

FRUIT, SEED AND POLLEN MORPHOLOGY OF *CHORISPORA* DC. SPECIES (BRASSICACEAE) OF TURKEY

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Abstract

Detailed description of fruit, seed and pollen macro- and micromorphological characters of Turkish *Chorispora* species are provided with illustrations. Typical fruits are linear, straight or strongly curved upward. Nonglandular and glandular trichomes are present or absent. Seeds varied in shape from oblong, oblong-broadly elliptic to subglobose and winged at the apex and base or not. The pollen grains are tricolpate and the basic shape of the pollen grains in species studied is perprolate. The surface sculpturing type is reticulate. Among the studied characters, fruit, seed size and colour, seed shape, fruit trichome structure and pollen size were of taxonomic importance and useful in separating taxa.

Introduction

Fruits of Brassicaceae are capsule forming siliqua or silicula and taxonomy of the family is based on fruit characters. The macro- and micromorphological characteristics of the fruit and seed of Brassicaceae have provided significant results between genera and sub-categoric taxa (Murley 1951, Fayed and El-Naggar (1988, 1996), Abdel Khalik and Maesen (2002). Koul *et al.* (2000), Moazzeni *et al.* (2007), Pinar *et al.* (2007, 2009), Kaya *et al.* (2011) and Paksoy *et al.* (2016) investigated the morphology of fruit and seed in certain genera of Brassicaceae and provided evidence for the close relationships among various genera.

Pollen morphology has provided an approach to the systematic relationships among the genera of Brassicaceae (Kaya *et al.* 2017, Pinar *et al.* 2009). Anchev and Deneva (1997) investigated 17 Brassicaceae species and they classified its pollen into two types. Perveen *et al.* (2004) examined pollen morphology of Brassicaceae from Pakistan.

The genus *Chorispora* DC. is a member of the family Brassicaceae and represented by 12 species in the world (Warwick *et al.* 2006). Only, three species of the genus are found in Turkish Flora: *Chorispora iberica* (M. Bieb.) DC., *C. purpurascens* (Banks & Sol.) Eig., *C. tenella* (Pall.) DC. Turkish *Chorispora* species are annual herbs (Cullen 1965).

Until now, the morphology of the fruit, seed and pollen in relation to taxonomy has not been reported in *Chorispora*. The present investigation concerns with the taxonomic significance of fruit, seed and pollen characters as a criterion for the separation of *Chorispora* species studied in Turkey.

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Materials and Methods

Chorispora species were collected from different localities of Turkey. Voucher specimens were deposited in the herbarium of the Faculty of Science and Arts of Yuzuncu Yıl University (VANF). *Chorispora* materials were compared with similar materials at the Berlin (B), Edinburgh (E) herbaria and Turkish herbaria (GAZI, ANK, EGE, ISTE, ISTO, HUB).

Only mature fruits and seeds of the specimens were taken for investigation and 15 dried fruits and seeds samples were examined for each species. Measurements and optical observations of fruit and seed colours were carried out under a stereomicroscope.

Fruit and seed micromorphology were studied by Tabletop Scanning Electron Microscopy (SEM). For the SEM, fruits and seeds were fixed on aluminum stubs using double-sided adhesive. The SEM micrographs were taken in JCM-5000 Tabletop Sem at an accelerating voltage of 10 - 15 kV. The terminology for describing seed surface sculpturing mainly follows Bojňanský and Fargašová (2007). Pollen grains for SEM were mounted directly on stubs, using single-side adhesive tape and coated with gold. Photographs were taken with EVO-50. Twenty pollen grains for each species were examined. The terms used for describing the pollen patterns have been adopted according to Walker and Doyle (1975).

Results and Discussion

The morphological characters of the fruit, seed and pollen of *Chorispora* are given below and data obtained from the study of stereomicroscope and SEM investigation are presented in Tables 1 - 4 and Figs 1 - 4.

Fruit linear, strongly curved upward (Fig. 1a), straw coloured, mature fruit 24 - 35 × 3.0 - 4.5 mm, stragulate, strongly torulose and with 5 - 9 constrictions on each side, beak 6 - 23 mm. The pedicels are 4 - 6 mm. There are slightly cuticl folds on epicarp cell. Nonglandular and glandular trichomes are present but they are rare. Nonglandular trichomes are simple and short or long, glandular trichomes are capitate type. Stomata $15.10 \pm 3.47 \times 6.84 \pm 1.44 \mu\text{m}$ (Tables 1 - 2, Figs 2a, b).

C. purpurascens (Syn. *C. syriaca* Boiss.): Fruit linear, straight or strongly curved upward (Fig. 1b), greenish yellow, mature fruits 40 - 45 × 2.0-4.5 mm, strongly torulose and with 6-10 constrictions on each side, beak 18 - 29 mm. The pedicels are 4 - 7 mm. There are slightly cuticl folds on epicarp cell. Nonglandular and glandular trichomes are present. Nonglandular trichomes are usually long and dense. Glandular trichomes are capitate type and rare. Stomata $15.70 \pm 1.76 \times 7.41 \pm 1.03 \mu\text{m}$ (Tables 1 - 2, Figs. 2c, d).

Table 1. Morphological characters of fruits of *Chorispora* species.

Species	Dimension (mm)	Shape	Colour	Pedicel (mm)	Loculus number	Beak (mm)
<i>C. iberica</i>	24.0 - 35 × 3.0 - 4.5	Linear	Straw coloured	4 - 6	5 - 9	6.0 - 23
<i>C. purpurascens</i>	40.0 - 45 × 2.0 - 4.5	Linear	Greenish-yellow	4 - 7	6 - 10	18.0 - 29
<i>C. tenella</i>	13.5 - 22 × 1.5 - 2.0	Linear	Straw coloured	2 - 5	8 - 12	10.5 - 15

C. tenella: Fruit linear, strongly curved upward (Fig. 1c), straw coloured, mature fruits 13.5 - 22 × 1.5 - 2.0 mm, winged, edge corky, slightly torulose, with 8 -12 constrictions on each side, subulate beak is 10.5 - 15 mm and elongated upwards. The pedicels of *C. tenella* are 2 - 5 mm. There are denser cuticl folds on epicarp cell. Fruit surface has glandular trichome which is the

capitate type and dense. Nonglandular trichomes are absent. Stomata $12.40 \pm 0.96 \times 7.87 \pm 1.12$ μm (Tables 1 - 2, Figs 2e, f).

Table 2. Micromorphological characters of fruits of *Chorispora* species.

Species	Cuticl folds in surface	Stomata (μm)		Trichome	
		Length	Width	Nonglandular	Glandula
<i>C. iberica</i>	Slight	15.10 ± 3.47	6.84 ± 1.44	$0.21 \pm 0.08/\text{rare}$	$0.16 \pm 0.03/\text{rare}$
<i>C. purpurascens</i>	Slight	15.70 ± 1.76	7.41 ± 1.03	$0.32 \pm 0.07/\text{dense}$	$0.06 \pm 0.01/\text{rare}$
<i>C. tenella</i>	Dense	12.40 ± 0.96	7.87 ± 1.12	-	$0.16 \pm 0.04/\text{dense}$



Fig. 1. Fruits of *Chorispora* species, a: *C. iberica*, b: *C. purpurascens* and c: *C. tenella*.

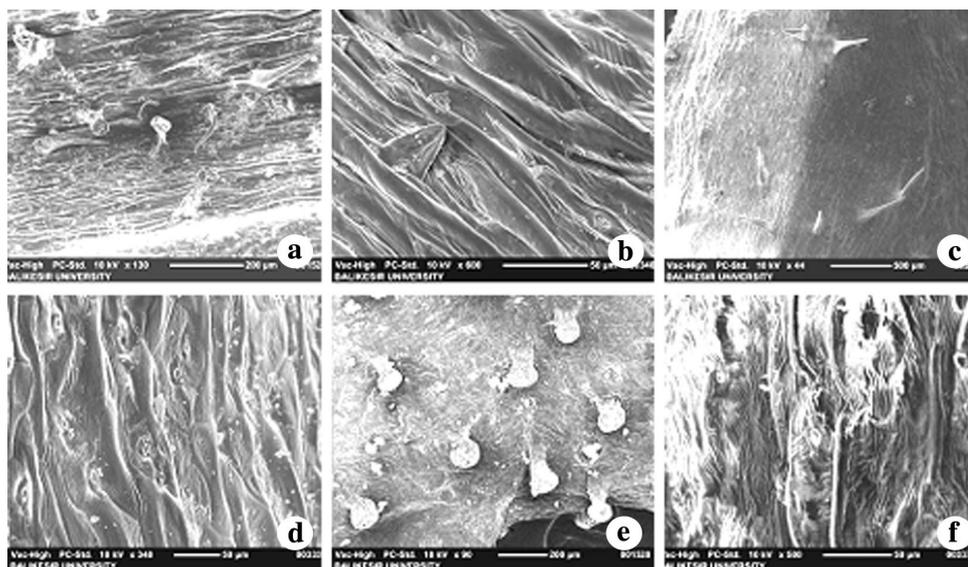


Fig. 2. Fruit surfaces of *Chorispora* species in SEM, a-b: *C. iberica*, c-d: *C. purpurascens* and e-f: *C. tenella*.

Seed characters: C. iberica: Seeds are brown in colour, oblong, narrowly oblong, $2.64 \pm 0.27 \times 1.10 \pm 0.10$ mm, winged at the apex and base. The surface pattern is irregular reticulate and epidermal cell shape isodiametric 5-6-gonal cells. The size of epidermal cells is $60.50 \pm 16.41 \times 26.25 \pm 3.79$ μ m (Table 3, Fig. 3a).

C. purpurascens: Seeds are dark brown in colour, subglobose, $1.86 \pm 0.51 \times 1.04 \pm 0.61$ mm, winged at the apex. The surface pattern is irregular reticulate and epidermal cell shape isodiametric 5-6-gonal cells. The size of epidermal cells is $39.36 \pm 6.21 \times 24.18 \pm 3.84$ μ m (Table 3, Fig. 3b).

C. tenella: Seeds are yellowish-brown in colour, oblong or broadly elliptic, $1.46 \pm 0.15 \times 0.84 \pm 0.11$ mm, winged at the apex. The surface pattern is irregular reticulate and epidermal cell shape narrowly 5-6-gonal cells. The size of epidermal cells is $42.30 \pm 8.57 \times 17.50 \pm 4.33$ μ m (Table 3, Fig. 3c).

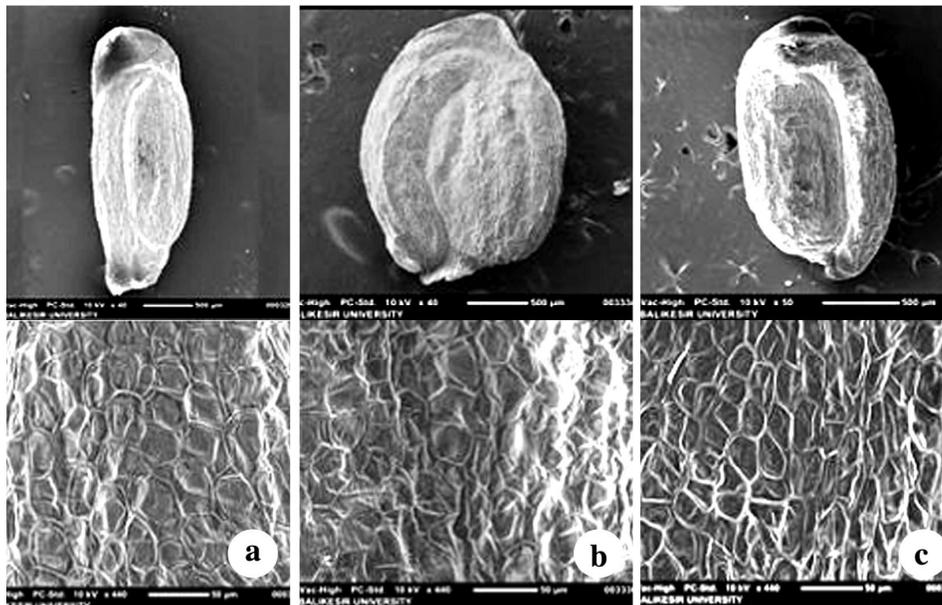


Fig. 3. Seed surfaces of *Chorispora* species. a: *C. iberica*, b: *C. purpurascens* and c: *C. tenella*

Pollen characters: Representative pollen grains are illustrated in Fig. 4, and the main palynological features of the species of *Chorispora* are summarized in Table 4. Pollen grains of the species are single, isopolar and tricolpate. The mean of polar axis and equatorial axis are 40.8 and 18.9 μ m in *C. iberica*, 36.8 and 18 μ m in *C. purpurascens* and 27 μ m and 13 μ m in *C. tenella*. The shape of pollen grains is prolate ($P/E = 2.07 - 2.18$ μ m). The colpi length and colpus width are 31.9 and 2.4 μ m in *C. iberica*, 33 and 2 μ m in *C. purpurascens* and 22 and 1 μ m in *C. tenella* (Table 4). Outline is elliptic in the equatorial view and triangular-circular in the polar view. Sculpturing of exine is distinguished reticulate with irregular polygonal lumina shape (Fig. 4). The colpi converge close to the polar ends. The lumina width is 0.5-2.7 μ m in *C. iberica*, 0.2 - 3 μ m in *C. purpurascens* and 0.3 - 1.8 μ m in *C. tenella*. The muri width is 0.4 - 0.7 μ m in *C. iberica* and *C. purpurascens*, 0.3 - 0.6 μ m in *C. tenella*. The surface of muri is smooth-undulate in all the species.

Table 3. Seed macro- and micromorphological characters of *Chorispora* species.

Species	Size (mm)	Color	Shape	Surface	Epidermal cell shape	Size of epidermal cells	
						Length (μm)	Width (μm)
<i>C. iberica</i>	2.64 \pm 0.27 \times 1.10 \pm 0.10	Brown	Oblong, narrowly oblong	Irregular Reticulate	Isodiametric 5-6 gonal cells	60.50 \pm 16.41	26.25 \pm 3.79
<i>C. purpurascens</i>	1.86 \pm 0.51 \times 1.04 \pm 0.61	Dark brown	Subglobose	Irregular Reticulate	Isodiametric 5-6 gonal cells	39.36 \pm 6.21	24.18 \pm 3.84
<i>C. tenella</i>	1.46 \pm 0.15 \times 0.84 \pm 0.11	Yellowish-brown	Oblong, broadly elliptic	Reticulate	Narrowly 5-6 gonal cells	42.30 \pm 8.57	17.50 \pm 4.33

Table 4. Pollen micromorphological characters of *Chorispora* species.

Species	Polar axis		Equatorial axis	P/E ratio (μm)	Shape	Sculpturing	Colpus (μm)		Lumina (μm)		Muri (μm)	
	Mean (range) μm	Mean (range) μm					Length	Width	Width	Width	Width	Width
<i>C. iberica</i>	40.8 (36.6-45)	18.9 (17.3-20.6)	2.15 (2-2.4)	Perprolate	Reticulate	31.9	2.4	0.5 - 2.7	0.4 - 0.7			
<i>C. purpurascens</i>	36.8 (33.6-40)	18 (16-20)	2.18 (1.87-2.5)	Perprolate	Reticulate	33	2	0.2 - 3	0.4 - 0.7			
<i>C. tenella</i>	27 (25-29)	13 (12-14)	2.07 (2.06-2.08)	Perprolate	Reticulate	22	1	0.3 - 1.8	0.3 - 0.6			

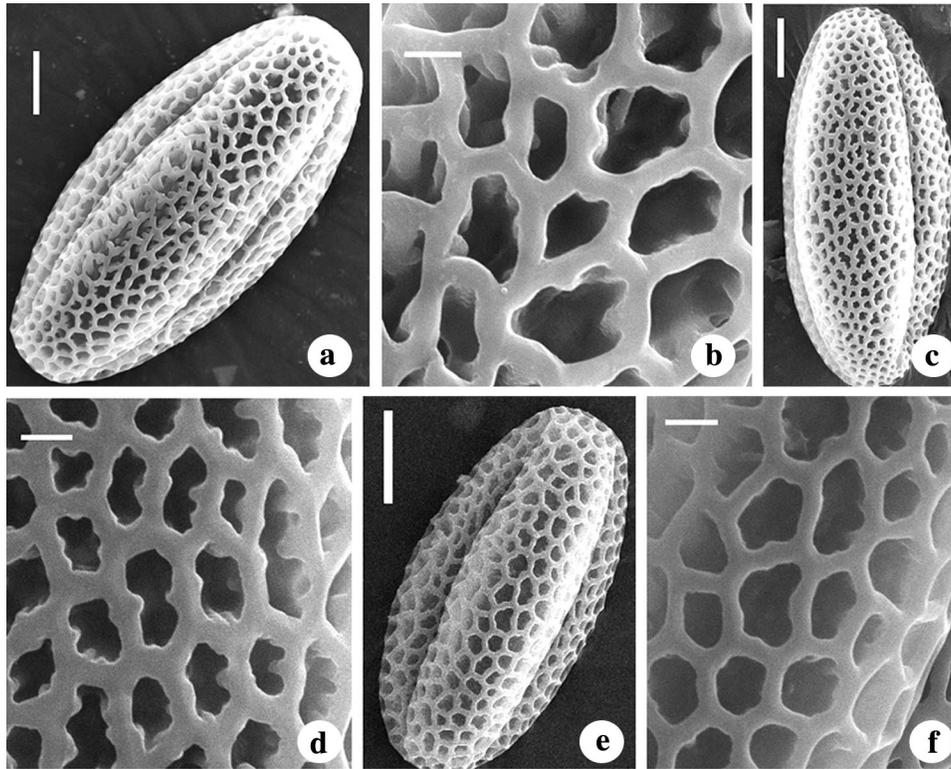


Fig. 4. Pollen grains of *Chorispora* species in SEM: a-b. *C. iberica*, c-d. *C. purpurascens* and e-f. *C. tenella*. Scale bar: a, c, e = 6 µm; b, d, f = 1 µm.

The fruit dimensions were found to be useful to separate among three species of *Chorispora*. The fruit lengths ranged from the shortest length, 13.5 - 22 mm in *C. tenella* to the tallest length, 40 - 45 mm in *C. purpurascens*. The lengths of fruits of *C. tenella* (25 - 30 mm) and *C. purpurascens* (40 - 60 mm) in Flora of Turkey are longer than the present findings. But, in *C. iberica* samples are longer (24 - 35 mm) than flora of Turkey (up to 30 mm) (Cullen 1965). Also the width of fruits varies in different values, the smallest width is 1.5 - 2 mm in *C. tenella* while the largest width was 3 - 4.5 mm in *C. iberica*. Fruit pedicel lengths also have systematic significance. The pedicels of *C. tenella* were the smallest (2 - 5 mm), while they were 4 - 7 mm in *C. iberica* and *C. purpurascens*. Also, the beak lengths in fruit have systematic significance. The beak of *C. purpurascens* is the longest (18 - 29 mm), and easily distinguished this species from the other taxa. It differs in loculus number in fruits of the studied species. The loculus number was 5 - 9 in *C. iberica*, 6 - 10 in *C. purpurascens*, 8 - 12 in *C. tenella*. The most useful fruit features for this study were surface structure of fruit as cuticl folds on the epicarp and the indumentum: There are more cuticl folds on epicarp cell of fruit in *C. tenella* than other two taxa. The presence or absence of trichomes and length of trichomes in fruits can be used in characterizing among species. While nonglandular trichomes on the fruit surface of *C. purpurascens* were longer and denser than *C. iberica*, they are absent in *C. tenella*. Glandular trichomes on the fruit surface of *C. purpurascens* were shorter than the other two species. Also, glandular trichomes in *C. tenella* were denser than the remaining species. The stomata had been observed on the fruit surfaces and they had the smallest size on fruit surface of *C. tenella* (Table 2).

There is no information about seeds of *Chorispora* species in Flora of Turkey. The seed shape as observed in the present study seems to be diagnostic at the generic level. The shape of seeds are oblong-narrowly to oblong in *C. iberica*, oblong-broadly to elliptic in *C. tenella* and subglobose in *C. purpurascens*. *Chorispora* species have wings in investigated seeds. While the seeds of *C. iberica* have wings at the apex (largely expanded) and base (small), the seeds of other species have only wings at the apex (small). The place of wings and presence or absence of wings is of diagnostic value in distinguishing between the *Chorispora* species. This observation is in agreement with the work of Kapil *et al.* (1980). Seed dimensions are different in the taxa of *Chorispora*. The seeds of *C. iberica* were the biggest. The seed size as a variable criterion is considered diagnostic to some extent (Aniszewski *et al.* 2001). The seed colour varied from dark brown to yellowish brown. The seed colour is also diagnostic at the generic and specific level for some extent. Surface topography of seeds and larger dispersal units can be in many cases of diagnostic significance (Brisson and Peterson 1976). In all the taxa, the seed surface was smooth. The seed-surface sculpturing pattern was reticulate type. The epidermal cells on seed surface showed odiametric or narrowly pentagonal or hexagonal shape. The results obtained in the present study are in conformity with the earlier data (Koul *et al.* 2000, Kaya *et al.* 2011, Moazzeni *et al.* 2007).

The most comprehensive studies of Brassicaceae pollen is that of Rollins and Banerjee (1979). They examined the pollen grains of 227 species in 132 genera representing subfamilial groupings of Brassicaceae and found that the most pollen type is tricolpate. Appel and Al-Shehbaz (2002) also reported tricolpate, reticulate pollen in the family Brassicaceae. The main characteristic features of pollen in the *Chorispora* species here are similar with those reported earlier for Brassicaceae. Conforming to results of previous studies pollen grains of all species studied here, are shed as monad, radially symmetrical and isopolar. Moreover, they often possessed a polar axis longer than the equatorial axis, showed the tricolpate aperture type, and had a reticulate exine sculpturing.

The most common shape is prolate, and this type is present in genera of Brassicaceae. The basic shape of the pollen grains in examined species was prolate (Table 4). These results are congruent with the results of Rollins and Banerjee (1979), Anchev and Deneva (1997).

The polar and equatorial axes, lumina and muri width among the species studied showed variation. Therefore, they provide useful criteria for separating the species. Also, according to Kaya *et al.* (2017), pollen features have little variations. However, fine details as polar-equatorial axis, colpus length and width, lumina and muri width are characteristic to distinguish *Malcolmia*, *Strigosella* and *Zuvanda* species.

Pollen grains of *C. tenella* are distinct by having the smallest polar and equatorial axes and narrower lumina width (0.3 - 1.8 μm) and easily distinguished from the remaining species (Table 4). Average colpus lengths ranged from 22 to 33 μm and width from 1 to 2.4 μm among all species examined. Pollen grains of *C. tenella* (22 μm) can be distinguished from the remaining species (31.9 - 33 μm), examined by their colpus length.

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