

## An anatomical and ecological study of some *Crocus* L. taxa (Iridaceae) from the west part of Turkey

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A comparative anatomical and ecological study was made of nine *Crocus* taxa (*C. gargaricus* subsp. *gargaricus*, *C. chrysanthus*, *C. biflorus* subsp. *nubigena*, *C. flavus* subsp. *dissectus*, *C. olivieri* subsp. *istanbulensis*, *C. candidus*, *C. pallasii* subsp. *pallasii*, *C. cancellatus* subsp. *mazziaricus*, *C. pulchellus*) from the west part of Turkey. Leaf anatomy has been differentiated among the taxa. The lower surfaces of the arms and the sides of keels have projections only in *C. biflorus* subsp. *nubigena*. Anticlinal walls of epidermis in stomatal regions are generally sinuous, but sometimes straight. There are four large vascular bundles in the margin of the arms and on the corner of the keels. Sclerenchymatous tissue was observed in phloem and xylem poles of larger bundles in *C. flavus* subsp. *dissectus*, *C. olivieri* subsp. *istanbulensis*, *C. candidus*, *C. pallasii* subsp. *pallasii*, while it was observed only in the phloem pole in *C. gargaricus* subsp. *gargaricus*, *C. chrysanthus*, *C. biflorus* subsp. *nubigena*, *C. cancellatus* subsp. *mazziaricus*, *C. pulchellus*. All taxa grow on clayey-loamy and clayey soils, with pH 6.09–7.18, with 3.1–5.7% of CaCO<sub>3</sub>, 3.1–5.7% of organic matter, 2.5–67.7% of phosphorus, and 52.7–198.7% of potassium.

**Key words:** Anatomy, *Crocus*, ecology, leaf, Turkey.

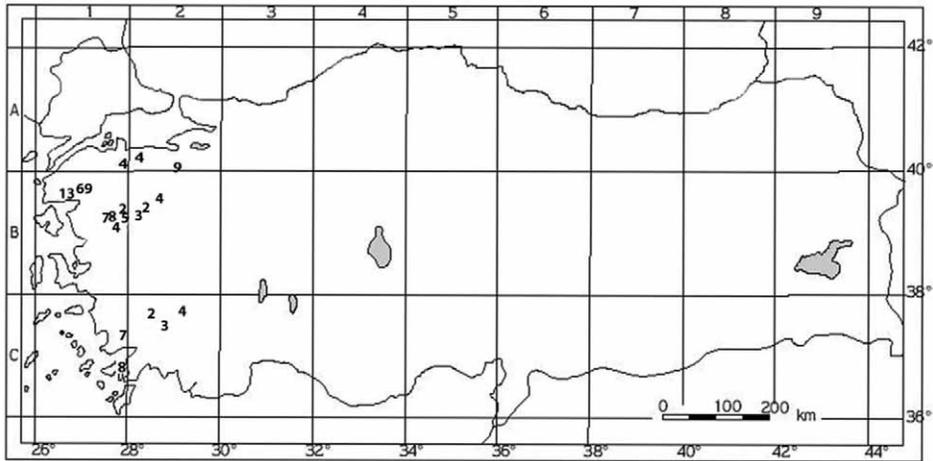
### Introduction

There are 80 species of *Crocus* worldwide (MABBERLY 1997), distributed mainly in the Mediterranean region. There are 63 taxa in Turkey. Thirty-one of these are endemic to Turkey (MATHEW 1984, 2000, DAVIS et al. 1988). Systematic studies have been presented by DAVIS et al. (1988), KERNDORFF and PASCHE (1994, 1996a, 1996b, 1997), MATHEW (1984, 1995, 2000), and PASCHE (1994a, 1994b), but there have been a few studies on the morphology and anatomy of *Crocus* species in Turkey (ÖZDEMİR et al. 2004, ÖZYURT 1978, AKAN and EKER 2004, AKAN et al. 2006).

The leaves of most *Crocus* species have a unique and distinctive shape in cross section. In the present study, detailed descriptions of the anatomical characteristics of leaves in nine *Crocus* species were studied in Turkey (Fig. 1), in order to provide more detailed descriptions. Five of these species are endemic to Turkey (Tab. 1).

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**Fig. 1.** Collection sites in Turkey for *Crocus* samples (1-*C. gargaricus* subsp. *gargaricus*, 2-*C. chrysanthus*, 3-*C. biflorus* subsp. *nubigena*, 4-*C. flavus* subsp. *dissectus*, 5-*C. olivieri* subsp. *istanbulensis*, 6-*C. candidus*, 7-*C. pallasii* subsp. *pallasii*, 8-*C. cancellatus* subsp. *mazziaricus*, 9-*C. pulchellus*).

**Tab. 1.** Collection data of studied *Crocus* taxa from Turkey.

	Collection data and collector number
<i>Crocus gargaricus</i> subsp. <i>gargaricus</i> (E)	<b>B1</b> Balıkesir: Edremit, Kazdağ, Kartalçimen, 1700 m, 07.04.2005, FS1382.
<i>C. chrysanthus</i>	<b>B1</b> Balıkesir: Dinkçiler, 140 m, 15.02.2005, SV1011. <b>B2</b> Balıkesir: Sındırgı, Ulus mountain, 1400 m, 19.04.2005, SV1040. <b>C2</b> Muğla: Göktepe, 1600 m, 29.03.2005, FS1392.
<i>C. biflorus</i> subsp. <i>nubigena</i> (E)	<b>B1</b> Balıkesir: Edremit, Kazdağ, 1400 m, 15.02.2005, FS1384. <b>B2</b> Balıkesir: Sındırgı, Kocabey village, 700 m, 01.02.2005, SV1008. <b>C2</b> Muğla: Göktepe, 1800 m, 29.03.2005, FS1402.
<i>C. flavus</i> subsp. <i>dissectus</i> (E)	<b>B1</b> Balıkesir: Çağış village, 140 m, 20.02.2005, SV1014. <b>B2</b> Balıkesir: Dursunbey, Esentepe, 800 m, 24.03.2005, SV1032. <b>A1</b> Balıkesir: Manyas, Akçaova village, 140 m, 15.03.2004, FS1420. <b>A2</b> Balıkesir: Bandırma, Dedeoba village, 145 m, 17.03.2004, FS1415. <b>C2</b> Denizli: Kazıkbeli, 1130 m, 28.03.2005, FS1403.
<i>C. olivieri</i> subsp. <i>istanbulensis</i> (E)	<b>B1</b> Balıkesir: Değirmen boğazı, 180 m, 04.03.2005, SV1019
<i>C. candidus</i> (E)	<b>B1</b> Çanakkale: Ezine to Truva, 200 m, 27.02.2005, FS1385. <b>B1</b> Balıkesir: Edremit, Ortaoba village, 350 m, 28.02.2005, SV1034.
<i>C. pallasii</i> subsp. <i>pallasii</i>	<b>B1</b> Balıkesir: Savaştepe, Kozören village, 500 m, 14.12.2004, SV1006. <b>C1</b> Aydın: 4. km from Selçuk to Kusadası, 40 m, 22.11.2005, FS1404
<i>C. cancellatus</i> subsp. <i>mazziaricus</i>	<b>B1</b> Balıkesir: Savaştepe, Kozören village, 500 m, 14.12.2005, SV1007. <b>C1</b> Muğla: 18. km Milas to Bodrum, 23.11.2005, FS14012
<i>C. pulchellus</i>	<b>B1</b> Balıkesir: Savaştepe, Kozören village, 500 m, 06.12.2004, SV1005 <b>B1</b> Balıkesir: Edremit, Kazdağ, 1400 m, 14.11.2005, FS1410 <b>A2</b> Bursa: Uludağ, 1800 m, 15.11.2005, FS1411

## Materials and methods

Material used in this study was collected from different localities in Turkey (Fig. 1). Voucher specimens (Tab. 1) were deposited in the Balıkesir University, Department of Biology.

Fresh plants were fixed in 70% alcohol. Developed leaves of species from fully flowered plants were used in the anatomical study. Five samples were taken from each specimen for transverse section. Transverse sections of leaves were made manually. Tissues were stained with Floroglucin+HCl and embedded in glycerine jelly (BAYTOP 1972). An Olympus BX50 phase contrast microscope with drawing tube was used in anatomical studies.

The physical and chemical analyses of the soil samples were taken from the sites presented in Fig. 1. Texture, pH, calcium carbonate, total soluble salts and organic matter content were determined (ÖZTÜRK et al. 1997). K% and P% were determined by flame photometer and the ammonium molybdate-tin chloride method, respectively (KAÇAR 1996).

## Results

### Leaf anatomy

Leaves of *Crocus* taxa have a unique morphology in the cross-section with a central square or rectangular »keel«, and two lateral »arms« (Fig. 2A). There are projections in the lower surfaces of the arms and the sides of keels only in *C. biflorus* subsp. *nubigena*. This structure is absent in other taxa (Figs 3C, 4C).

Epidermis cells are either rectangular or elliptical. Anticlinal walls of epidermis in stomatal regions are generally sinuous (in *C. gargaricus* subsp. *gargaricus*, *C. biflorus* subsp. *nubigena*, *C. flavus* subsp. *dissectus*, *C. olivieri* subsp. *istanbulensis*, and *C. candidus*) but sometimes straight (in *C. chrysanthus*, *C. pallasii* subsp. *pallasii*, and *C. cancellatus* subsp. *mazziaricus*) and straight-sinuous in *C. pulchellus* (Fig. 2D). The upper epidermis cells are longer and more orbicular than the lower epidermis cells (Fig. 2C).

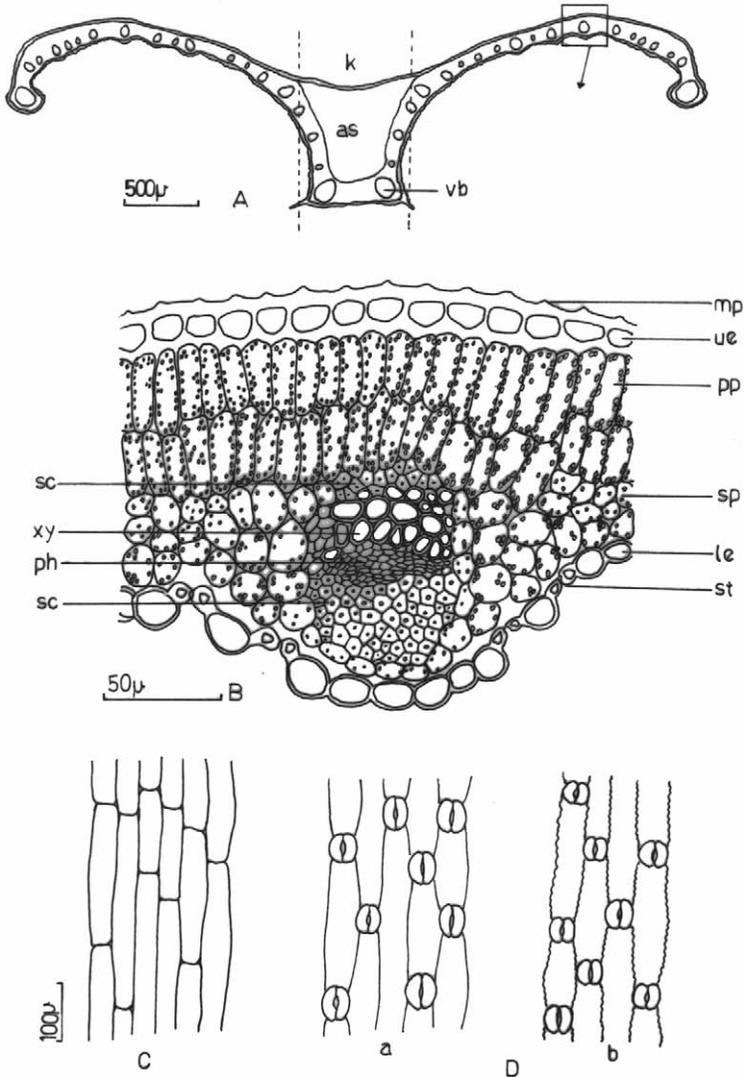
The cuticle of the upper epidermis is thicker than in the lower epidermis. Micropapillae are inconspicuous on the cuticle of *C. gargaricus* subsp. *gargaricus* (Tab. 2), but there are a conspicuous micropapillae on the cuticles of other 8 taxa (Figs. 2B, 4).

Hair like papillae are generally present on prominent ridges over the largest vascular bundles, or at the keel corner of *C. gargaricus* subsp. *gargaricus*, *C. flavus* subsp. *dissectus*, *C. olivieri* subsp. *istanbulensis*, *C. candidus*, *C. pallasii* subsp. *pallasii*, *C. cancellatus* subsp. *mazziaricus*, and *C. pulchellus* (Fig. 3). Hair-like papillae are absent in *C. chrysanthus* and *C. biflorus* subsp. *nubigena*.

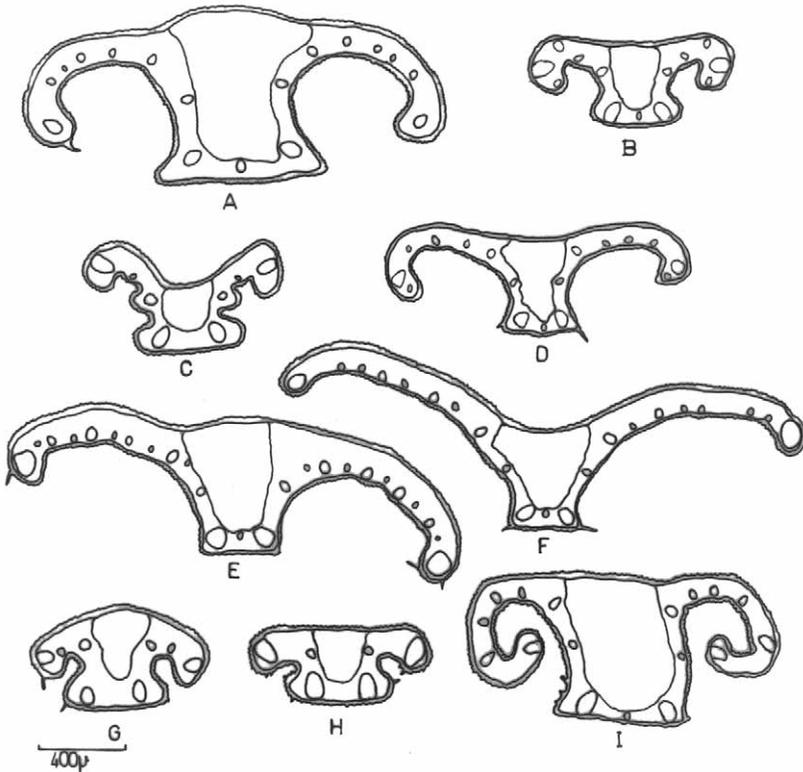
Stomata of all taxa are anomocytic and occur only on the lower surfaces. The stomata were mainly confined to the grooves in the recurved undersurface of the arms (Fig. 2B, 2D).

Mesophyll on the arms is differentiated into palisade and spongy parenchyma (Figs. 2B, 4). Palisade tissue is 2-layered (in *C. chrysanthus*, *C. olivieri* subsp. *istanbulensis*, *C. candidus*, *C. pallasii* subsp. *pallasii*, *C. cancellatus* subsp. *mazziaricus*, and *C. pulchellus*) or 1–2-layered (in *C. gargaricus* subsp. *gargaricus*, *C. biflorus* subsp. *nubigena*, and *C. flavus* subsp. *dissectus*). Spongy tissue is 2–3-layered in *C. chrysanthus* and *C. flavus* subsp. *dissectus*; 3–4-layered in *C. biflorus* subsp. *nubigena*, *C. candidus*, *C. pallasii*

subsp. *pallasii*, *C. pulchellus*, and 4–5-layered in *C. gargaricus* subsp. *gargaricus*; 3–5-layered in *C. olivieri* subsp. *istanbulensis* and *C. cancellatus* subsp. *mazziaricus* (Tab. 2). Spongy cells are round or oval. The central part of the keel consists of large thin walled parenchymatic cells.



**Fig. 2.** A-General drawing of transverse sections in *Crocus* from Turkey, B-Cross-section of leaf (in *C. olivieri* subsp. *istanbulensis*), C-Surface view of upper epidermis (in *C. olivieri* subsp. *istanbulensis*), D-Surface view of lower epidermis in regions with stomata (a-*C. chrysanthus*, b-*C. biflorus* subsp. *nubigena*). k-keel, as-air space, vb-vascular bundle, mp-micropapillae, ue-upper epidermis, pp-palisade parenchyma, sp-spongy parenchyma, le-lower epidermis, st-stomata, sc-sclerenchyma, xy-xylem, ph-phloem. Scale bars: A=500 μm, B=50 μm, C,D=100 μm.



**Fig. 3.** General drawing of transverse sections in *Crocus* leaves from Turkey. A) *C. gargaricus* subsp. *gargaricus*, B) *C. chrysanthus*, C) *C. biflorus* subsp. *nubigena*, D) *C. flavus* subsp. *dissectus*, E) *C. olivieri* subsp. *istanbulensis*, F) *C. candidus*, G) *C. pallasii* subsp. *pallasii*, H) *C. cancellatus* subsp. *mazziiaricus*, I) *C. pulchellus*. Scale bars: 400  $\mu\text{m}$ .

Vascular bundles are usually around the lower surface of keel and extend along the arms. There are large and small vascular bundles in the mesophyll. Four large bundles are always present in keel corners and arm margins. Small vascular bundles extend in between arm margins and keel. Vascular bundles are collateral. There are sclerenchymatous cells as caps only at the phloem poles of larger bundles and smaller bundles in *C. gargaricus* subsp. *gargaricus*, *C. chrysanthus*, *C. biflorus* subsp. *nubigena*, *C. cancellatus* subsp. *mazziiaricus*, and *C. pulchellus*. There are also sclerenchymatous cells in phloem poles and xylem poles of larger bundles in *C. flavus* subsp. *dissectus*, *C. olivieri* subsp. *istanbulensis*, *C. candidus*, and *C. pallasii* subsp. *pallasii* (Figs. 2B, 4).

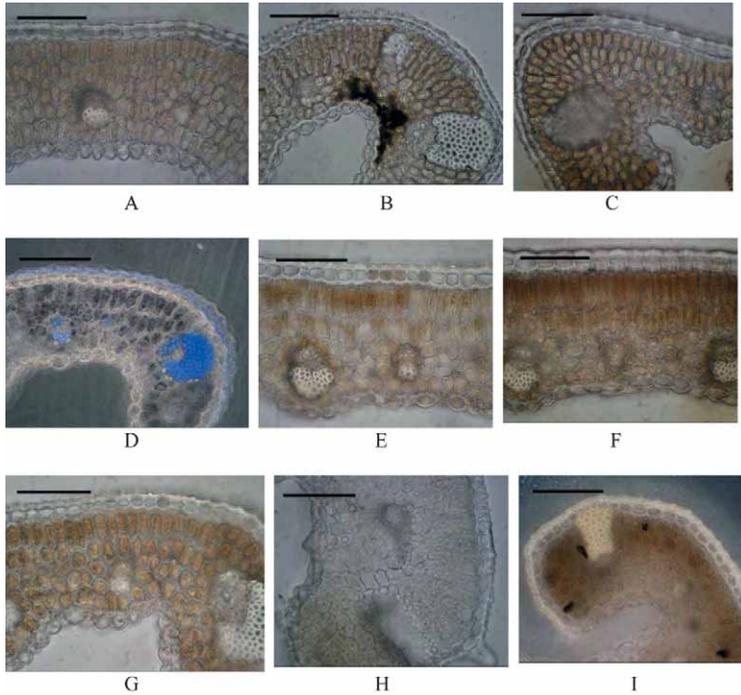
Larger bundles extend to the epidermis as girds in *C. chrysanthus*, *C. cancellatus* subsp. *mazziiaricus*, and *C. pulchellus*, but do not do so in other taxa (Figs. 3, 4B, H, I).

### Ecological characteristics

The investigated *Crocus* taxa grow on exposed limestone rocks, stony slopes, sparse woods, scrub, grassy places, alpine turf, and damp pastures, between sea level and 3000 m.

Tab. 2. The comparison of leaf anatomical characteristics.

	Micropapillae in cuticle	Hair like papillae	Anticlinal walls of epidermis in stomatal regions	Projecting in arms and side of keels	Palisade layer	Spongy layer	Larger bundles to epidermis
<i>Crocus gargaricus</i> subsp. <i>gargaricus</i>	inconspicuous	Present	sinuous	–	1–2	4–5	not extending
<i>C. chrysanthus</i>	conspicuous	–	straight	–	2	2–3	extending
<i>C. biflorus</i> subsp. <i>nubigena</i>	conspicuous	–	sinuous	projecting	1–2	3–4	not extending
<i>C. flavus</i> subsp. <i>dissectus</i>	conspicuous	Present	sinuous	–	1–2	2–3	not extending
<i>C. olivieri</i> subsp. <i>istanbulensis</i>	conspicuous	Present	sinuous	–	2	3–5	not extending
<i>C. candidus</i>	conspicuous	Present	sinuous	–	2	3–4	not extending
<i>C. pallasii</i> subsp. <i>pallasii</i>	conspicuous	Present	straight	–	2	3–4	not extending
<i>C. cancellatus</i> subsp. <i>mazzariacus</i>	conspicuous	Present	straight	–	2	3–5	extending
<i>C. pulchellus</i>	conspicuous	Present	straight-sinuous	–	2	3–4	extending



**Fig. 4.** Transverse sections of *Crocus* leaves. A) *C. gargaricus* subsp. *gargaricus*, B) *C. chrysanthus*, C) *C. biflorus* subsp. *nubigena*, D) *C. flavus* subsp. *dissectus*, E) *C. olivieri* subsp. *istanbulensis*, F) *C. candidus*, G) *C. pallasii* subsp. *pallasii*, H) *C. cancellatus* subsp. *mazziaricus*, I) *C. pulchellus*. Scale bars: 100  $\mu$ m.

**Tab. 3.** Soil characteristics of *Crocus* taxa localities.

	Texture	Total soluble salt (%)	pH	CaCO <sub>3</sub> %	Org. Matter (%)	P %	K %
<i>Crocus gargaricus</i> subsp. <i>gargaricus</i>	clayey	0.103	6.98	4.0	5.3	5.4	120.4
<i>C. chrysanthus</i>	clayey-loamy	0.041	6.25	0.8	3.1	2.5	52.7
<i>C. biflorus</i> subsp. <i>nubigena</i>	clayey-loamy	0.093	6.74	2.4	4.9	7.6	147.5
<i>C. flavus</i> subsp. <i>dissectus</i>	clayey	0.080	6.92	4.0	5.5	3.6	82.8
<i>C. olivieri</i> subsp. <i>istanbulensis</i>	clayey-loamy	0.051	6.67	1.6	5.7	47.0	144.5
<i>C. candidus</i>	clayey-loamy	0.046	6.34	0.4	4.3	18.3	82.8
<i>C. pallasii</i> subsp. <i>pallasii</i>	clayey	0.112	6.09	1.2	5.7	11.5	87.3
<i>C. cancellatus</i> subsp. <i>mazziaricus</i>	clayey-loamy	0.066	7.18	20.8	4.0	2.9	78.3
<i>C. pulchellus</i>	clayey-loamy	0.077	7.03	2.4	4.7	67.7	198.7

*Crocus* shares a habitat with maquis and phrygana like *Pinus* sp., *Quercus* sp., *Muscari* sp., *Scilla* sp., *Romulea* sp. and *Galanthus* sp.

The *Crocus* taxa investigated generally grow on clayey-loamy and clayey soils (Tab. 3). *C. pulchellus*, *C. candidus*, *C. biflorus* subsp. *nubigena*, *C. olivieri* subsp. *istanbulensis*, *C. cancellatus* subsp. *mazziaricus* and *C. chrysanthus* prefer clayey-loamy soils. *C. flavus* subsp. *dissectus*, *C. pallasii* subsp. *pallasii* and *C. gargaricus* subsp. *gargaricus* can grow well on clayey soils.

The pH values were from 6.09 to 7.18. Total salts were 0.041–0.112%, and calcium carbonate values were 0.4–20.8%. The organic matter values were 3.1–5.7%. The phosphorus and potassium values were 2.5–67.7% and 52.7–198.7%, respectively (Tab. 3).

## Discussion

Leaves of *Crocus* species have unique and distinctive shapes in cross section. They comprise a central square or rectangular »keel«, and two lateral »arms«, with their margins generally recurved towards the keel. The central part of the keel consists of large thin walled parenchyma cells which usually break down to form air space.

The arms in all taxa are symmetrical. The abaxial side of arms and adaxial of keels have protrusions only in *C. biflorus* subsp. *nubigena*. Similar results have been observed for *C. danfordiae* (ÖZDEMİR et al. 2004) and *C. cancellatus* (RUDALL and MATHEW 1990).

Hair-like papillae are absent only in *C. chrysanthus* and *C. biflorus* subsp. *nubigena*. There are inconspicuous micropapillae only on the cuticle of *C. gargaricus* subsp. *gargaricus*, but it is conspicuous in other taxa.

Anticlinal walls of the epidermis in stomatal regions for all taxa are generally sinuous, or sometimes straight. The same features have been observed on the leaf of *Crocus candidus*, *C. flavus* and *C. benadicus* (RUDALL and MATHEW 1990).

The mesophyll of all taxa consists of 1–2-layered palisade and 2–5-layered spongy cells. Vascular bundles are collateral. There are four large bundles in the margins of the arms and on the corners of keels. Small bundles extend between the large bundles.

Larger bundles extend to epidermis as girds in *C. chrysanthus*, *C. cancellatus* subsp. *mazziaricus*, and *C. pulchellus* but not in *C. gargaricus* subsp. *gargaricus*, *C. biflorus* subsp. *nubigena*, *C. flavus* subsp. *dissectus*, *C. olivieri* subsp. *istanbulensis*, *C. candidus*, *C. pallasii* subsp. *pallasii*.

The investigated *Crocus* taxa generally grow on clayey-loamy and clayey soils. The pH of the soil varies between 6.09–7.18. *Crocus* taxa generally prefer neutral and slightly acidic soils. All taxa in this study generally grow on calcareous soils. Soils where *Crocus* taxa occurs are rich in potassium and organic matter. Soils where *C. pulchellus*, *C. pallasii* subsp. *pallasii*, *C. candidus*, *C. olivieri* subsp. *istanbulensis* occur are rich in phosphorus, but soils where *C. gargaricus* subsp. *gargaricus*, *C. chrysanthus*, *C. flavus* subsp. *dissectus*, and *C. cancellatus* subsp. *mazziaricus* occur are poor in phosphorus. Phosphorus values are medium in soils where *C. biflorus* subsp. *nubigena* is found.

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