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A karyomorphological study on the genus *Muscari* Mill. growing in Kahramanmaraş (Turkey)

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Abstract: The karyotypes and idiograms of nine *Muscari* Mill. species from 21 populations distributed in Kahramanmaraş province, southern Turkey, were examined: *M. armeniacum* Leichtlin ex Baker $2n = 18$ (diploid); *M. aucheri* (Boiss.) Baker $2n = 18$ (diploid); *M. anatolicum* Cowley & Özhatay $2n = 27$ (triploid); *M. neglectum* Guss. $2n = 18$ (diploid), 36 (tetraploid), 54 (hexaploid); *M. parviflorum* Desf. $2n = 36$ (tetraploid); *M. babachii* Eker & Koyuncu $2n = 18$ (diploid); *M. comosum* Miller $2n = 18$ (diploid); *M. tenuiflorum* Tausch $2n = 18$ (diploid); and *M. azureum* Fenzl $2n = 18$ (diploid). *M. anatolicum* is an endemic species to Turkey and the $2n = 27$ triploid population for this species is recorded for the first time. Idiograms and karyotypes of the species were obtained by the use of Cameram software.

Key words: Chromosome numbers, karyotypes, *Muscari*, Kahramanmaraş, Turkey

1. Introduction

The genus *Muscari* (Asparagaceae) has a wide distribution in the Mediterranean basin as far as the Caucasus, temperate Europe, North Africa, and Southwest Asia (Speta, 1998; Jafari et al., 2008). In Turkey, it is represented by 37 species, 25 of which are endemic (Davis and Stuart, 1984; Davis et al., 1988; Özhatay, 2000; Özhatay et al., 2006, 2009, 2011; Demirci et al., 2013; Pirhan et al., 2014; Kaya, 2014; Yıldırım, 2015, 2016).

Infrageneric arrangement of the genus *Muscari* is not settled. An approach of taxonomical splitting has been put forward by Garbari and Greuter (1970). They proposed a division of *Muscari* into the genera *Muscari* Mill., *Leopoldia* Parl., *Muscarimia* Kostel. ex Los., and *Pseudomuscari* Garbari & Greuter mainly on the basis of their karyological characteristics. However, this approach was criticized several times. Authors dealing with the evolution of *Muscari* (Davis and Stuart, 1980, 1984; Speta, 1982, 1989) found transition to character expressions and suggested to treat the genera only as subgenera. The recently published book of the *List of Turkish Vascular Plants* (Güner et al., 2012) and *World Checklist of Selected Plant Families* (Govaerts, 2015) accepted *Muscari*.

The majority of *Muscari* species are diploid with a chromosome number of $2n = 2x = 18$, although several populations from Turkey that were studied were polyploid (Özhatay and Johnson, 1996). Based on certain karyological investigations (Stuart, 1970; Karlén, 1984; Dalgıç, 1991; Johnson, 1994; Özhatay and Johnson, 1996; Johnson and Brandham, 1997), a few species are triploid ($2n = 3x = 27$) (Karlén, 1984), tetraploid ($2n = 4x = 36$) (Johnson and Brandham, 1997), pentaploid ($2n = 5x = 45$) (Dalgıç, 1991), and hexaploid ($2n = 6x = 54$) (Karlén, 1984).

The aim of the present study was to understand the karyological characteristics of the genus *Muscari* growing in Kahramanmaraş Province.

2. Materials and methods

2.1. Plant materials

In 2011–2014, living plants were collected from Kahramanmaraş and voucher specimens were prepared and kept at ISTE Herbarium (Herbarium of İstanbul University, Faculty of Pharmacy). The plants were all grown and maintained in the Geophyte Garden in Yalova Atatürk Central Horticultural Research Institute. The localities, populations, and herbarium numbers are given in Table 1.

2.2. Chromosome analysis

Root tips were collected on warm sunny mornings in June and pretreated with ABN (alpha bromonaphthalene) for 24 h at +4 °C. Before staining, the material was fixed in

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Table 1. Localities of used taxa in research area (Kahramanmaraş).

Taxa	Population number	Locality	Herbarium number (ISTE)
Subgen. *Botryanthus*			
M. armeniacum	1–5	Saygılı village, 20.07.2012; Andırın, Kargaçayırı, 1200 m, 23.07.2012; Türkoğlu, Çakıroğlu village, 1262 m, 13.04.2012; Geben, Meryemçil, 1450 m, 03.06.2012. Rahmacılar village, 536 m, 13.07.2011.	100156; 100181; 100174; 100192; 100172
M. anatolicum	6	Ahır mountain, 1480 m, 19.03.2013.	100085
M. aucheri	7	Andırın, Azgıt castle, 1100 m, 11.03.2012.	100073
M. neglectum	8–13	Rahmacılar village, 650 m, 13.07.2011; Andırın, Çokak, 1283 m, 10.05.2013; Göksun, Göksun – Saimbeyli, 1350 m, 23.03.2013; Andırın, Osmancık village, 1144 m, 10.04.2012; Andırın, Tırıl mountain, 1800 m, 16.03.2013; Rifatiye village, 100 m, 10.04.2012.	100126; 100132; 100136; 100124; 100133; 100112
M. parviflorum	14–17	Andırın, Bulgurkaya village, 550 m, 07.11.2012; Andırın, İspirli, 500 m, 07.11.2012; Boztopraklı village, Dadılar, 530 m, 07.11.2012; Sarımsak mountain, 1138 m, 18.12.2011.	100138; 100140–100142
Subgen. *Pseudomuscari*			
M. azureum	18	Kaleboynu – Geben, 1455 m, 15.06.2013.	100176
Subgen. *Leopoldia*			
M. babachii	19	Andırın, Elmadağ, Körçoban, 1450 m, 06.06.2012.	100082
M. comosum	20	Göksun, Hançerderesi, 1350 m, 23.03.2013.	100102
M. tenuiflorum	21	Başkonuş lake, 1250 m, 23.07.2012.	100150

Carnoy solution and hydrolyzed in 1 N HCl for 13 min at 60 °C. The material was stained with basic fuchsin and then squashed in a drop of 2% acetic orcein onto glass microscope slides. The slides were made permanent using liquid CO_2. At least five metaphase plates were examined from different individuals for all the counts. Preparations were examined using an Olympus BX53 light microscope equipped with a digital camera. Moreover, measurements of somatic chromosomes were taken by CAMERAM software; they were calculated with a formula of the relative variation in chromosome length (CV_{CL}) and mean centromeric asymmetry (M_{CA}) (Zuo and Yuan, 2011; Peruzzi and Eroğlu, 2013). The classification of chromosomes as having metacentric (m), submetacentric (sm), subtelocentric (st), and telocentric (t) centromeres was used, according to Levan et al. (1964). Chromosomal data of the specimens are summarized in Table 2.

3. Results

In the present study a karyotype analysis of nine *Muscari* taxa from the Kahramanmaraş area (southern Turkey) was carried out. The karyotypes and idiograms of 21 different populations of nine *Muscari* species are summarized in the figures. The chromosome length ranges, total haploid chromosome length, intrachromosomal asymmetries, and the interchromosomal asymmetry index of *Muscari* taxa are given in detail in Table 2.

Subgen. *Botryanthus* (Kunth) Rouy

M. armeniacum Leichtlin ex Baker: Five populations were examined (Table 1). Chromosome number $2n = 2x = 18 = 12m + 4sm + 2st^{SAT} = 2n = 2x = 18 = 12m + 4sm + 2st$. Satellites were observed (Figure 1). The intrachromosomal asymmetry index (M_{CA}) varies from 9.88 to 24.28. The interchromosomal asymmetry index (CV_{CL}) varies 15.97 to 35.46 (Table 2). Previous reports: $2n = 18$ (Stuart, 1970; Karlén, 1984; Dalgıç, 1991; Johnson and Brandham, 1997), $2n = 27$ and 36 (Dalgıç, 1991; Johnson and Brandham, 1997), $2n = 18 + 0 – 3B$ (Dalgıç, 1991; Özhatay and Johnson, 1996).

M. anatolicum Cowley & N.Özhatay (endemic)*:* One population was examined (Table 1). Chromosome number $2n = 3x = 27 = 15m + 9sm + 3st$ (Figure 1). The intrachromosomal asymmetry index (M_{CA}) is 24.60. The interchromosomal asymmetry index (CV_{CL}) is 41.33 (Table 2). Previous reports: $2n = 18$ and 36 (Johnson, 1994; Johnson and Brandham, 1997).

M. aucheri Baker (endemic)*:* One population was examined (Table 1). Chromosome number $2n = 2x = 18$

Table 2. Chromosomal comparison of the 21 populations of *Muscari* species.

Taxa	Accession number	2*n*	Chromosome length ranges (μm)	Total haploid chromosome length (μm)	Intrachromosomal asymmetry index (M_{CA})	Interchromosomal asymmetry index (CV_{CL})	Karyotype formula
Subgen. *Botryanthus*							
M. armeniacum	100156 (Pop. 1)	18	1.73 to 5.42	37.02	24.28	35.62	12m + 4sm + $2st^{SAT}$
	100181 (Pop. 2)	18	1.87 to 4.08	21.77	22.17	25.82	12m + 4sm + 2st
	100174 (Pop. 3)	18	1.96 to 3.09	22.01	09.88	15.97	12m + 4sm + 2st
	100192 (Pop. 4)	18	1.58 to 4.05	20.88	16.94	34.03	12m + 4sm + $2st^{SAT}$ +
	100172 (Pop. 5)	18	1.34 to 4.34	24.36	16.23	35.46	12m + 4sm + 2st
M. anatolicum	100085 (Pop. 6)	27	1.46 to 5.52	22.84	24.60	41.33	15m + 9sm + 3st
M. aucheri	100173 (Pop. 7)	18	1.84 to 4.73	23.16	28.88	39.10	12m + 4sm + 2st
M. neglectum	100126 (Pop. 8)	18	1.31 to 2.78	20.61	10.99	26.61	8m + 6sm + 4st
	100132 (Pop. 9)	18	1.31 to 2.18	17.01	23.61	15.97	8m + 6sm + 4st
	100136 (Pop. 10)	18	1.15 to 3.56	24.81	28.44	28.86	4m + 10sm + $4st^{SAT}$
	100124 (Pop. 11)	36	1.71 to 3.63	23.07	25.51	37.9	16m + 12sm + 8st
	100133 (Pop. 12)	54	1.25 to 2.16	16.71	17.07	18.75	35m + m^{SAT} + 18sm
	100112 (Pop. 13)	54	1.25 to 3.55	16.5	17.12	37.58	36m + 18sm
M. parviflorum	100142 (Pop. 14)	36	1.71 to 3.63	23.12	08.98	22.56	23m +m^{SAT} + 8sm + 4st
	100138 (Pop. 15)	36	1.94 to 3.20	22.5	09.23	17.31	24m + 8sm + 4st
	100140 (Pop. 16)	36	2.23 to 3.85	26.55	20.94	20.36	24m + 8sm + 2st + $2st^{SAT}$
	100141 (Pop. 17)	36	2.18 to 3.43	24.62	11.34	13.68	24m + 8sm + 2st + $2st^{SAT}$
Subgen. *Pseudomuscari*							
M. azureum	100176 (Pop. 18)	18	1.85 to 4.98	35.43	32.45	33.96	5m + m^{SAT} + 10sm + 2st
Subgen. *Leopoldia*							
M. babachii	100082 (Pop. 19)	18	1.61 to 4.88	25.64	27.94	40.93	8m + 6sm + 2st + $2st^{SAT}$
M. tenuiflorum	100150 (Pop. 20)	18	1.94 to 5.78	24.54	27.61	43.12	8m + 6sm + 4st
M. comosum	100102 (Pop. 21)	18	1.08 to 4.60	21.68	26.08	56.92	10m + 6sm + 2st

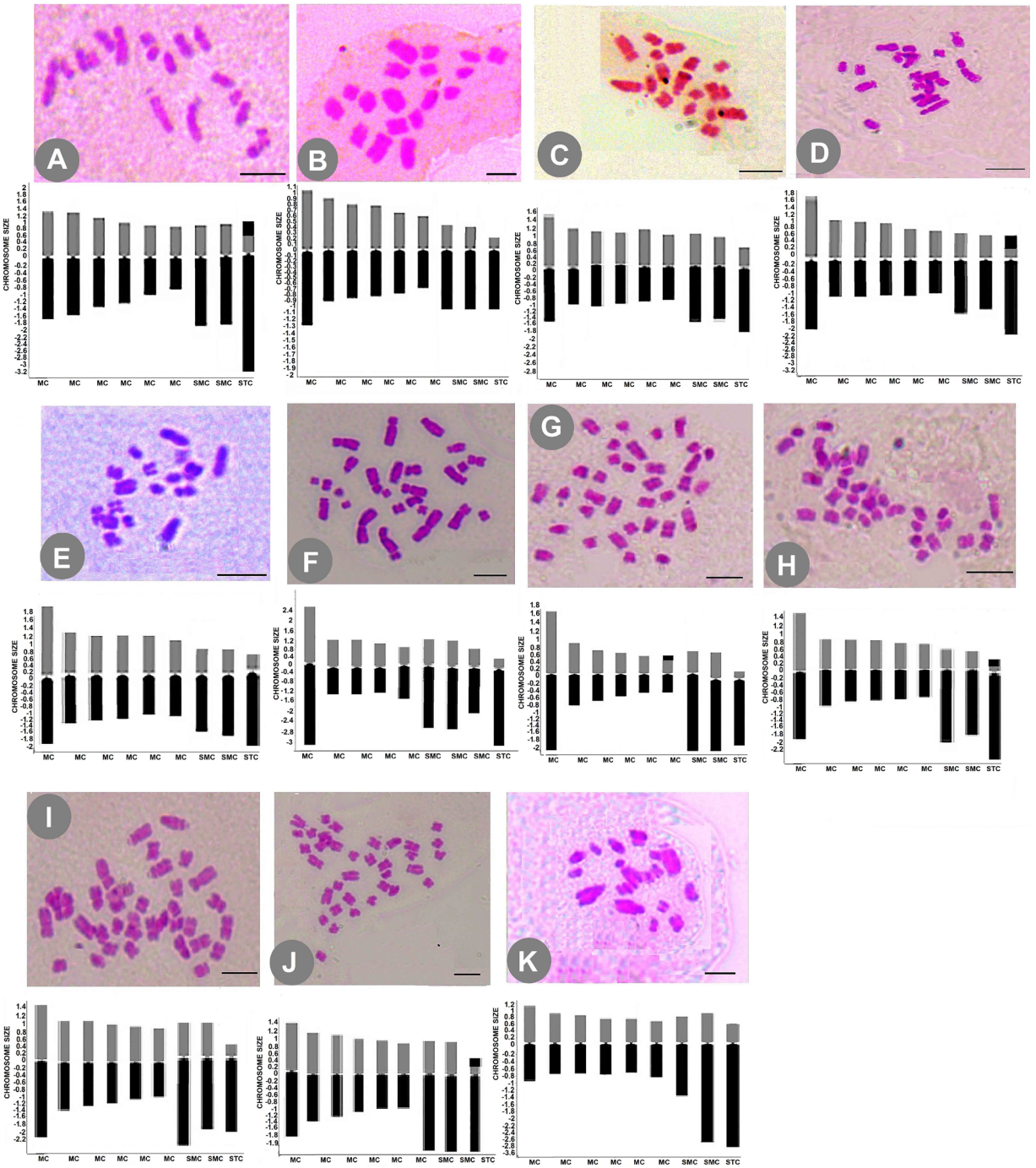

Figure 1. Metaphase chromosomes in root tip cells and idiograms of *M. armeniacum* (A: Pop. 1, B: Pop. 2, C: Pop. 3, D: Pop. 4, E: Pop. 5); *M. anatolicum* (F: Pop. 6); *M. parviflorum* (G: Pop. 14, H: Pop. 15, I: Pop. 16, J: Pop. 17); *M. aucheri* (K: Pop. 7) (Subgen. *Botryanthus*). Scale bars: 5 µm.

= 12m + 4sm + 2st (Figure 1). The intrachromosomal asymmetry index (M_{CA}) is 28.88. The interchromosomal asymmetry index (CV_{CL}) is 39.10 (Table 2). Previous reports: $2n$ = 18, 36 (Stuart, 1970; Özhatay and Johnson, 1996; Johnson and Brandham, 1997).

M. parviflorum Desf: Four populations were examined (Table 1). Chromosome number $2n = 4x = 36$ = 23m + m^{SAT} + 8sm + 4st = $2n = 4x = 36$ = 24m + 8sm + 4st = $2n = 4x = 36$ = 24m + 8sm + 2st + $2st^{SAT}$ (Figure 1). The intrachromosomal asymmetry index (M_{CA}) varies from

8.98 to 20.94. The interchromosomal asymmetry index (CV_{CL}) varies 13.68 to 22.56 (Table 2). Previous reports: 2*n* = 36, 45 (Rossi and Capineri, 1982; Speta, 1982; Garbari, 1984).

M. neglectum Guss*:* Six populations were examined (Table 1). Chromosome number 2*n* = 2*x* = 18 = 8m + 6sm + 4st = 2*n* = 2*x* = 18 = 4m + 10sm + $4st^{SAT}$ = 2*n* = 4*x* = 36 = 16m + 12sm + 8st = 2*n* = 6*x* = 54 = 35m + m^{SAT} + 18sm = 2*n* = 6*x* = 54 = 36m + 18sm. Satellites were observed (Figure 2). The intrachromosomal asymmetry index (M_{CA}) varies from 10.99 to 28.44. The interchromosomal asymmetry index (CV_{CL}) varies 15.97 to 37.90 (Table 2). Previous reports: 2*n* = 18 (Stuart, 1970), 2*n* = 28 (Dalgıç, 1991), 2*n* = 45 (Dalgıç, 1991), 2*n* = 54 (Karlén, 1984; Nersesian, 2001).

Subgen. *Pseudomuscari* Garbari & Greuter

M. azureum Fenzl (endemic): One population was examined (Table 1). Chromosome number 2*n* = 2x = 18 = 5m + m^{SAT} + 10sm + 2st (Figure 2). The intrachromosomal asymmetry index (M_{CA}) is 32.45. The interchromosomal asymmetry index (CV_{CL}) is 33.96 (Table 2). Previous reports: 2*n* = 18 (Speta, 1982).

Subgen. *Leopoldia* (Parl.) Rouy.

M. babachii Eker & Koyuncu (endemic): One population was examined (Table 1). Chromosome number 2*n* = 2*x* = 18 = 8m + 6sm + 2st + $2st^{SAT}$. Satellites were observed (Figure 2). The intrachromosomal asymmetry index (M_{CA}) is 27.94. The interchromosomal asymmetry index (CV_{CL}) is 40.93 (Table 2). Previous reports: 2*n* = 18 (Demirci et al., 2013).

M. comosum (L.) Miller: One population was examined (Table 1). Chromosome number 2*n* = 2*x* = 18 = 10m + 6sm + 2st (Figure 2). The intrachromosomal asymmetry index (M_{CA}) is 26.08. The interchromosomal asymmetry index (CV_{CL}) is 56.92 (Table 2). Previous reports: 2*n* = 18 (Stuart, 1970; Bentzer, 1973; Dalgıç, 1991; Özhatay and Johnson, 1996).

M. tenuiflorum Tausch: One population was examined (Table 1). Chromosome number 2*n* = 2*x* = 18 = 8m + 6sm + 4st (Figure 2). The intrachromosomal asymmetry index (M_{CA}) is 27.61. The interchromosomal asymmetry index (CV_{CL}) is 43.12 (Table 2). Previous reports: 2*n* = 18 (Stuart, 1970; Dalgıç, 1991; Nersesian, 2001; Krahulcová, 2003).

4. Discussion

The genus *Muscari* was formerly included in the family Liliaceae and then the family Hyacinthaceae; recently the Angiosperm Phylogeny Group (APG) reassessed the taxonomic position of this genus and finally *Muscari* was placed in the family Asparagaceae (Reveal and Chase, 2011). We accepted the genus *Muscari* in a wide sense and consider it reasonable to treat '*Botryanthus*', '*Pseudomuscari*', and '*Leopoldia*' as subgenera. In the present study, nine species of *Muscari* distributed in Kahramanmaraş Province were studied karyologically. Examined specimens were collected from natural habitats in the province from 21 populations. Out of the nine species examined, four species are endemic to Turkey. All the studied species had the basic chromosome number of *x* = 9. In all the studied taxa, the most frequent chromosome types were metacentric, submetacentric, and subtelocentric. The satellites in *Muscari* are usually minute and situated on the chromosomes in pair no. 1 on the long arm and pair 9 on the short arm (only population pair no. 5). Satellites on chromosomes in pairs 2–8 are obviously very rare.

Muscari subgen. *Botryanthus*: In the present study, the chromosome number and the karyotype formulae of *M. armeniacum* from five populations were counted as 2*n* = 2*x* = 18 = 12m + 4sm + $2st^{SAT}$ = 2*n* = 2*x* = 18 = 12m + 4sm + 2st. Karlén (1984) determined a different karyotype formula of the species as 2*n* = 2*x* = 18 = 7m + 2sm in three populations. Johnson and Brandham (1997) reported its chromosome number as being 2*n* = 2*x* = 18. Özhatay and Johnson (1996) determined the chromosome number of the species as 2*n* = 2*x* = 18 in four populations, as 2*n* = 2*x* + 3 = 18 + 3B in a population (aneuploidy), as 2*n* = 2*x* - 3= 18 + 0 – 3B in a population, and 2*n* = 4*x* = 36 in a population (tetraploid).

The chromosome number of *M. aucheri* from a population is 2*n* = 2*x* = 18 = 12m + 4sm + 2st (diploid), while Johnson and Brandham (1997) reported its karyotype as 2*n* = 4*x* = 36 (tetraploid) with the same karyotype. Johnson (1994) reported the karyotype of *M. anatolicum* as 2*n* = 2*x* = 18 and 2*n* = 4*x* = 36, while Johnson and Brandham (1997) reported its karyotype as being 2*n* = 4*x* = 36. In the present study, karyotypes of *M. anatolicum* were determined with a different chromosome number and karyotype formula with 2*n* = 3*x* = 27 = 15m + 9sm + 3st. The triploid population was observed for the first time for this species (Table 2). *M. neglectum* is one of the most variable species within the genus *Muscari*. In previous studies ploidy levels were found in *M. neglectum*, together with the presence of B-chromosomes; although diploid karyotypes are the most common ones (Stuart, 1970; Van Loon, 1980; Van Loon and Oudemans, 1982; Garbari and Crisman, 1988; Özhatay and Johnson, 1996; Johnson and Brandham, 1997), triploid (Johnson et al., 1996), tetraploid (Natarajan, 1979; Garbari, 1984; Özhatay and Johnson, 1996; Johnson and Brandham, 1997; Marcucci et al., 2005), pentaploid (Garbari, 1984; Dalgıç, 1991; Dobea et al., 1997; Nersesian, 2001), and hexaploid (Natarajan, 1979; Garbari, 1984; Dalgıç, 1991) have also been recorded previously. Six populations collected from different localities were studied. The chromosome numbers were identified as 2*n* = 2*x* = 18, 2*n* = 4*x* = 36, and 2*n* = 6*x* = 54,

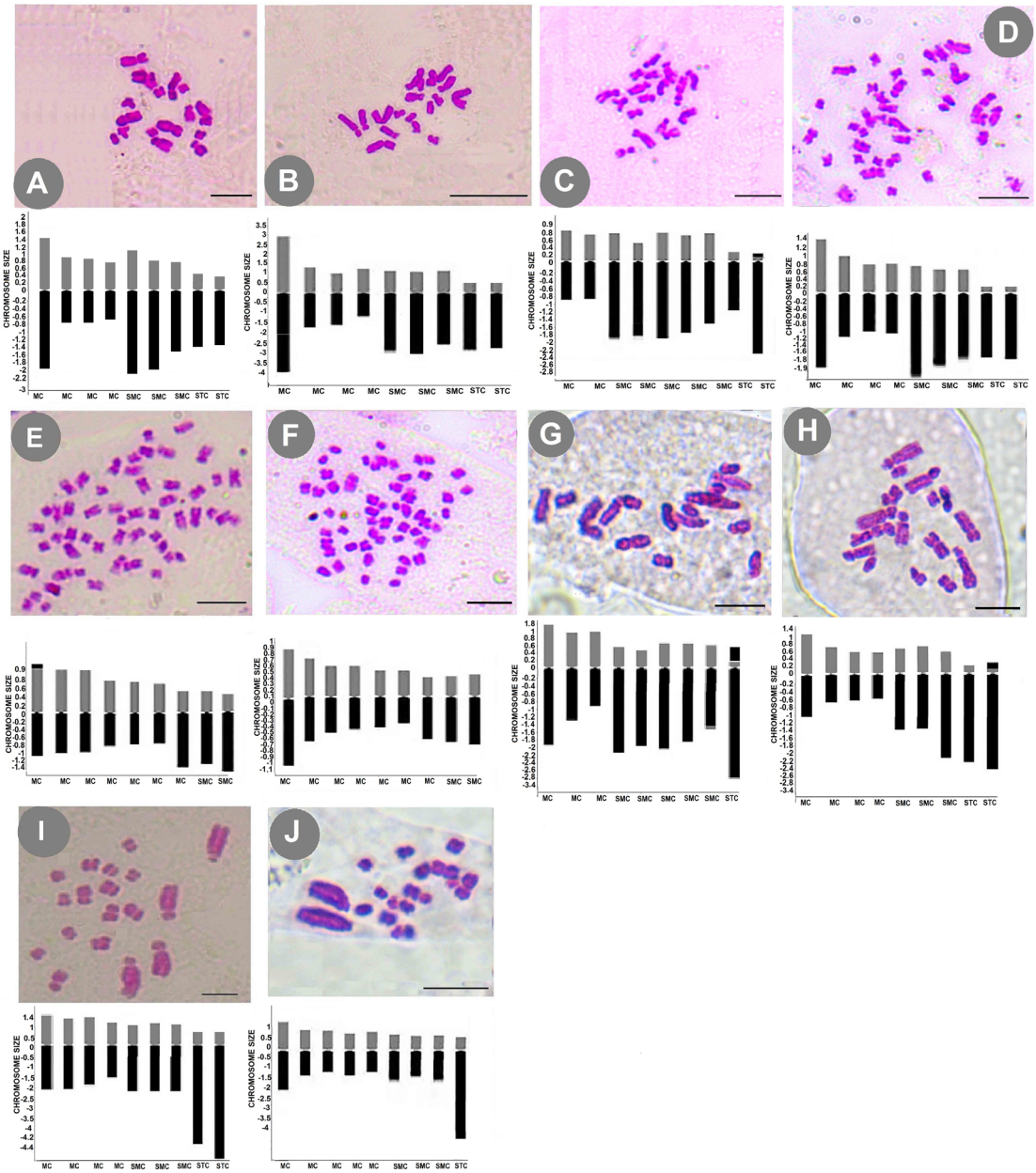

Figure 2. Metaphase chromosomes in root tip cells and idiograms of *M. neglectum* subgen. *Botryanthus*) (A: Pop. 8, B: Pop. 9, C: Pop. 10, D: Pop. 11, E: Pop. 12, F: Pop. 13); *M. azureum* (G: Pop. 18) (subgen. *Pseudomuscari*); *M. babachii* (H: Pop. 19); *M. comosum* (J: Pop. 20); *M. tenuiflorum* (I: Pop. 21) (subgen. *Leopoldia*). Scale bars: 5 μm.

identical to the literature values. However, the karyotype formulae of the species were different from those in previous studies. The karyotype formula was determined as $2n = 2x = 18 = 8m + 6sm + 4st$ in two populations (diploid), while it was $2n = 2x = 18 = 4m + 10sm + 4st^{SAT}$ in a population (diploid), $2n = 4x = 36 = 16m + 12sm + 8st$ in a population (tetraploid), $2n = 6x = 54 = 35m + m^{SAT} + 18sm$ in a population (hexaploid), and $2n = 6x = 54 = 36m + 18sm$ in a population (hexaploid). The karyotype of the species was counted for 87 populations by Karlén (1984). The chromosome numbers of the species were found as $2n = 2x = 18$ (diploid), $2n = 4x = 36$ (tetraploid), $2n = 6x = 54$ (hexaploid), and $2n = 8x = 72$ (oktaploid) and the karyotype formulae are 4m + 5sm (Karlén, 1984). Jafari et al. (2008) determined the karyotype formulae of the species as $2x = 2n - 1 = 53 = 13m + 11$ sm + 2st + t = 23m + 3sm = 21m + 5 sm = 16m + 9 sm + t in four populations, as $2x = 2n+3 = 48 = 16m + 7$ sm = 13m + 9 sm + st = 17m + 5sm + st in three populations (aneuploidy), as $2n = 2x = 45 = 17m + 5sm + st$ in a population (autopentaploid),

and $2n = 2x = 36 = 14m + 3sm$ in a population (tetraploid). However, several populations of *M. neglectum* from European Turkey studied by Dalgıç (1991) were polyploid. Azizi et al. reported the karyotype formulae of the species as $2n = 5x = 45 = 45m$ (pentaploid), $2n = 6x = 54 = 54m$ (hexaploid), and $2n = 8x = 72 = 72m$ (octoploid) (Azizi et al., 2016).

The chromosome number and karyotype formulae of *M. parviflorum* from four populations counted as $2n = 4x = 36 = 23m + m^{SAT} + 8sm + 4st = 2n = 4x = 36 = 24m + 8sm + 4st = 2n = 4x = 36 = 24m + 8sm + 2st + 2st^{SAT}$ concur with previous studies (Rossi and Capineri, 1982; Speta, 1982; Garbari, 1984).

Muscari subgen. *Pseudomuscari*: In the present study, the karyotype of *M. azureum* from a population was determined as $2n = 2x = 18$. Speta (1982) reported the same karyotype.

Muscari subgen. *Leopoldia*: All of the investigated taxa derived from nine populations in the subgen. *Leopoldia* are diploid ($2n = 2x = 18$), with the same chromosome numbers as previous studies. The chromosome number and karyotype formula of *M. babachii* was counted as $2n = 2x = 18 = 8m + 6sm + 2st + 2st^{SAT}$ in our study, which is the same result given in our previous study (Demirci et al., 2013). Azizi et al. (2016) reported the karyotype of *M. comosum* as $2n = 2x = 18 = 2t + (1m + 1sm) + 14m$, while Ruiz Rejon et al. (1990) reported its karyotype as $2n = 2x = 18 = 14m + 2sm + 2t$. Two populations of this species are constituted by different karyotype formulae as $2n = 2x = 18 = 3m + 2sm + 4st$ and $2n = 2x = 18 = 2m + 4sm + 3st$ (Jafari et al., 2008). In our study, the chromosome numbers of the species from a population were identified as $2n = 2x = 18 = 10m + 6sm + 2st$, which is consistent with literature values. However, the karyotype formulae of the populations were different from those of previous studies. Jafari et al. (2008) reported the karyotype of *M. tenuiflorum* from two populations as $2n = 2x = 18 = 5m + 3sm + 1st$ (diploid) and as $2n = 3x = 27 = 1m + 5sm + 2st + 1t$. In our study, the chromosome numbers of the species from a population were identified as $2n = 2x = 18 = 8m + 6sm + 4st$.

The karyological investigation of different populations showed different karyotype formulae and chromosome numbers of the species of *Muscari*. In terms of morphological characters, *Muscari* subgen. *Botryanthus* is more variable than *Muscari* subgen. *Leopoldia*. In addition, karyological results confirmed taxonomic positions. Most of variations in morphological characters and ploidy were found in *Muscari* subgen. *Botryanthus* (Figure 3). In the studied area, characteristics such as size, scape size, perigon color, and leaf size of *M. neglectum* are variable. Population 11 (tetraploid) of *M. neglectum* was isolated from other populations of *M. neglectum* and located at 1455 m. Other polyploid populations of the species were growing in a close locality with the same weather and habitats. Three contributing causes may explain some of the differences in our results. They are altitude, weather contribution, and geographical differences. The genus *Muscari* has clearly highly variable species karyologically and morphologically, especially *M. neglectum*, in our study. The species of the genus are adapted to varying habitats: dry lands, meadows, rocky places, and woods, and exhibit large variation morphologically. The karyotype formula and the chromosome number of the species have been found to be quite variable as well. The different habitats could have contributed to the morphological distinctions and even the genetic differences. This is very important for hybridizations and chromosome evolutions for the genus. The reason for this variation and instability is the chromosome number and size, resulting in taxonomical problems in defining its species and genus (Valdez and Diaz Lifante, 1992; Arslan and Uysal, 2009).

Karyotype asymmetry indices have been widely used to make assumptions about the mechanisms of chromosomal evolution in plants (Paszko, 2006). The CVCL and MCA scatter plots are preferred much more than scatter diagrams based on other incidents because they are better suited to demonstrate karyotype relationships among taxa, especially when chromosome size variation is negligible (Peruzzi and Eroglu, 2013). In our study, the scatter plot presents three groups of populations. The populations of *M. comosum* showed a high asymmetry index value with a high level of karyotype asymmetry (Figure 4). The interchromosomal asymmetry index average (CVCL) of *M. comosum* is 56.92 and the species have the most asymmetrical karyotypes. *M. comosum*, with highest karyotype asymmetry, showed evident variation in morphological features of chromosomes as compared to those of *M. babachii* and *M. tenuiflorum*. The results show the intrachromosomal asymmetry in *M. babachii* and *M. tenuiflorum* was high (Table 2). *M. babachii* had CVCL of 40.93 and MCA of 27.94, and *M. tenuiflorum* had CVCL of 43.12 and MCA of 27.61), and therefore possessed the most asymmetrical and evolutionary karyotype. Conversely, population 14 of *M. parviflorum* had the most symmetrical karyotype among the studied populations (CVCL = 22.56; MCA = 8.98). *M. parviflorum* (Pop. 16) with $2n = 4x = 36$ had MCA = 20.94 and *M. parviflorum* (Pop. 14) with $2n = 4x = 36$ had MCA= 08.98. All of them indicate that polyploidy has been carried with chromatin loss. Similar results have been reported in previous studies (Jafari et al., 2008). Polyploidy is one of the main evolutionary mechanisms promoting genetic diversity and speciation in plants (Stebbins, 1950; Grant, 1971). The majority of *Muscari* species are diploid with a chromosome number of $2n = 2x = 18$, especially *Muscari*

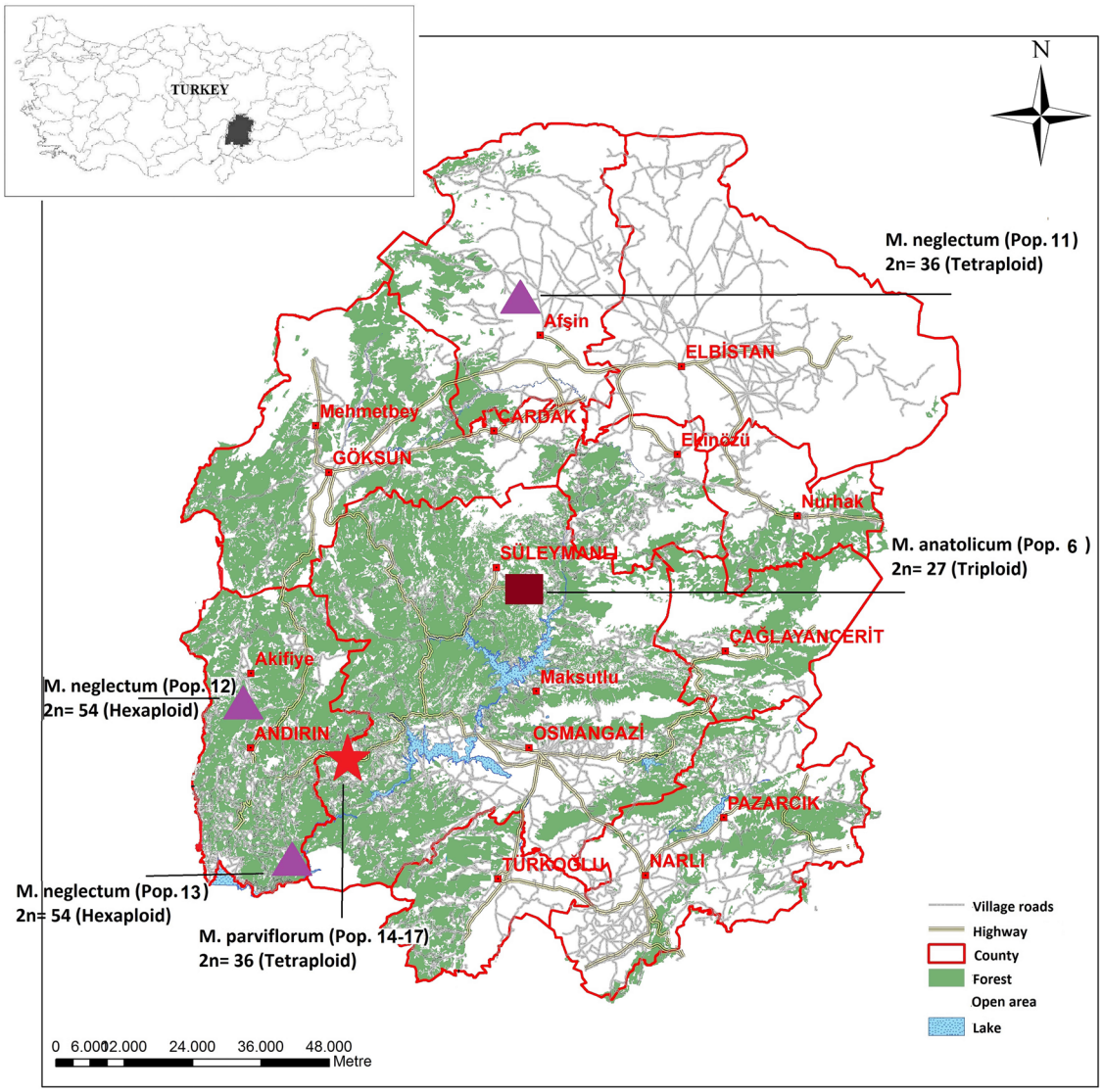

Figure 3. Polyploidy species in research area (Kahramanmaraş).

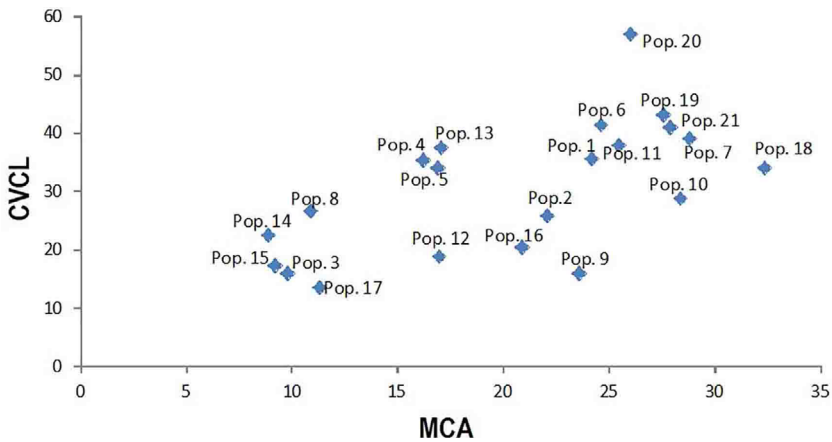

Figure 4. Scatter plot of interchromosomal and intrachromosomal asymmetries (CVCL vs. MCA) of *Muscari* populations of 9 *Muscari* species: Pop. 1–5 (*M. armeniacum*), Pop. 6 (*M. anatolicum*), Pop. 7 (*M. aucheri*), Pop. 8–13 (*M. neglectum*), Pop. 14–17 (*M. parviflorum*), Pop. 18 (*M. azureum*), Pop. 19 (*M. babachii*), Pop. 20 (*M. comosum*), Pop. 21 (*M. tenuiflorum*).

subgen. *Leopoldia*. However, several studied populations showed polyploidy in the subgenus *Botryanthus*. Thirteen populations were diploid with $2n = 2x = 18$, a population was triploid with $2n = 3x = 27$, five populations were tetraploid with $2n = 4x = 36$, and two populations were hexaploid with $2n = 6x = 54$. In the study area, in the southwest of the province around the village of Andırın, polyploid specimens were identified more frequently than in other parts of Kahramanmaraş Province. Twenty-one populations have been studied, five of which are polyploid; three of the polyploid specimens grow around Andırın. A high coincidence of polyploidy may be related to altitudes and high latitudes (Löve and Löve, 1949). However, this has not been valid for all species. According to our results, the polyploid species of *M. neglectum* have a distribution ranging from 1144 m to 1800 m. However, *M. parviflorum* has a distribution ranging from 500 m to 1138 m. A similar situation has been observed in other regions by Löve (1953). Löve reported that the mountain flora in Iceland does not show higher frequencies of polyploids than does the lowland flora. This is assumed to be caused by the fact that the flora of the lowland areas already shows a rate of polyploidy close to the highest one obtainable (Löve, 1953).

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