Karyomorphological Studies of Six Species of Turkish *Muscari* (Asparagaceae)

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Summary In this study, chromosome length, karyomorphology and chromosome asymmetry of six Turkish *Muscari* species; *Muscari muglaensis*, *M. nazimiyensis*, *M. pallens*, *M. pamiryigidii*, *M. inundatum* and *M. fatmacereniae* were evaluated. The somatic chromosome number of all examined taxa was determined as $2n=18$. The basic chromosome number was $x=9$. Chromosomes consist of metacentric, submetacentric, and subtelocentric chromosomes. This is the first report on chromosome number and morphology for five of the six taxa studied. Studies on the karyotype and chromosomal diversity of *Muscari* may provide insight into taxonomic relationships and differences within the genus.

Keywords Chromosome number, Endemic, Karyomorphology, Karyotype, *Muscari*, Turkey.

Muscari is a genus of bulbous plants belonging to the Asparagaceae family. The genus has a wide distribution in the Mediterranean basin, Central and Southwest Europe, the Caucasus, Southwest Asia and Central Asia (Speta 1998, Jafari *et al.* 2008). While the genus is represented by 77 species in the world (Eker and Yıldırım 2021), it is represented by 51 species, 34 of which are endemic in Turkey (Davis and Stuart 1984, Eker 2012, Demirci *et al.* 2013, 2014, 2019, Kaya and Rastgeldi 2014, Pirhan *et al.* 2014, Yıldırım 2015, 2016, Pınar *et al.* 2018, Doğu and Uysal 2019, Eker 2019a, b, Eker *et al.* 2019, Eroğlu *et al.* 2019, Eroğlu and Pınar 2019, Yıldırım and Kılıç 2019, Eker *et al.* 2020, Eker and Kandemir 2020, Eker and Yıldırım 2021, Eker 2021). When considering the density of the species number and endemism rate in *Muscari*, Turkey is one of the main differentiation and gene centers (Yıldırım 2016, Böhnert and Lobin 2017, Doğu and Uysal 2019). The situation of the genus *Muscari* is highly controversial both taxonomically and karyologically (Speta 1989, 1998, Davis and Stuart 1980, 1984, Karlén 1991, Azizi *et al.* 2016). Numerous karyological studies have been performed on *Muscari* to date, and these, combined with morphological evidence, have provided most of the taxonomic data for the genus (Garbari, 1966, 1972, 1973, Stuart 1970, Bentzer 1972, Ruiz-Rejón 1978, Ruiz-Rejón and Oliver 1978, Karlén 1984a, b, Ruiz-Rejón *et al.* 1985, 1986). The infrageneric classification of *Muscari* is an unresolved problem. In fact, taxonomic divisions within the genus were supported by karyological data by Garbari

and Greuter (1970). Although most taxa of the genus are diploid, there are also some polyploid taxa (Stuart 1970, Karlén 1984b, Dalgıç 1991, Özhatay and Johnson 1996, Johnson and Brandham 1997, Demirci Kayıran and Özhatay 2017, Bozkurt 2020, Kiran *et al.* 2020a, b). Chromosome number and chromosome morphology are increasingly used in plant taxonomy (Eroğlu *et al.* 2013). Chromosomes can reveal all cytogenetic possibilities for understanding the boundaries, affinities and evolution of taxa. Karyotype is the characterization of the number, size and morphology of the chromosome set of a species. Karyotype studies are important in determining karyotypic polymorphism and inter- and intra-species cytogenetic variation and evolution (Marques de Resende 2017). The most important aim of this report is to complete lacking chromosomal information of Turkish *Muscari* species which are published in soon. Therefore, this study includes the chromosomal number and karyomorphological reports of six *Muscari* taxa which are *M. muglaensis*, *M. nazimiyensis*, *M. pallens*, *M. pamiryigidii*, *M. inundatum* and *M. fatmacereniae*.

Materials and methods

The bulbs of the studied *Muscari* species were collected from natural areas of Turkey (Table 1). The bulbs of the examined taxa were germinated by placing them in foams prepared properly in water. Chromosome counts were performed using the squashing technique at the somatic metaphase (Goldblatt 1996). Root tips germinated from bulbs were pretreated with 8-hydroxyquinoline for 8 h at 4°C. After pretreatment, root tips were placed in Carnoy fixative and fixed at low temperature for

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Table 1. Taxa studied and localities.

Subgenus	Taxa	Locality
<i>Leopoldia</i>	<i>M. muglaensis</i> Eker, H. Duman & Yıldırım	Muğla, Ağla, Köyceğiz, Kartal gölün kuzey ve güney yamaçları, 1810m, serpantin, amfiolit kayaç açıklıkları, <i>T. Uysal</i> 4317 & <i>A. Aksoy</i>
<i>Botryanthus</i>	<i>M. nazimiyensis</i> Yıld. & Kılıç	Tunceli, Tunceli-Erzincan yolu, Nazimiye, Yiğitler mevkii, <i>T. Uysal</i> 4254 & <i>A. Aksoy</i>
<i>Botryanthus</i>	<i>M. pallens</i> (M. Bieb.) Fisch.	Van, Gevaş, Göründü köyü, gölün güneydoğu yamaçları, <i>T. Uysal</i> 4261 & <i>A. Aksoy</i>
<i>Botryanthus</i>	<i>M. pamiryigidii</i> Eker	Bolu, Mudurnu, Örencik yaylası, vericiye doğru, 1550–1820m, <i>T. Uysal</i> 4343
<i>Botryanthus</i>	<i>M. inundatum</i> Yıldırım & Eker	Hatay, Kisecek köyü, Aşağı Sorgun yaylası, radarın doğusu, çayırılık ıslak dere kenarları, 1350–1450m, <i>T. Uysal</i> 4292 & <i>A. Aksoy</i>
<i>Botryanthus</i>	<i>M. fatmacereniae</i> Eker	Adana, Tufanbeyli-Saimbeyli yolu, Tufanbeyli'den Saimbeyli'ye doğru 10–15km kala, yolun solunda kalan orman açıklıkları, 1550m, <i>T. Uysal</i> 4234

Fig. 1. Mitotic metaphase chromosomes of *Muscari* taxa. A: *M. muglaensis*, B: *M. nazimiyensis*, C: *M. pallens*, D: *M. pamiryigidii*, E: *M. inundatum*, F: *M. fatmacereniae*. Scale bar=10 μ m.

24h. For dyeing, the tips were hydrolyzed in 5M HCl for one hour at room temperature and stained with 1% aceto-orcin prepared by adding 45% acetic acid. After obtaining the best metaphase image, chromosome pictures were taken with an Olympus DP72 digital camera mounted on an Olympus BX53 microscope. Karyotype measurements were performed on the photographed metaphase chromosome images with the KAMERAM program (KAMERAM 122, Argenit, İstanbul, Turkey) and karyomorphologies were determined using various symmetry indices. According to Levan *et al.* (1964), the morphologies of the chromosomes were named. According to Zarco (1986), Paszko (2006), and Peruzzi and Eroğlu (2013), karyotype measurements and symmetry index calculations were made.

Results

Karyotype analysis of six *Muscari* species, five of which were first, was performed. Metaphase plates and karyotypes of species belonging to the *Muscari* are shown in Figs. 1 and 2. In addition, the karyomorphological details of the species are listed in Tables 2 and 3.

M. muglaensis is a locally endemic species known

from southwestern Anatolia. The chromosome number and morphology of the species were determined for the first time. *M. muglaensis* is a diploid species with $2n=18$ chromosomes. The basic chromosome number is $x=9$. Karyotypes are composed of metacentric, submetacentric, and subtelocentric chromosomes. The karyotype formula is $10m+4sm+4st$. The smallest chromosome of the species is $3.04\mu m$ and the largest chromosome is $12.17\mu m$. The total haploid chromosome length is $55.00\mu m$. Among the karyotype asymmetry indices of this species, the CV_{CL} and CV_{CI} are 52.56 and 23.28, respectively. Other chromosomal measurements and symmetry indices are given in Tables 2 and 3.

M. nazimiyensis is a locally endemic species known from eastern Anatolia. The chromosome number and morphology of the species were determined for the first time. *M. nazimiyensis* is a diploid species with $2n=18$ chromosomes. The basic chromosome number is $x=9$. Karyotypes consist of metacentric and submetacentric chromosomes. The karyotype formula is $14m+4sm$. The smallest chromosome of the species is $2.01\mu m$ and the largest chromosome is $5.13\mu m$. The total haploid chromosome length is $29.85\mu m$. Among the karyotype asymmetry indices of this species, the CV_{CL} and CV_{CI}

Fig. 2. Karyograms of *Muscari* taxa. A: *M. muglaensis*, B: *M. nazimiyensis*, C: *M. pallens*, D: *M. pamiryigidii*, E: *M. inundatum*, F: *M. fatmacereniae*. Scale bar=10 μ m.

Table 2. The chromosome features of *Muscari* taxa.

Taxa	2n	R SC-LC (μ m)	R-LC/SC	p (μ m) mean ($\pm$ SD)	q (μ m) mean ($\pm$ SD)	CL (μ m) mean ($\pm$ SD)	TCL (μ m)	CI mean ($\pm$ SD)	KF
<i>M. muglaensis</i>	18	3.04–12.17	4.00	2.03 ($\pm$ 0.66)	4.09 ($\pm$ 2.71)	6.11 ($\pm$ 3.21)	55.00	37 ($\pm$ 0.09)	10m+4sm+4st
<i>M. nazimiyensis</i>	18	2.01–5.13	2.55	1.31 ($\pm$ 0.25)	2.01 ($\pm$ 0.84)	3.32 ($\pm$ 1.00)	29.85	41 ($\pm$ 0.07)	14m+4sm
<i>M. pallens</i>	18	1.77–4.80	2.71	1.20 ($\pm$ 0.29)	1.73 ($\pm$ 0.80)	2.92 ($\pm$ 1.08)	26.32	43 ($\pm$ 0.05)	14m+4sm
<i>M. pamiryigidii</i>	18	2.34–4.96	2.11	1.47 ($\pm$ 0.24)	2.09 ($\pm$ 0.61)	3.56 ($\pm$ 0.81)	32.02	42 ($\pm$ 0.04)	12m+6sm
<i>M. inundatum</i>	18	2.15–6.58	3.06	1.26 ($\pm$ 0.19)	2.26 ($\pm$ 1.42)	3.52 ($\pm$ 1.56)	31.70	40 ($\pm$ 0.09)	14m+4st
<i>M. fatmacereniae</i>	18	1.67–4.40	2.64	1.12 ($\pm$ 0.20)	1.66 ($\pm$ 0.69)	2.78 ($\pm$ 0.88)	25.05	42 ($\pm$ 0.05)	14m+4sm

R: Range, SC: shortest chromosome length, LC: longest chromosome length, p: mean length of the short arm, q: mean length of the long arm, CL: mean chromosome length, TCL: total haploid complement length, CI: mean centromeric index, SD: standard deviation, KF: karyotype formula, m: metacentric, sm: submetacentric, st: subtelocentric.

Table 3. The karyotype indices of *Muscari* taxa.

Taxa	A ₁	A ₂	CV _{CL}	CV _{CI}	AI	M _{CA}
<i>M. muglaensis</i>	0.38	0.52	52.56	23.28	12.24	33.66
<i>M. nazimiyensis</i>	0.28	0.30	30.21	16.59	5.01	21.08
<i>M. pallens</i>	0.24	0.36	36.90	11.37	4.19	18.08
<i>M. pamiryigidii</i>	0.26	0.22	22.87	10.61	2.43	17.41
<i>M. inundatum</i>	0.30	0.44	44.42	23.37	10.38	28.4
<i>M. fatmacereniae</i>	0.26	0.31	31.45	12.67	3.98	19.42

A₁: Intrachromosomal asymmetry index, A₂: interchromosomal asymmetry index, CV_{CL}: coefficient of variation of chromosome length, CV_{CI}: coefficient of variation of the centromeric index, AI: karyotype asymmetry index, M_{CA}: mean centromeric asymmetry.

are 30.21 and 16.59, respectively. Other chromosomal measurements and symmetry indices are given in Tables 2 and 3.

The chromosome number of *M. pallens* species has been reported as $2n=18$ and 36 (Stuart 1970, Magulaev 1992, Gadnidge *et al.* 1998). In this study, the chromosome number of the species was determined as $2n=18$. The basic chromosome number is $x=9$. Karyotypes consist of metacentric and submetacentric chromosomes. The karyotype formula is $14m+4sm$. The smallest chromosome of the species is $1.77\mu m$, and the largest chromosome is $4.80\mu m$. The total haploid chromosome length is $26.32\mu m$. Satellites were observed in one chromosome pair and at the short arms of the second large chromosome. Among the karyotype asymmetry indices of this species, the CV_{CL} and CV_{CI} are 36.90 and 11.37, respectively. Other chromosomal measurements and symmetry indices are given in Tables 2 and 3.

M. pamiryigidii is a locally endemic species known from northwest Anatolia. The chromosome number and morphology of the species were determined for the first time. *M. pamiryigidii* is a diploid species with $2n=18$ chromosomes. The basic chromosome number is $x=9$. Karyotypes consist of metacentric and submetacentric chromosomes. The karyotype formula is $12m+6sm$. The smallest chromosome of the species is $2.34\mu m$ and the largest chromosome is $4.96\mu m$. The total haploid chromosome length is $32.02\mu m$. Satellites were observed in one chromosome pairs and at the short arms of the first large chromosomes. Among the karyotype asymmetry indices of this species, the CV_{CL} and CV_{CI} are 22.87 and 10.61, respectively. Other chromosomal measurements and symmetry indices are given in Tables 2 and 3.

M. inundatum is a locally endemic species known from southern Anatolia. The chromosome number and morphology of the species were determined for the first time. *M. inundatum* is a diploid species with $2n=18$ chromosomes. The basic chromosome number is $x=9$. Karyotypes consist of metacentric and subtelocentric chromosomes. The karyotype formula is $14m+4st$. The smallest chromosome of the species is $2.01\mu m$ and the largest chromosome is $5.13\mu m$. The total haploid chromosome length is $31.70\mu m$. Among the karyotype asymmetry indices of this species, the CV_{CL} and CV_{CI} are 44.42 and 23.37, respectively. Other chromosomal measurements and symmetry indices are given in Tables 2 and 3.

M. fatmacereniae is a locally endemic species known from southern Anatolia. The chromosome number and morphology of the species were determined for the first time. *M. fatmacereniae* is a diploid species with $2n=18$ chromosomes. The basic chromosome number is $x=9$. Karyotypes consist of metacentric and submetacentric chromosomes. The karyotype formula is $14m+4sm$. The smallest chromosome of the species is $1.67\mu m$ and the largest chromosome is $4.40\mu m$. The total haploid chro-

mosome length is $25.05\mu m$. Satellites were observed in one chromosome pair and at the short arms of the second large chromosome. Among the karyotype asymmetry indices of this species, the CV_{CL} and CV_{CI} are 31.45 and 12.67, respectively. Other chromosomal measurements and symmetry indices are given in Tables 2 and 3.

Discussion

In the genus *Muscari*, most species are diploid, with a basic chromosome number of $x=9$ and a chromosome number of $2n=18$ (Stuart, 1970, Karlén 1984b, Dalgıç 1991, Özhatay and Johnson 1996, Johnson and Brandham 1997, Demirci Kayıran and Özhatay 2017, Bozkurt 2020, Kiran *et al.* 2020a, b). The current study confirms the former reports for all studied species. Metacentric and submetacentric chromosomes are seen as more common in studied species. Satellites have been observed in *M. pallens*, *M. pamiryigidii* and *M. fatmacereniae* and are minute as reported in previous studies (Demirci Kayıran and Özhatay 2017, Kiran *et al.* 2020a).

Eker *et al.* (2020) reported that *M. muglaensis* is morphologically similar to *M. weissii*, *M. comosum*, *M. cycladicum* and *M. elmasii*, but differs mainly by its large bulbs and fruit structure from *M. weissii* and *M. comosum*, and long pedicels of fertile flowers and transversely growing raceme in fruit from *M. cycladicum* and *M. elmasii*. Besides with the morphological differences, we can easily declare that karyotypes of this endemic species are seen quite distinct from *M. weissii*, *M. comosum*, and *M. elmasii* (Table 4; Demirci Kayıran and Özhatay 2017, Kiran *et al.* 2020a).

Yıldırım and Kılıç (2019) reported that *M. nazimiyensis* is closely related to *M. inconstrictum* and *M. aucheri*, but differs by its shorter fertile flowers from *M. inconstrictum*, smaller capsule and linear leaves from *M. aucheri*. Karlén (1984a) reported that there is a more or less continuous decrease in length in the five longer m to sm pairs and the short pairs are m to sm. In addition to, he reported that the satellite is the situation on the short arm of one of the chromosomes in the first pair. Demirci Kayıran and Özhatay (2017) reported the karyotype of *M. aucheri* as $2n=12m+4sm+2st$. We can say that *M. nazimiyensis* differs from *M. inconstrictum* and *M. aucheri* in terms of karyological features. Especially, the species has two fairly long sm, four medium m, and finally three small m chromosomes.

Eker (2019b) reported that *Muscari pamiryigidii* is similar to *M. armeniacum*, *M. aucheri*, and *M. bourgaei*, but is easily distinguished from them by its shorter stems, dark brown outer tunics, prominently veined humistrate, and spreading leaves. As with suitable this morphological differences, karyotypes of this endemic species are seen quite comparing to *M. armeniacum*, *M. aucheri* and *M. bourgaei* (Table 4; Karlén 1984b, Demirci Kayıran and Özhatay 2017, Kiran *et al.* 2020b)

Table 4. Comparison of the results with the previously reported karyotype formulas for *Muscari* taxa.

Taxa	Karyotype formula	References
<i>M. muglaensis</i>	10m+4sm+4st (diploid)	in this study
<i>M. comosum</i>	14m+2sm+2t (diploid)	Kiran <i>et al.</i> (2020a)
	10m+6sm+2st (diploid)	Demirci Kayıran and Özhatay (2017)
<i>M. weissii</i>	12m+2sm+4st (diploid)	Kiran <i>et al.</i> (2020a)
<i>M. elmasii</i>	14m+4st (diploid)	Kiran <i>et al.</i> (2020a)
<i>M. pamiryigidii</i>	12m+6sm	in this study
<i>M. aucheri</i>	2M+12m+4sm	Kiran <i>et al.</i> (2020b)
	12m+4sm+2st	Demirci Kayıran and Özhatay (2017)
<i>M. armeniacum</i>	12m+4sm+2st ^{SAT} , 12m+4sm+2st	Demirci Kayıran and Özhatay (2017)
	n=7m+2sm	Karlén (1984b)
	2M+14m+2sm	Kiran <i>et al.</i> (2020b)
<i>M. bourgaei</i>	2st+2st ^{SAT} +14m	Karlén (1987)
<i>M. inundatum</i>	14m+4st	in this study
<i>M. neglectum</i>	4m+10sm+4st ^{SAT} (diploid)	Demirci Kayıran and Özhatay (2017)
	16m+12sm+8st (tetraploid)	Demirci Kayıran and Özhatay (2017)
	35m+m ^{SAT} +18sm	Demirci Kayıran and Özhatay (2017)
	36m+18sm (hexaploid)	
	n=4m+5sm (diploid, tetraploid, hexaploid, octaploid)	Karlén (1984b)
	13m+11sm+2st+t, 23m+3sm, 21m+5sm, 16m+9sm+t or 16m+7sm, 13m+9sm+st,	Jafari <i>et al.</i> (2008)
	17m+5sm+st (aneuploidy)	
	17m+5sm+st (autopentaploid)	Jafari <i>et al.</i> (2008)
	14m+3sm (tetraploid)	Jafari <i>et al.</i> (2008)
	2M+28m+6sm (diploid)	Kiran <i>et al.</i> (2020b)

Eker and Yıldırım (2021) reported that *M. inundatum* is morphologically similar to *M. neglectum* and *M. adillii*, but differs mainly by its shouldered fertile flowers with erect to slightly recurved lobes at maturity. Karyotypes of this endemic species are quite distinct from *M. neglectum* (Table 4; Karlén 1984b, Jafari *et al.* 2008, Demirci Kayıran and Özhatay 2017, Kiran *et al.* 2020b).

Eker (2019a) reported that *M. fatmacereniae* is similar to *M. armeniacum* and *M. botryoides*, but the former is easily distinguished from both latter species by its shouldered and strongly constricted flowers; blackish-brown outer tunics; gracile, mostly flat erect leaves; and lax raceme. As concerning *M. botryoides*, Karlén (1984b) reported that the idiogram consists of two pairs of long st chromosomes, three pairs of medium-sized m to sm pairs and four pairs of short m to sm chromosomes. In addition, he reported that the satellites are situated on the short arms of the second pair. Kiran *et al.* (2020b) reported the karyotype of *M. botryoides* as 14m+2sm+2sm^{SAT}. Therefore, we can interpret the karyotypes of this endemic species are partly similar to *M. armeniacum* in terms of having 7m and 2sm chromosomes (Table 4 for *M. armeniacum*; Karlén 1984a, b, Demirci Kayıran and Özhatay 2017, Kiran *et al.* 2020b).

Demirci Kayıran and Özhatay (2017) reported that the TCL of the taxa in the subgenus *Leopoldia* varied from 40 to 56 µm. Also, they reported that the TCL of the species in the subgenus *Botryanthus* ranged from 22 to 35 µm. Kiran *et al.* (2020a) reported that the TCL of 11 species in the subgenus *Leopoldia* ranged from 44 to 67 µm. In addition, Kiran *et al.* (2020b) reported that the TCL of the taxa in the subgenus *Botryanthus* varied from 24 to 32 µm. The TCL value of the *M. muglaensis* (TCL:

55 µm), which is a member of the *Leopoldia*, is compatible with the values. The TCL values (TCL: 25–32 µm) of the *M. nazimiyensis*, *M. pallens*, *M. pamiryigidii*, *M. inundatum* and *M. fatmacereniae* in the subgenus *Botryanthus* is compatible with the previously declared information. As consistent with former reports, The TCL values for *Botryanthus* taxa are smaller than *Leopoldia* taxa (Demirci Kayıran and Özhatay 2017, Kiran *et al.* 2020a, b). Regarding karyomorphological aspects, symmetrical karyotypes have been considered as less derived and asymmetrical karyotypes as the more derived ones (Stebbins 1971). CV_{CI} is a parameter that indicates heterogeneity of the centromeric index. Our results showed that CV_{CI} values ranged from 10 to 23. CV_{CL} shows different chromosome lengths of a complement. The M_{CA} index used to measure intrachromosomal asymmetry correlates with CV_{CL}. Our results indicated that both CV_{CL} and M_{CA} have the highest value in *M. muglaensis*. Bentzer (1973) reported that the Aegean representatives of *Leopoldia* are in an active phase of evolution and show considerable morphological variation as well as polyploidization. We can say that *M. muglaensis*, which has the most asymmetrical karyotypes and highest karyotype indices among all examined species, is a derived species.

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References

- Azizi, N., Amirouche, R. and Amirouche, N. 2016. Karyological investigations and new chromosome number reports in *Bellevia* Lapeyrouse, 1808 and *Muscari* Miller, 1758 (Asparagaceae) from Algeria. *Comp. Cytogenet.* **10**: 171–187.
- Bentzer, B. 1972. Structural chromosome polymorphism in diploid *Leopoldia weissii* Freyn ex Heldr. (Liliaceae). *Bot. Not.* **125**: 180–185.
- Bentzer, B. 1973. Taxonomy, variation and evolution in representatives of *Leopoldia* Parl. (Liliaceae) in the southern and central Aegean. *Bot. Not.* **126**: 69–132.
- Bozkurt, M. 2020. Karyological analysis of endemic five *Muscari* taxa. *Cytologia* **85**: 289–294.
- Böhnert, T. and Lobin, W. 2017. *Leopoldia neumannii* sp. nov. (Asparagaceae, Scilloideae): A new species of *Muscari sensu lato* from Greece. *Willdenowia* **47**: 179–185.
- Dalgıç, G. 1991. Cytotaxonomic studies on the genus *Muscari* in European Turkey. *Bot. Chronika* **10**: 819–825.
- Davis, P. H. and Stuart, D. C. 1980. *Muscari* Mill. In: Tutin, T.G., Heywood, V.H. and Valentine, D.H. (eds.), *Flora Europaea*, Vol. 5. Cambridge University Press, London, UK. pp. 46–49.
- Davis, P. H. and Stuart, D. C. 1984. *Muscari* Mill. In: Davis, P. H. (ed.), *Flora of Turkey and the East Aegean Islands* 8. Edinburgh University Press, Edinburgh. pp. 245–263.
- Demirci, S., Özhatay, N. and Koçyiğit, M. 2013. *Muscari erdalii* (Asparagaceae, Scilloideae), a new species from Southern Turkey. *Phytotaxa* **154**: 38–46.
- Demirci, S., Özhatay, N., Gürdal, B. and Kaya, E. 2014. Contributions to the Turkish Geophyte Flora. In: Kaya, E. (ed.) *Muscari* Mill. Türkiye Geofitleri 2. Atatürk Bahçe Kültürleri Merkez Araştırma Enstitüsü, Yayın No: 96, Yalova. pp. 543–550. (in Turkish).
- Demirci Kayıran, S. and Özhatay, F. N. 2017. A karyomorphological study on the genus *Muscari* Mill. growing in Kahramanmaraş (Turkey). *Türk. J. Bot.* **41**: 289–298.
- Demirci Kayıran, S., Özhatay, N. and Kaya, E. 2019. *Muscari tauricum* (Asparagaceae, Scilloideae), a new species from Turkey. *Phytotaxa* **399**: 109–118.
- Doğu, S. and Uysal, T. 2019. *Muscari savranii* (Asparagaceae), A New species from central Anatolia, Turkey. *Phytotaxa* **402**: 155–164.
- Eroğlu, H. E., Şimşek, N., Koç, M. and Hamzaoglu, E. 2013. Karyotype analysis of some *Minuartia* L. (Caryophyllaceae) taxa. *Plant Syst. Evol.* **299**: 67–73.
- Eroğlu, H. and Pınar, S. M. 2019. The taxonomic resurrection of *Muscari haradjianii* (Asparagaceae, Scilloideae), and a new synonym in the genus *Muscari* in Turkey. *Phytotaxa* **418**: 97–106.
- Eroğlu, H., Pınar, S. M. and Fidan, M. 2019. *Muscari sabihapınari* sp. nov. (Asparagaceae) from Anatolia, Turkey. *Nord. J. Bot.* **37**: 02514.
- Eker, İ. 2012. *Muscari* Mill. In: Güner, A., Aslan, S., Ekim, T., Vural, M. & Babaç, M.T. (eds.), *Türkiye Bitkileri Listesi (Damarlı Bitkiler)*. Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmaları Derneği Yayını, İstanbul, pp. 98–100. (in Turkish).
- Eker, İ. 2019a. *Muscari fatmacereniae* (Asparagaceae, Scilloideae), a new species from southern Anatolia. *Phytotaxa* **397**: 99–106.
- Eker, İ. 2019b. *Muscari pamiryigidii* (Asparagaceae, Scilloideae), a new species from northwestern Anatolia. *Phytotaxa* **408**: 255–266.
- Eker, İ. 2021. What is *Muscari massayanum* and what is not? Second species born of confusion: *Muscari erzincanicum* (Asparagaceae, Scilloideae), a new species from Turkey. *Phytotaxa* **487**: 41–055.
- Eker, İ., Duman, H. and Yıldırım, H. 2020. *Muscari muglaensis* (Asparagaceae, Scilloideae), a new species from southwestern Anatolia. *Phytotaxa* **475**: 267–278.
- Eker, İ. and Kandemir, A. 2020. Taxonomic resurrection of *Muscari sintenisii* Freyn (Asparagaceae) and lectotypification of the species. *Bağbahçe Bilim Dergisi* **7**: 12–24. (in Turkish)
- Eker, İ. and Yıldırım, H. 2021. *Muscari inundatum* (Asparagaceae, Scilloideae), a new species from southern Anatolia. *Phytotaxa* **484**: 181–194.
- Eker, İ., Yıldırım, H. and Armağan, M. 2019. Türkiye Florası İçin Yeni Bir Müşkürüm Kaydı: *Muscari pallens* (M.Bieb.) Fisch. (Kuşkonmazgiller/Asparagaceae). *Bağbahçe Bilim Dergisi* **6**: 45–53. (in Turkish)
- Garbari, F. 1966. Contributo Allo Studio Citologico dei *Muscari* Italiani. *Caryologia* **19**: 419–428.
- Garbari, F. 1972. Note sul genere *Pseudomuscari* (Liliaceae). *Webbia* **27**: 369–381.
- Garbari, F. 1973. Le specie del genere *Leopoldia* Parl. (Liliaceae) in Italia. *Webbia* **28**: 57–80.
- Garbari, F. and Greuter, W. 1970. On the taxonomy and typification of *Muscari* Miller (Liliaceae) and allied genera, and on the typification of generic names. *Taxon* **19**: 329–335.
- Gadnidge, R. I., Gviniasvili, T. N., Danelia, I. M. and Churadze, M. V. 1998. Chromosome numbers of the species of the Georgian flora. *Bot. Zhurn.* **83**: 143–147.
- Goldblatt, P. 1996. Index to plant chromosome numbers 1992–1993. *Monographs in Systematic Botany from the Missouri Botanical Garden*. **58**: 1–276.
- Jafari, A., Maassoumi, A. A. and Farsi, M. 2008. Karyological study on *Bellevia* and *Muscari* (Liliaceae) species of Iran. *Asian J. Plant Sci.* **7**: 50–59.
- Johnson, M. A. T. and Brandham, P. E. 1997. New chromosome numbers in petaloid monocotyledons and in other miscellaneous angiosperms. *Kew Bull.* **52**: 121–138.
- Karlén, T. 1984a. *Muscari pulchellum* (Liliaceae) and associated taxa in Greece and W Turkey. *Willdenowia* **14**: 89–118.
- Karlén, T. 1984b. Karyotypes and chromosome numbers of five species of *Muscari* (Liliaceae). *Willdenowia* **14**: 313–320.
- Karlén, T. 1987. *Muscari sandracicum* (Liliaceae), a new species from Turkey. *Willdenowia* **16**: 375–382.
- Karlén, T. 1991. *Muscari* Miller. In: Strid, A. and Tan, K. (eds.), *Mountain Flora of Greece*, Vol. 2. Edinburgh Univ. Press, Edinburgh. pp. 697–701.
- Kaya, E. and Rastgeldi, U. 2014. *Muscari* Mill. In: Kaya, E. (ed.), *Türkiye Geofitleri*. Vol. 2. – Furkan Ofset, Yalova. pp. 338–411.
- Kiran, Y., Pınar, S. M., Dogan, G. and Eroğlu, H. 2020a. A karyomorphological study on the subgenus *Leopoldia* of the genus *Muscari* growing in Turkey. *Cytologia* **85**: 79–83.
- Kiran, Y., Pınar, S. M., Dogan, G. and Eroğlu, H. 2020b. A karyomorphological study on the genus *Muscari* Miller growing in Turkey. *Cytologia* **85**: 301–305.
- Levan, A., Fredga, K. and Sandberg, A. A. 1964. Nomenclature for centromeric position on chromosomes. *Hereditas* **52**: 201–220.
- Magulaev, A. Y. 1992. Chromosome numbers in some species of vascular plants of the northern Caucasus flora. *Bot. Zhurn.* **77**: 88–90.
- Marques de Resende, K. F. 2017. Karyotype Evolution: Concepts and Applications. In: Bhat, T. A. and Aijaz Ahmad Wani, A. A. (eds.), *Chromosome Structure and Aberrations*. Springer India, New Delhi. pp. 181–200.
- Özhatay, N. and Johnson, M. 1996. Some karyological remarks on Turkish *Allium* sect. *Allium*, *Bellevia*, *Muscari*, *Ornithogalum* subg. *Ornithogalum*. *Bocconea* **5**: 239–249.
- Paszko, B. 2006. A critical review and a new proposal of karyotype asymmetry indices. *Plant Syst. Evol.* **258**: 39–48.
- Peruzzi, L. and Eroğlu, H. E. 2013. Karyotype asymmetry: Again, how to measure and what to measure? *Comp. Cytogenet.* **7**: 1–9.
- Pınar, M. P., Fidan, M. and Eroğlu, H. 2018. *Muscari botryoides* (L.) Mill.: A new record for the family Asparagaceae from Turkey.

- Türk. J. Agric. Res. **5**: 116–119. (*in Turkish*)
- Pirhan, A. F., Yıldırım, H. and Altıoğlu, Y. 2014. *Muscari serpentini-cum* sp. nova (Asparagaceae): A new species from western Anatolia, Turkey. *Ot Sist. Bot. Dergisi* **21**: 1–14.
- Ruiz-Rejón, M. 1978. Estudios cariológicos en especies españolas del orden Liliales. III. Familia Liliaceae. *Ana. Inst. Bot. Cavanilles* **34**: 733–759.
- Ruiz-Rejón, M. and Oliver, J. L. 1978. Números cromosómicos para la Flora española. Número 68: *Scilla autumnalis*; Número 69: *Muscari atlanticum*. *Lagascalia* **8**: 113–117.
- Ruiz-Rejón, M., Pascual, L., Ruiz-Rejón, C., Valdés, B. and Oliver, J. L. 1985. A new species of *Muscari* subgenus *Leopoldia* from the Iberian Peninsula. *Biochem. Syst. Ecol.* **13**: 239–250.
- Ruiz-Rejón, C., Lozano, R. and Ruiz-Rejón, M. 1986. Números cromosómicos para la flora española. *Lagascalia* **14**: 273–304.
- Speta, F. 1989. *Muscari* (subg. *Leopoldia*) *mirum* Speta, spec. nova, im kreise seiner nächsten verwandten. *Phyton* **29**: 105–114.
- Speta, F. 1998. Hyacinthaceae. In: Kubitzki K., (ed.). *The Families and Genera of Vascular Plants*, Vol. 3. Springer-Verlag, Heidelberg. pp. 261–285.
- Stebbins, G. L. 1971. *Chromosomal Evolution in Higher Plants*. Edward Arnold, London.
- Stuart, D. C. 1970. Chromosome numbers in the genus *Muscari*. *Notes R. Bot. Gard. Edinb.* **30**: 189–196.
- Yıldırım, H. 2015. *Muscari atillae* sp. nova (Asparagaceae): A new species from eastern Anatolia, Turkey. *Phytotaxa* **213**: 291–295.
- Yıldırım, H. 2016. *Muscari elmasii* sp. nova (Asparagaceae): A new species from western Anatolia, Turkey. *Türk. J. Bot.* **40**: 380–387.
- Yıldırım, H., Ş. and Kılıç, Ö. 2019. A new species of *Muscari* Mill. (Asparagaceae/Liliaceae), *M. nazimiyensis* from Tunceli, Turkey. *Ot. Sist. Bot. Dergisi* **26**: 13–16.
- Zarco, C. R. 1986. A new method for estimating karyotype asymmetry. *Taxon* **35**: 526–530.
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