) and wild chive (*A. ramosum*) Hebei Nongye Daxue Xuebao. *J. Hebei Agric. Univ.* **8(1)**, 12-17.