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POLLEN MORPHOLOGY OF SOME TURKISH *CROCUS* L. (IRIDACEAE) SPECIES

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Pollen grains of 29 Turkish taxa of genus *Crocus* L. belonging to Iridaceae were examined by light and electron microscopy. The pollen of *Crocus* is spheroidal in shape, with a thin exine characterized by echinate (spinulate)-microperforate sculpture and a relatively thick intine. Three types of aperture are recognized: a spiral furrow, more or less extensive furrows, and short furrows. Spiral furrows appear to be the most frequent aperture type among the Turkish *Crocus* species. Apertures vary within some species. The results are compared with those on the pollen morphology of *Crocus* species previously investigated by several European workers.

Key words: *Crocus*, Iridaceae, pollen morphology, Turkey.

INTRODUCTION

The genus *Crocus* L. (Iridaceae) comprises about 80 species distributed mainly in the Mediterranean region. It is widely dispersed in Turkey; at present about 67 taxa (including subspecies and varieties) are recognized there (Mathew, 1984, 1988, 1995, 2000; Kerndorff and Pasche, 2003, 2004).

The Turkish *Crocus* species have received attention by several workers, who have concentrated mainly on morphology (e.g., Mathew, 1984) and anatomy (Akan and Eker, 2004; Özdemir, 2002; Özdemir et al., 2004). In Europe, several *Crocus* species have been examined for pollen morphology (Grilli Caiola et al., 1993; Chichiriccò, 1999; Furness, 1985; Heslop-Harrison, 1977; Mariotti, 1988). There is no detailed study of the pollen morphology of Turkish *Crocus* species. This study investigates the pollen morphology of some of these taxa, using light and electron microscopy, and provides palynological information about the genus in the Turkish flora.

MATERIALS AND METHODS

The material was collected from the field or taken from the herbaria of Hacettepe University (HUB), Gazi University (GAZI), and Yüzüncü Yıl University (VANF). The voucher specimens are listed in Table 1.

Altogether, 46 specimens of 29 taxa were examined. Wild-growing species varying in level of specialization were selected. In many cases more than one specimen per taxon were investigated to determine possible intraspecific variation, but some were of limited availability.

For light microscopy, the pollen was first treated with 70% alcohol to remove oily substances, then embedded in glycerine jelly stained with basic fuchsin, following the method of Wodehouse (1935). The following parameters were measured: pollen diameter (PD), spinule height and number per 100 μm^2, exine (sexine and nexine) thickness, and intine (exintine and endintine) thickness. PD values are means of ~50 pollen grains. For the other parameters, ~10 measurements were made. Spinule number per 100 μm^2 was counted using the Leica Q-win program.

The photomicrographs were made with a Nikon E600 microscope.

To examine the exine sculpture in detail, scanning electron microscopy (SEM) was also used. For SEM study, the pollen was first treated with 70% alcohol, then dried before mounting on stubs with gold. The photomicrographs were taken with Jeol JSM–5600 and Jeol JSM–840 electron microscopes.

The palynological terminology mainly follows Punt et al. (1994).

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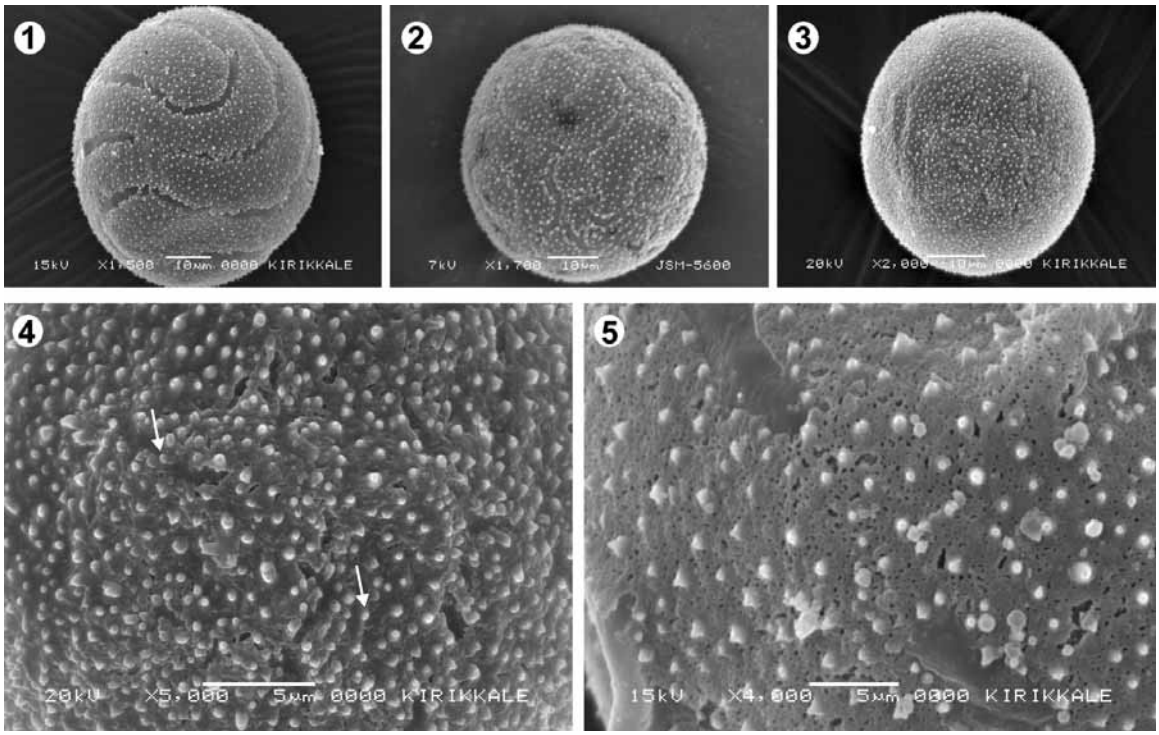


Figs. 1–5. SEM images of some Turkish *Crocus* species. **Fig. 1.** *C. danfordiae*; pollen with spiral furrow. **Fig. 2.** *C. reticulatus* ssp. *reticulatus*; pollen with more or less extensive furrows. **Figs. 3–4.** *C. biflorus* ssp. *nubigena*. **Fig. 3.** Pollen with short furrows. **Fig. 4.** Closer view of short furrows (arrows). **Fig. 5.** *C. pulchellus*; exine sculpture with spinules and microperforations.

RESULTS

A summary of the *Crocus* pollen morphological observations is given in Tables 1–3. The pollen grains have various aperture types: a spiral furrow (spiraperturate) (Fig. 1), more or less extensive furrows (Fig. 2), or short furrows (Figs. 3, 4). Within some species there are variations in pollen type; pollen grains are provided with either a spiral furrow [*C. biflorus* Miller ssp. *isauricus* (Siehe ex Bowles) Mathew, *C. biflorus* Miller ssp. *punctatus* Mathew, *C. biflorus* Miller ssp. *pulchricolor* (Herbert) Mathew, *C. biflorus* Miller ssp. *tauri* (Maw) Mathew, *C. cancellatus* Herbert ssp. *cancellatus*, *C. cancellatus* Herbert ssp. *damascenus* (Herbert) Mathew], extensive furrows (*C. cancellatus* Herbert ssp. *lycius* Mathew) or short furrows [*C. biflorus* Miller ssp. *nubigena* (Herbert) Mathew].

All pollen grains are spheroidal and medium- to large-sized, with diameters ranging from 47.25 μm (*C. graveolens* Boiss. & Reuter) to 130 μm [*C. cancellatus* Herbert ssp. *damascenus* (Herbert) Mathew]. Size varies within some species; the pollen of *C. sieheanus* Barr ex Burtt (58.5–113 μm), *C. danfordiae* Maw (52.5–105 μm) and *C. cancellatus* ssp. *damascenus* (78–130 μm) are particularly variable in size.

The exine is intectate and echinate (with spinules)-microperforate (under SEM; Fig. 5). Spinule height ranges from 0.75 μm to 2.5 μm, while spinule number per 100 μm^2 ranges from 4 to 72. The sexine is thicker than the nexine. The former is 0.25–2 μm and the latter is <0.5–0.5 μm in thickness. The intine (1.5–6.75 μm) is thicker than the exine (0.75–2.5 μm) (Fig. 6). The exintine (1–6 μm) and the endintine (0.5–0.75 μm) are distinguishable. The former thickens near the aperture (Fig. 7).

DISCUSSION

The pollen grains of the examined Turkish *Crocus* taxa are similar in shape, pollen wall stratification and sculpture. All are spheroidal and characterized by a thin exine with echinate-microperforate sculpture and a thick intine. Some of the taxa, however, show various pollen types (aperture features), even within species. Differences between some closely related taxa of Turkish *Crocus* (*C. pallasii* Goldb. ssp. *turcicus* Mathew and C. *cancellatus* Herbert ssp. *damascenus* (Herbert) Mathew) have been also recorded in relation to leaf anatomy (Akan and Eker, 2004). On the other hand, the pollen morphological features of the taxa examined do not show

TABLE 1. Aperture features of Turkish *Crocus* species

Taxon*	Specimen [abbreviation of herbarium**]	Aperture type	PD		
			M (µm)	SD	V (µm)
Crocus fleischeri	B2 Afyon : Z. Aytaç 5486 [G]	spiral furrow	73.08	±0.28	67.5-81
C. reticulatus ssp. *reticulatus*	C5 Mersin: A. A. Dönmez 8198 – B. Mutlu [H]	extensive furrows	84.5	±1.6	67.5-92.5
	C5 Mersin: A. A. Dönmez 8205 – B. Mutlu [H]	extensive furrows	78.8	±3.8	71-86
C. abantensis	A3 Bolu: A. A. Dönmez 10417 [H]	spiral furrow	79.54	±6.86	61-91
C. gargaricus ssp. *herbertii*	A1 Çanakkale: A. A. Dönmez 10441 [H]	spiral furrow	82.1	±4.6	73-91
C. ancyrensis	A4 Ankara: E. Oybak Dönmez 86 – A. A. Dönmez [H]	spiral furrow	73.6	±2.2	62.5-85
	B4 Ankara: A. A. Dönmez 8256 – B. Mutlu [H]	spiral furrow	72.3	±1.6	62.5-82.5
	C5 Niğde: A. A. Dönmez 8252a – B. Mutlu [H]	spiral furrow	74.56	±4.19	63-88
	A3 Bolu: A. A. Dönmez 10419 [H]	spiral furrow	73	±3.14	66-80
C. sieheanus	C5 Niğde: A. A. Dönmez 8252b – B. Mutlu [H]	spiral furrow	95.04	±0.12	68-113
	C5 Adana: A. Güner 1495 [H]	spiral furrow	75.24	±0.47	58.5-83.25
C. chrysanthus	C4 Konya: A. A. Dönmez 8159 – B. Mutlu [H]	spiral furrow	71	-	60-87.5
	B3 Isparta: A. A. Dönmez 8147 – B. Mutlu [H]	spiral furrow	72.5	±1.5	65-82.5
C. danfordiae	C5 Niğde: A. A. Dönmez 8254a – B. Mutlu [H]	spiral furrow	65	±1.9	52.5-75
	A4 Ankara: S. Işık 1003 – E. Oybak Dönmez - A. A. Dönmez [H]	spiral furrow	82.5	±2	75-97.5
	B3 Isparta: A. A. Dönmez 8152 – B. Mutlu [H]	spiral furrow	79.82	±9.68	60-101
	B6 Sivas: A. A. Dönmez 8421 [H]	spiral furrow	82.36	±9.81	60-105
C. biflorus ssp. *nubigena*	A1 Çanakkale: A. A. Dönmez 10443 [H]	short furrows	68.92	±3.49	61-78
C. biflorus ssp. *isauricus*	C4 Karaman: A. A. Dönmez 8173 [H]	spiral furrow	70.4	±2.3	62.5-82.5
	A1 Çanakkale: A. A. Dönmez 10438 [H]	spiral furrow	66.76	±1.61	60.5-75
C. *biflorus* ssp. *punctatus*	C2 Muğla: A. A. Dönmez 8308 [H]	spiral furrow	74.44	±6.05	61-93
C. biflorus ssp. *pulchricolor*	A2 Bursa: A. A. Dönmez 8653 [H]	spiral furrow	84.55	±3.1	62.9-99.2
	A3 Bolu: A. A. Dönmez 10414 [H]	spiral furrow	78.52	±2.55	73-85
C. biflorus ssp. *tauri*	B8 Muş: A. A. Dönmez 5769 – E. Oybak Dönmez [H]	spiral furrow	83.1	±1.3	75-90
	B9 Van: M. Koyuncu 11595 et al. [V]	spiral furrow	78.98	±7.58	63-96
C. aerius	A8 Rize: A. Güner 5512 – M. Vural [G]	spiral furrow	66.51	±0.66	49.5-76.5
C. leichtlinii	C8 Mardin: A. Güner 1595 [H]	spiral furrow	83.12	±3.02	76-90
C. flavus ssp. *dissectus*	A1 Balıkesir: A. A. Dönmez 10431 [H]	spiral furrow	89.16	±4.25	80-98
C. olivieri ssp. *olivieri*	A4 Ankara: S. Işık 1001–E. Oybak Dönmez – A.A. Dönmez [H]	spiral furrow	77.36	±1.8	70-90
	A3 Bolu: A. A. Dönmez 10418 [H]	spiral furrow	75.16	±5.34	65-90
	A2 Bursa: A. A. Dönmez 10445 [H]	spiral furrow	71.08	±5.36	61-88
C. candidus	A1 Çanakkale: S. Işık 1036 et al. [H]	spiral furrow	73.78	±3.3	68-83
C. graveolens	C5 Mersin: A. A. Dönmez 8191 – B. Mutlu [H]	spiral furrow	65.6	±0.85	60-70
	C4 Karaman: A. A. Dönmez 8167 – B. Mutlu [H]	spiral furrow	71.7	±1.22	66.5-77.4
	C5 Adana: A. A. Dönmez 8245 – B. Mutlu [H]	spiral furrow	58.05	±0.5	47.25-58.05
C. kotschyanus ssp. *kotschyanus*	B6 K. Maraş: B. Yıldız 2362 [H]	short furrows	104.85	±0.91	72-117
C. kotschyanus ssp. *cappadocicus*	B6 Sivas: A. A. Dönmez 4241 – Z. Yeşilyurt [H]	short furrows	102.88	±8.84	90-116
	B7 Sivas: A. A. Dönmez 10182 [H]	short furrows	86.1	±3.86	80-98
C. pallasii ssp. *pallasii*	B6 K. Maraş: Aytaç & Duman [G]	short furrows	68.49	±0.39	56.25-76.5
C. pallasii ssp. *turcicus*	B3 Isparta: B. Mutlu 1134 [H]	short furrows	88.02	±0.62	76.5-99
C. cancellatus ssp. *cancellatus*	C5 Niğde: M. Vural 7217 et al. [G]	spiral furrow	74.96	±5.73	65-84
C. cancellatus ssp. *lycius*	C2 Muğla: S. Işık 1028 – A. A. Dönmez [H]	extensive furrows	88.5	±5.24	76-100
C. cancellatus ssp. *damascenus*	B9 Van: A. A. Dönmez 10288 [H]	spiral furrow	97.76	±8.38	78-130
C. speciosus ssp. *speciosus*	A4 Bartın: S. Işık 1006 – A. A. Dönmez [H]	spiral furrow	92.28	±4.99	78-101
C. speciosus ssp. *ilgazensis*	A4 Kastamonu: A. A. Dönmez 3023 et al. [H]	spiral furrow	84.38	±2.09	72.6-99.2
C. pulchellus	A2 İstanbul: S. Işık 1014 – A. A. Dönmez [H]	spiral furrow	82.86	±1.38	73.8-89.5

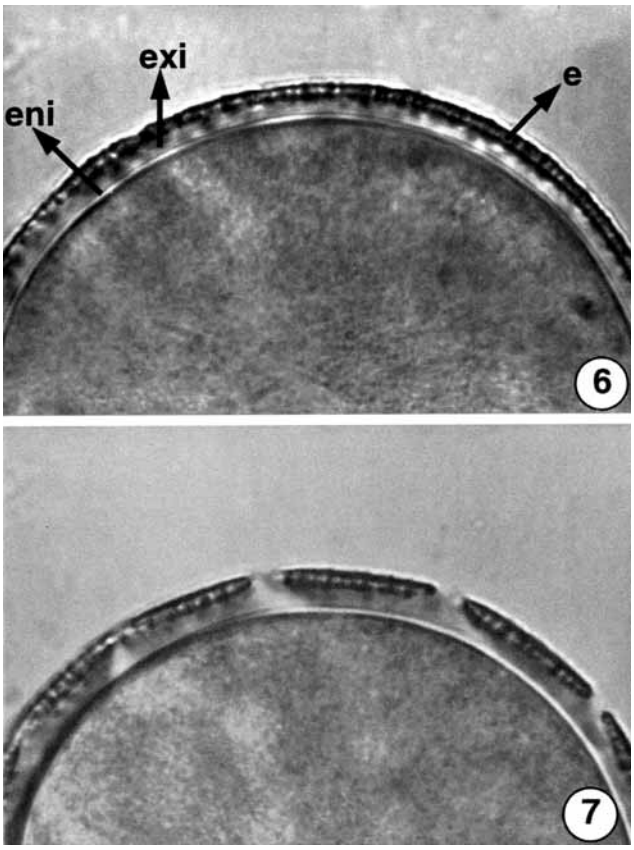
M – mean value; PD – pollen diameter; SD – standard deviation; V – variation; * taxa are in taxonomic order according to Mathew (1984; 1988; 2000); **abbreviation of herbaria in brackets: [H] – HUB; [G] – GAZI; [V] – VANF.

TABLE 2. Spinule and sexine features of Turkish *Crocus* species

Taxon	Specimen	Spinule height (µm)	Spinule number per 100 µm²	Sexine thickness (µm) except of spinules
C. fleischeri	B2 Afyon : Z. Aytaç 5486	(1)-1.07-(1.25)	(23)-33-(38)	(1)-1.42-(1.75)
C. reticulatus ssp. *reticulatus*	C5 Mersin: A. A. Dönmez 8198 – B. Mutlu	(1)-1.32-(1.5)	(9)-14-(17)	(1)-1.37-(2)
	C5 Mersin: A. A. Dönmez 8205 – B. Mutlu	(1.5)-1.52-(1.75)	(13)-15-(18)	(1.25)-1.47-(1.5)
C. abantensis	A3 Bolu: A. A. Dönmez 10417	(1.5)-1.82-(2)	(7)-11-(15)	(1)-1.65-(2)
C. gargaricus ssp. *herbertii*	A1 Çanakkale: A. A. Dönmez 10441	(1)-1.02-(1.25)	(37)-42-(55)	(1)-1.22-(1.5)
C. ancyrensis	A4 Ankara: E. Oybak Dönmez 86 – A. A. Dönmez	(1)-1.1-(1.25)	(44)-53-(65)	(1)-1.25-(1.5)
	B4 Ankara: A. A. Dönmez 8256 – B. Mutlu	(1)-1.25-(1.5)	(11)-17-(22)	(1)-1.32-(1.5)
	C5 Niğde: A. A. Dönmez 8252a – B. Mutlu	(1)-1.52-(2)	(21)-29-(35)	(1.5)-1.67-(2)
	A3 Bolu: A. A. Dönmez 10419	(1)-1.3-(1.5)	(12)-17-(23)	(1)-1.37-(1.5)
C. sieheanus	C5 Niğde: A. A. Dönmez 8252b – B. Mutlu	(1)-1.42-(1.75)	(14)-20-(23)	(1)-1.27-(1.5)
	C5 Adana: A. Güner 1495	(1)-1.62-(2)	(11)-12-(14)	(1.5)-1.72-(2)
C. chrysanthus	C4 Konya: A. A. Dönmez 8159 – B. Mutlu	(1)-1.4-(1.5)	(9)-12-(14)	(1.5)-1.65-(2)
	B3 Isparta: A. A. Dönmez 8147 – B. Mutlu	(1)-1.3-(1.5)	(10)-13-(19)	(1)-1.3-(1.75)
C. danfordiae	C5 Niğde: A. A. Dönmez 8254a – B. Mutlu	(1)-1.1-(1.5)	(36)-44-(53)	(1)-1.37-(1.5)
	A4 Ankara: S. Işık 1003 – E. Oybak Dönmez – A. A. Dönmez	(0.75)-0.95-(1)	(26)-35-(44)	(0.75)-0.97-(1)
	B3 Isparta: A. A. Dönmez 8152 – B. Mutlu	(1)-1.15-(1.5)	(20)-26-(31)	(1)-1.3-(1.5)
	B6 Sivas: A. A. Dönmez 8421	(1)-1.3-(1.75)	(14)-18-(26)	(1)-1.32-(2)
C. biflorus ssp. *nubigena*	A1 Çanakkale: A. A. Dönmez 10443	(1)-1.02-(1.25)	(35)-43-(49)	(1)-1.1-(1.25)
C. biflorus ssp. *isauricus*	C4 Karaman: A. A. Dönmez 8173	(0.75)-0.97-(1)	(25)-30-(37)	(1)-1.17-(1.5)
	A1 Çanakkale: A. A. Dönmez 10438	1	(42)-50-(55)	(1)-1.22-(1.5)
C. biflorus ssp. *punctatus*	C2 Muğla: A. A. Dönmez 8308	(1)-(1.45)-(2)	(15)-19-(23)	(1)-1.5-(2)
C. biflorus ssp. *pulchricolor*	A2 Bursa: A. A. Dönmez 8653	(1)-1.5-(2)	(10)-14-(20)	(1)-1.35-(2)
	A3 Bolu: A. A. Dönmez 10414	(1)-1.75-(2)	(10)-12-(16)	(1.5)-1.67-(1.75)
C. biflorus ssp. *tauri*	B8 Muş: A. A. Dönmez 5769 – E. Oybak Dönmez	(1)-1.32-(1.5)	(17)-25-(29)	(1.25)-1.52-(1.75)
	B9 Van: M. Koyuncu 11595 et al.	(1.25)-1.6-(2)	(10)-14-(17)	(1.25)-1.57-(1.75)
C. aerius	A8 Rize: A. Güner 5512 - M. Vural	(1.25)-1.52-(2)	(12)-15-(19)	(1.25)-1.65-(1.75)
C. leichtlinii	C8 Mardin: A. Güner 1595	(1)-1.3-(1.75)	(17)-24-(34)	(1.25)-1.5-(1.75)
C. flavus ssp. *dissectus*	A1 Balıkesir: A. A. Dönmez 10431	(1)-1.25-(1.5)	(44)-49-(60)	(1.5)-1.57-(1.75)
C. olivieri ssp. *olivieri*	A4 Ankara: S. Işık 1001 – E. Oybak Dönmez – A. A. Dönmez	(1)-1.07-(1.25)	(50)-55-(62)	(0.75)-0.97-(1)
	A3 Bolu: A. A. Dönmez 10418	(1)-1.15-(1.5)	(41)-50-(60)	(1)-1.37-(1.75)
	A2 Bursa: A. A. Dönmez 10445	(1)-1.02-(1.25)	(43)-51-(58)	(1.25)-1.35-(1.5)
C. candidus	A1 Çanakkale: S. Işık 1036 et al.	(1)-1.2-(1.5)	(53)-61-(70)	(1.25)-1.4-(1.5)
C. graveolens	C5 Mersin: A. A. Dönmez 8191 – B. Mutlu	(1)-1.22-(1.5)	(40)-48-(52)	(1.25)-1.3-(1.5)
	C4 Karaman: A. A. Dönmez 8167 – B. Mutlu	(1)-1.75-(1.5)	(51)-63-(72)	(1.25)-1.47-(1.5)
	C5 Adana: A. A. Dönmez 8245 – B. Mutlu	(1)-1.15-(1.5)	(63)-67-(72)	(1.25)-1.37-(1.75)
C. kotschyanus ssp. *kotschyanus*	B6 K.Maraş: B. Yıldız 2362	(1.75)-2.12-(2.5)	(4)-7-(11)	(1)-1.15-(1.25)
C. kotschyanus ssp. *cappadocicus*	B6 Sivas: A. A. Dönmez 4241 – Z. Yeşilyurt	(1)-1.72-(2)	(4)-5-(6)	(0.75)-0.8-(1)
	B7 Sivas: A. A. Dönmez 10182	(0.75)-(1.12)-(2)	(11)-16-(22)	0.75
C. pallasii ssp. *pallasii*	B6 K. Maraş: Aytaç & Duman	(1.25)-1.45-(1.75)	(8)-14-(19)	(1)-1.42-(1.75)
C. pallasii ssp. *turcicus*	B3 Isparta: B. Mutlu 1134	(0.75)-0.98-(1)	(10)-12-(16)	(0.75)-0.82-(1)
C. cancellatus ssp. *cancellatus*	C5 Niğde: M. Vural 7217 et al.	(0.75)-1-(1.5)	(12)-16-(19)	(0.75)-0.95-(1.25)
C. cancellatus ssp. *lycius*	C2 Muğla: S. Işık 1028 – A. A. Dönmez	(1)-1.2-(1.5)	(17)-21-(27)	(1)-1.17-(1.5)
C. cancellatus ssp. *damascenus*	B9 Van: A. A. Dönmez 10288	(0.75)-1.3-(1.5)	(10)-14-(19)	(0.25)-0.77-(1)
C. speciosus ssp. *speciosus*	A4 Bartin: S. Işık 1006 – A. A. Dönmez	(1.5)-2.02-(2.5)	(9)-13-(19)	(1.25)-1.47-(1.75)
C. speciosus ssp. *ilgazensis*	A4 Kastamonu: A. A. Dönmez 3023 et al.	(1.5)-1.7-(2.25)	(12)-15-(17)	(1)-1.40-(1.75)
C. pulchellus	A2 İstanbul: S. Işık 1014 – A. A. Dönmez	(1.5)-2.02-(2.25)	(7)-10-(15)	(1.5)-1.57-(1.75)

TABLE 3. Exintine and endintine features of Turkish *Crocus* species

Taxon	Specimen	Exintine thickness (µm)	Exintine thickness near aperture (µm)	Endintine thickness (µm)
C. fleischeri	B2 Afyon : Z. Aytaç 5486	(1.5)-1.95-(2)	(2.5)-2.87-(3)	(0.5)-0.55-(0.75)
C. reticulatus ssp. *reticulatus*	C5 Mersin: A. A. Dönmez 8198 – B. Mutlu	(1.5)-2.57-(4)	(2)-3.55-(5)	(0.5)-0.55-(0.75)
	C5 Mersin: A. A. Dönmez 8205 – B. Mutlu	(1.5)-2.12-(3.5)	(2)-3.05-(4)	(0.5)-0.62-(0.75)
C. abantensis	A3 Bolu: A. A. Dönmez 10417	(2)-2.55-(3)	(2.5)-2.96-(4)	(0.5)-0.65-(0.75)
C. gargaricus ssp. *herbertii*	A1 Çanakkale: A. A. Dönmez 10441	(1)-1.7-(2)	(2)-2.4-(3.5)	(0.5)-0.6-(0.75)
C. ancyrensis	A4 Ankara: E. Oybak Dönmez 86 – A. A. Dönmez	(1.5)-1.77-(2)	(2)-2.55-(4)	(0.5)-0.55-(0.75)
	B4 Ankara: A. A. Dönmez 8256 – B. Mutlu	(2)-2.8-(5)	(2.5)-3.45-(6.5)	(0.5)-0.57-(0.75)
	C5 Niğde: A. A. Dönmez 8252a – B. Mutlu	(2)-2.8-(4)	(3)-3.85-(5)	(0.5)-0.55-(0.75)
	A3 Bolu: A. A. Dönmez 10419	(1.75)-2.12-(2.5)	(2.5)-2.85-(3)	(0.5)-0.57-(0.75)
C. sieheanus	C5 Niğde: A. A. Dönmez 8252b – B. Mutlu	(1.5)-1.95-(2.5)	(1.75)-2.25-(3)	0.5
	C5 Adana: A. Güner 1495	(1.5)-2.2-(3)	(2)-3.05-(4.5)	0.5
C. chrysanthus	C4 Konya: A. A. Dönmez 8159 – B. Mutlu	(1.5)-2-(2.5)	(1.75)-2.27-(3)	(0.5)-0.65-(0.75)
	B3 Isparta: A. A. Dönmez 8147 – B. Mutlu	(1.5)-3.5-(5)	(2.5)-4.4-(5.5)	(0.5)-0.55-(0.75)
C. danfordiae	C5 Niğde: A. A. Dönmez 8254a – B. Mutlu	(1.5)-1.8-(2)	(2)-2.45-(3)	(0.5)-0.52-(0.75)
	A4 Ankara: S. Işık 1003 – E. Oybak Dönmez – A. A. Dönmez	(1)-1.6-(2.5)	(1.5)-2.1-(3)	0.5
	B3 Isparta: A. A. Dönmez 8152 – B. Mutlu	(1)-1.62-(2)	(1.5)-2.2-(3)	0.5
	B6 Sivas: A. A. Dönmez 8421	(1)-2.15-(4)	(1.5)-2.8-(5)	0.5
C. biflorus ssp. *nubigena*	A1 Çanakkale: A. A. Dönmez 10443	(1.25)-1.45-(1.5)	(1.5)-1.87-(2.5)	0.5
C. biflorus ssp. *isauricus*	C4 Karaman: A. A. Dönmez 8173	(1.75)-2.97-(3.75)	(2)-3-(5)	0.5
	A1 Çanakkale: A. A. Dönmez 10438	(1.5)-1.9-(3)	(2)-2.5-(4)	0.5
C. biflorus ssp. *punctatus*	C2 Muğla: A. A. Dönmez 8308	(1)-1.7-(2.5)	(1.75)-2.37-(3.5)	0.5
C. biflorus ssp. *pulchricolor*	A2 Bursa: A. A. Dönmez 8653	(1)-2.05-(3.5)	(2)-2.8-(4.5)	0.5
	A3 Bolu: A. A. Dönmez 10414	(1.75)-2.22-(3)	(2)-2.7-(3.5)	0.5
C. biflorus ssp. *tauri*	B8 Muş: A. A. Dönmez 5769 – E. Oybak Dönmez	(1.5)-1.8-(2.25)	(2)-2.8-(3.5)	0.5
	B9 Van: M. Koyuncu 11595 et al.	(1.5)-1.8-(2)	(2)-2.65-(3.5)	0.5
C. aerius	A8 Rize: A. Güner 5512 - M. Vural	(1)-1.52-(2)	(2)-2.6-(3)	0.5
C. leichtlinii	C8 Mardin: A. Güner 1595	(1.5)-2.02-(2.5)	(2.5)-2.95-(3)	0.5
C. flavus ssp. *dissectus*	A1 Balıkesir: A. A. Dönmez 10431	(1.5)-2.2-(3)	(2)-2.95-(4)	(0.5)-0.52-(0.75)
C. olivieri ssp. *olivieri*	A4 Ankara: S. Işık 1001 – E. Oybak Dönmez – A. A. Dönmez	(1)-1.37-(1.5)	(1.5)-1.9-(2)	0.5
	A3 Bolu: A. A. Dönmez 10418	(1.5)-1.8-(2)	(2)-2.65-(3.5)	(0.5)-0.52-(0.75)
	A2 Bursa: A. A. Dönmez 10445	(1)-1.32-(2)	(1.5)-2.02-(2.5)	(0.5)-0.55-(0.75)
C. candidus	A1 Çanakkale: S. Işık 1036 et al.	(1.5)-1.77-(2.5)	(2)-2.6-(3)	(0.5)-0.6-(0.75)
C. graveolens	C5 Mersin: A. A. Dönmez 8191 – B. Mutlu	(1)-1.62-(2)	(2)-2.25-(2.5)	0.5
	C4 Karaman: A. A. Dönmez 8167 – B. Mutlu	(1.5)-2-(2.5)	(2.5)-3-(3.5)	0.5
	C5 Adana: A. A. Dönmez 8245 – B. Mutlu	(1)-1.55-(2.5)	(1.5)-1.95-(3)	(0.5)-0.52-(0.75)
C. kotschyanus ssp. *kotschyanus*	B6 K.Maraş: B. Yıldız 2362	(3)-3.65-(6)	-	0.5
C. kotschyanus ssp. *cappadocicus*	B6 Sivas: A. A. Dönmez 4241 – Z. Yeşilyurt	(2.5)-4.25-(6)	-	0.5
	B7 Sivas: A. A. Dönmez 10182	(2)-2.32-(2.75)	-	0.5
C. pallasii ssp. *pallasii*	B6 K. Maraş: Aytaç & Duman	(1)-1.65-(2.5)	(1.75)-2.2-(2.5)	(0.5)-0.55-(0.75)
C. pallasii ssp. *turcicus*	B3 Isparta: B. Mutlu 1134	(1)-1.67-(2.5)	(1.5)-2-(2.75)	0.5
C. cancellatus ssp. *cancellatus*	C5 Niğde: M. Vural 7217 et al.	(1.5)-2.05-(2.5)	(2)-2.25-(2.5)	0.5
C. cancellatus ssp. *lycius*	C2 Muğla: S. Işık 1028 – A. A. Dönmez	(1.5)-1.92-(2.5)	(1)-2.55-(3)	0.5
C. cancellatus ssp. *damascenus*	B9 Van: A. A. Dönmez 10288	(1)-1.85-(2.5)	(1.5)-2.35-(3)	0.5
C. speciosus ssp. *speciosus*	A4 Bartın: S. Işık 1006 – A. A. Dönmez	(2.5)-2.85-(3)	(3)-3.15-(3.5)	0.5
C. speciosus ssp. *ilgazensis*	A4 Kastamonu: A. A. Dönmez 3023 et al.	(1.5)-2-(3.5)	(2)-2.8-(4)	0.5
C. pulchellus	A2 İstanbul: S. Işık 1014 – A. A. Dönmez	(2)-2.7-(3)	(3)-3.45-(4)	0.5



Figs. 6–7. Pollen wall of *Crocus*. **Fig. 6.** *C. abantensis*; main layers of pollen wall. e – exine; exi – exintine; eni – endintine. **Fig. 7.** *C. ancyrensis*; exintine thickening near aperture. ×1000.

a correlation with the chromosome numbers given by Mathew (1988). It is widely accepted that pollen size usually increases as chromosome number increases. However, in our study we observed that some taxa with smaller pollen grains have higher chromosome numbers (e.g., *C. fleischeri*, 2n = 20; C. *gargaricus* ssp. *herbertii*, 2n = 30) than those with larger pollen grains (e.g., *C. kotschyanus* ssp. *cappadocicus*, 2n = 10; *C. cancellatus* ssp. *damascenus*, 2n = 8, 10, 12).

In the monocotyledons, elliptical pollen grains are quite common (cf. Zavada, 1983), but spheroidal pollen has also been recorded in monocotyledonous families, for example in *Iris* species of the subgenus *Scorpiris* (Iridaceae) (Oybak Dönmez and Pınar, 2001), a group closely related to the genus *Crocus*.

According to Heslop-Harrison (1977), the pollen walls of some monocotyledons consist of a thin exine and relatively thick intine, as in the pollen of the *Crocus* species under study. However, the role of the thick intine in angiosperm pollen is not fully understood, apart from their known role in pollen germination (Hesse, 2000).

Based on exine sculpture, the *Crocus* pollen grains under study are characterized by echinate (spinulate)-microperforate exine. In this connection, the *Crocus* pollen rather differs from related genera in the Turkish flora belonging to Iridaceae, in most of which reticulate exine predominates (Işık and Oybak Dönmez, unpub. data). Several investigations have shown positive correlations between pollen ornamentation (exine sculpture) and pollination mechanisms. For example, Grayum (1986) points out that spinose pollen is closely associated with fly pollination, and suggests that it more effectively guarantees the attachment of pollen among the hairs or bristles of rapidly flying insects such as bees or flies. Grayum also states that exine sculpture is not the only pollen character that may be affected by pollinator selection. The *Crocus* species are pollinated by insects (Chichiriccò, 1999). Thus, the echinate (spinulate) exine of *Crocus* pollen would be partly related to insect pollination. The presence of pollenkitt observed on the surface of *Crocus* pollen by Chichiriccò (1999) is support for insect pollination, because pollenkitt is widely thought to be useful for adhesion and is usually present on pollen transported by insects.

For the Turkish *Crocus* taxa studied, spinule height and number were not of systematic significance. Spinule height did not differ significantly between taxa, and spinule number varied within species such as *C. ancyrensis* and *C. danfordiae*.

As stated above, the Turkish *Crocus* taxa varied in pollen type related to aperture features. The most common type of aperture is the spiral furrow (spiraperturate pollen type). Furness (1985) suggested that the spiraperturate type may increase the germination rate. The other aperture types, rarely present in the Turkish *Crocus* species, are more or less extensive furrows and short furrows (polyrugoidate and polycolpate pollen types). Thanikaimoni (1986) argued that the diversity of pollen aperture forms is the result of various factors such as the particular mode of development (ontogenetic factor) determined genetically, or adaptation to the habitat and mode of pollination (ecological factor). In the *Crocus* taxa, variations occur, although rarely, especially within some species. All the subspecies of *C. biflorus* Miller have pollen with a spiral furrow except for *C. biflorus* ssp. *nubigena* which have short furrows. Similarly, *C. cancellatus* ssp. *cancellatus* and ssp. *damascenus* feature a spiral furrow, whereas pollen grains of *C. cancellatus* ssp. *lycius* have extensive furrows. It is difficult to give a simple explanation of such diversity in pollen type within *Crocus* species. In terms of the factors considered by Thanikaimoni (1986), the ontogenetic factor may play a crucial role in the aperture forms of the taxa, because the mentioned subspecies live under almost similar ecological conditions.

Furness and Rudall (2000) write that pollen with a reduced aperture or no aperture is widespread in monocotyledons, and that this is probably related to the relatively thin exine: many monocotyledons with such pollen types prefer wet or moist habitats. They believe that pollen in such environments may not undergo desiccation. However, inaperturate pollen with reduced exine has been also recorded in plants of dry habitats, for example in Liliaceae (Furness and Rudall, 2000). In the *Crocus* species examined in this study, all the pollen grains have a thin exine and relatively thick intine, but most species, including those with short furrows, grow in open rocky places or sparse coniferous woods.

The results of this study are comparable to some findings from Europe on pollen morphology in the genus *Crocus* (Erdtman, 1952; Heslop-Harrison, 1977; Mariotti, 1988; Chichiriccò, 1999). The pollen grains of the European and Turkish species are quite similar in pollen shape (spheroidal), aperture types [spirally disposed furrows, more or less extensive furrows, or short furrows (inaperturate according to some authors)], pollen wall stratification (thin exine and thick intine) and exine sculpture (usually provided with small spinules). The pollen sizes given for some European *Crocus* species are 60–105 μm (based on 11 species) (Erdtman, 1952), 80–110 μm (1 species) (Mariotti, 1988), 60 μm (1 species) (Grilli Caiola et al., 1993) and 61–84.5 μm (10 species) (Chichiriccò, 1999). The studied Turkish *Crocus* species showed a wider range of pollen diameter, from 47.25 to 130 μm (29 species); this is probably attributable to our use of embedding in glycerine jelly, which causes size increase.

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