

Fruit and seed morphology of the *Fumaria* L. species (Papaveraceae) of Iran

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Abstract: The macro and micro fruit and seed morphology and surface ornamentations of 21 populations of 6 *Fumaria* L. species were investigated using stereomicroscope and scanning electron microscopy. These data are shown to support data from the general morphology. The results indicate that the fruit and seed characters of the genus *Fumaria* are valuable for taxonomic applications and are useful for classification. *F. officinalis* show a different shape in their fruit. The close relationships are observed for *F. parviflora* and *F. vaillantii*. *F. indica*, as a hybrid between *F. asepalata* and *F. parviflora*, shows intermediate micro-morphological features.

Key words: *Fumaria*, scanning electron microscopy, systematic, seed, fruit.

Introduction

The genus *Fumaria* L. (Papaveraceae) comprises 60 species, most of which grow around the Mediterranean region. In total, 8 *Fumaria* species have been reported from Iran. Wendelbo (1974) reported 7 species from the country and recently Lidén (2000) reported *F. officinalis* L. as a new species for the flora of Iran.

In the Lidén Monograph (Lidén 1986) the genus *Fumaria* has been divided into 2 sections; most of the species growing in Iran belong to the section *microsepala*. The identification of *Fumaria* species is difficult due to the variability present in their vegetative and reproductive features, possibly due to the occurrence of inter-specific hybridisation (Murphy, 2009).

Characteristics such as sepal size, upper petal shape, and dry fruit shape are important in

distinguishing these taxa. The best condition to identify a *Fumaria* species is to study fresh material, as many changes occur in the herbarium specimens during drying, and significant changes in flower colour occur after drying.

Fumitory species grow mainly in the temperate and cooler regions of the old world, often as weeds (Jafri, 1974). Many authors have considered the fruit and seed ornamentations as a useful tool for taxonomic considerations (Sheikh Akbari & Azizian, 2006; Kaya & Dirmenci, 2008; Pınar et al., 2009; Bayrakdar et al., 2010). The morphological characters of the seed and fruit have been considered an essential aid in the taxonomic treatment of Papveraceae (Lidén, 1986). Fruit surface, seed-coat development, and structure as well as seed anatomy are some of these informative characters. Fukuhara (1992) examined the development and structure of

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the seed-coats in 16 species of *Corydalis* and 2 species of *Dicentra*. Fukuhara (1995) studied the vascular patterns in the fruit of *Trigonocapnos* and *Discocapnos* (Papaveraceae-Fumarioideae). Seed-coat anatomy has been described in 122 species of Fumarioideae, which represent all the genera, subgenera, and most sections (Fukuhara & Lidén, 1995a; Fukuhara, 1995). Fukuhara and Lidén (1995b) studied the pericarp anatomy in Fumariaceae-Fumarioideae, while Fukuhara (1999) studied the seed morphology of Fumariaceae-Fumarioideae. However, similar studies have not been carried out on the *Fumaria* species of Iran. Therefore, the objective of this paper is to provide a detailed account of the macro and micro seed and fruit morphology in the *Fumaria* species of Iran and to determine the extent to which such data can be used in the taxonomy of the genus. This paper presents a detailed account of the seed and fruit morphology of 6 species of *Fumaria* collected from Iran for the first time.

Methods and materials

Plant materials

Twenty-one populations of 6 *Fumaria* growing in Iran, namely 1- *F. asepala* Boiss., 2- *F. densiflora* DC., 3- *F. indica* (Hauskn.) Pugsley, 4- *F. officinalis* L., 5- *F. parviflora* Lam. and 6- *F. vaillantii* Loisel. were studied. The details of the voucher specimens and their localities are given in Table 1. The voucher specimens are deposited at the Herbarium of Alzahra University. The specimens were collected from nature.

For numerical taxonomy analyses, 7 qualitative and quantitative seed and fruit characteristics were studied (Table 2).

Samples were studied by a Dino-Lite pro hand stereomicroscope at first. For SEM studies, the samples were suspended in a drop of water and directly transferred by fine pipette to a metallic stub using double-sided adhesive tape and coated with gold in a sputtering chamber (Sputter Coater BAL-TEC, SCDOOS). The coating was restricted to 100 Å. The SEM examination was carried out on a Philips XL30 microscope, and the measurements carried out were based on 10 to 20 readings from each specimen.

Statistical analysis

To reveal species relationships we used cluster analysis and principal coordinate analysis (PCO)

plotting. For multivariate analysis, the mean of the quantitative characters was used, while qualitative characters were coded as binary/multi-state characters. Standardised variables (mean = 0, variance = 1) were used in the statistical analysis. The average taxonomic distances and squared Euclidean distances were used as dissimilarity coefficients in the cluster analysis of morphological data. SPSS ver. 9 (1998) and NTSYS ver. 2.02 (1998) were used for statistical analysis. Cophenetic correlations were determined for the fit of the dendrograms obtained.

Results

Morphological observations

Our observations indicated that the general shape of the seed is somehow similar in different species of studied *Fumaria*. The seed is spherical to ellipsoid and has an apical pore and rib. The fruit is spherical to elliptic and is pointed in all studied *Fumaria* species except for *F. officinalis*, which has cordate fruits with emarginated tips.

The seed shape in *Fumaria* species is determined by the ratio of a seed's vertical diameter to a seed's horizontal diameter. Therefore, the seed shape was spherical in *F. asepala*, and *F. vaillantii*, elliptical in *F. parviflora* and *F. densiflora*, and elliptic-lanceolate in *F. officinalis*. The maximum vertical diameter and apical pore depth is seen in *F. officinalis* (509.74 and 282.91 Mm). The minimum values of the same parameters were observed in *F. asepala* (237.79 and 133.9 Mm).

Seed color is a diagnostic character in *Fumaria* species as well. The seed color is grey to gold in *F. asepala*, brown in *F. densiflora*, green to gold with red spots and dots in *F. officinalis*, green in *F. parviflora*, and green with red stripes in *F. vaillantii* (Figure 1).

Seed surface ornamentations are of diagnostic value in the *Fumaria* species of Iran. *F. asepala* show scaly-form ornamentation with round borders, while scaly-form right angled ornamentations with gland appendage are observed in *F. densiflora*. The seed surface shows scaly-form ornamentations on a wrinkled substrate in *F. officinalis*, but the wrinkled substrate is somehow different in *F. parviflora* populations. The seed surface in *F. indica* is smooth or plicate. The Yazd and Fassa populations

Table 1. Voucher details of *Fumaria* sampled in this study.

Vouchers	Species
Mazandaran, Gadook, <i>Keshavarzi</i> , 8612 (Herb. of Alzahra Univ.)	<i>Fumaria vaillantii</i>
Mazandaran, on the road of Karaj to Chalous, Pole Zanguleh, 2400 m, <i>Ebrahimzadeh</i> 8613 (Herb. of Alzahra Univ.)	<i>F. vaillantii</i>
Tehran, Jajrood, <i>Ebrahimzadeh</i> 8614 (Herb. of Alzahra Univ.)	<i>F. vaillantii</i>
Tehran, Baraghan, <i>Keshavarzi</i> 8620 (Herb. of Alzahra Univ.)	<i>F. vaillantii</i>
Tehran, Moderiat, <i>Ebrahimzadeh</i> 8626 (Herb. of Alzahra Univ.)	<i>F. vaillantii</i>
Hamedan, Heidareh, <i>Keshavarzi</i> 8628 (Herb. of Alzahra Univ.)	<i>F. vaillantii</i>
Tehran, Abali, Mobarak abad, <i>Nataj</i> 8639 (Herb. of Alzahra Univ.)	<i>F. parviflora</i>
Golestan, Golestan park, <i>Ebrahimzadeh</i> 8641 (Herb. of Alzahra Univ.)	<i>F. parviflora</i>
Lorestan, Dasht Chegene, <i>Derekvandi</i> 8642 (Herb. of Alzahra Univ.)	<i>F. parviflora</i>
Lorestan, Garesan, <i>Derekvandi</i> 8643 (Herb. of Alzahra Univ.)	<i>F. parviflora</i>
Fars, Fassa, <i>Rastipisheh</i> 8646 (Herb. of Alzahra Univ.)	<i>F. parviflora</i>
Yazd, Yazd, <i>Keshavarzi</i> 8647 (Herb. of Alzahra Univ.)	<i>F. parviflora</i>
Yazd, Taft, <i>Keshavarzi</i> 8648 (Herb. of Alzahra Univ.)	<i>F. parviflora</i>
Kermanshah, Ostandari park, <i>Gholame</i> 8649 (Herb. of Alzahra Univ.)	<i>F. parviflora</i>
Tehran, Cheitgar park, <i>Ebrahimzadeh</i> 8635 (Herb. of Alzahra Univ.)	<i>F. indica</i>
Charmahal Bakhtiyari, Borojen, <i>Yazdanbakhsh</i> 8652 (Herb. of Alzahra Univ.)	<i>F. asepala</i>
Fars, Kakan, <i>Yazdanbakhsh</i> 8654 (Herb. of Alzahra Univ.)	<i>F. asepala</i>
Tehran, Taleghan, <i>Falatory</i> 8657 (Herb. of Alzahra Univ.)	<i>F. asepala</i>
Mazandaran, Kelardasht, <i>Ebrahimzadeh</i> 8659 (Herb. of Alzahra Univ.)	<i>F. densiflora</i>
Mazandaran, Namakabrood, <i>Ebrahimzadeh</i> 8660 (Herb. of Alzahra Univ.)	<i>F. densiflora</i>
Mazandaran, Galoogah, <i>Nataj</i> 8661 (Herb. of Alzahra Univ.)	<i>F. officinalis</i>

Table 2. Morphological characters

Depth of seed apical gap (mm)
Ratio of first diameter to second diameter of seed
Ratio of first diameter to second diameter of seed apical gap
Seed color: green with red lines = 1, green = 2, ochre-golden = 3, brown = 4, golden green with red spots = 5
Seed shape: spheroid = 1, ellipsoid = 2, elongated ellipsoid = 3
Seed surface ornamentation pattern: scale form = 1, semi smooth and undulating = 2, low walled scales = 3, round angled scales = 4, right angled scales with tuberosus extensions = 5, scales on a wrinkled substrate = 6
Fruit surface ornamentation pattern: highly crowded protruding with velutinus appearance = 1, wrinkled with prickle base = 2, crowded wrinkle with prickle base = 3, wrinkled granular = 4, fossulate = 5, crowded wrinkled = 6

of *F. parviflora* show dense and compact forms. *F. vaillantii* also shows scaly form ornamentations that are similar somehow to *F. officinalis* ornamentations (Figure 1).

Fruit surface ornamentations are useful in species identification in the *Fumaria* populations of Iran. *F. asepala* show a wrinkled surface with

compact ornamentations. *F. densiflora* has a granular and wrinkled fruit surface. The fruit surface ornamentations in *F. officinalis* show fossulate patterns with deep gaps (Figure 2).

The fruit surface in 3 different populations of *F. parviflora* show wrinkled patterns with prickle shapes. *F. indica* shows the same pattern, which is

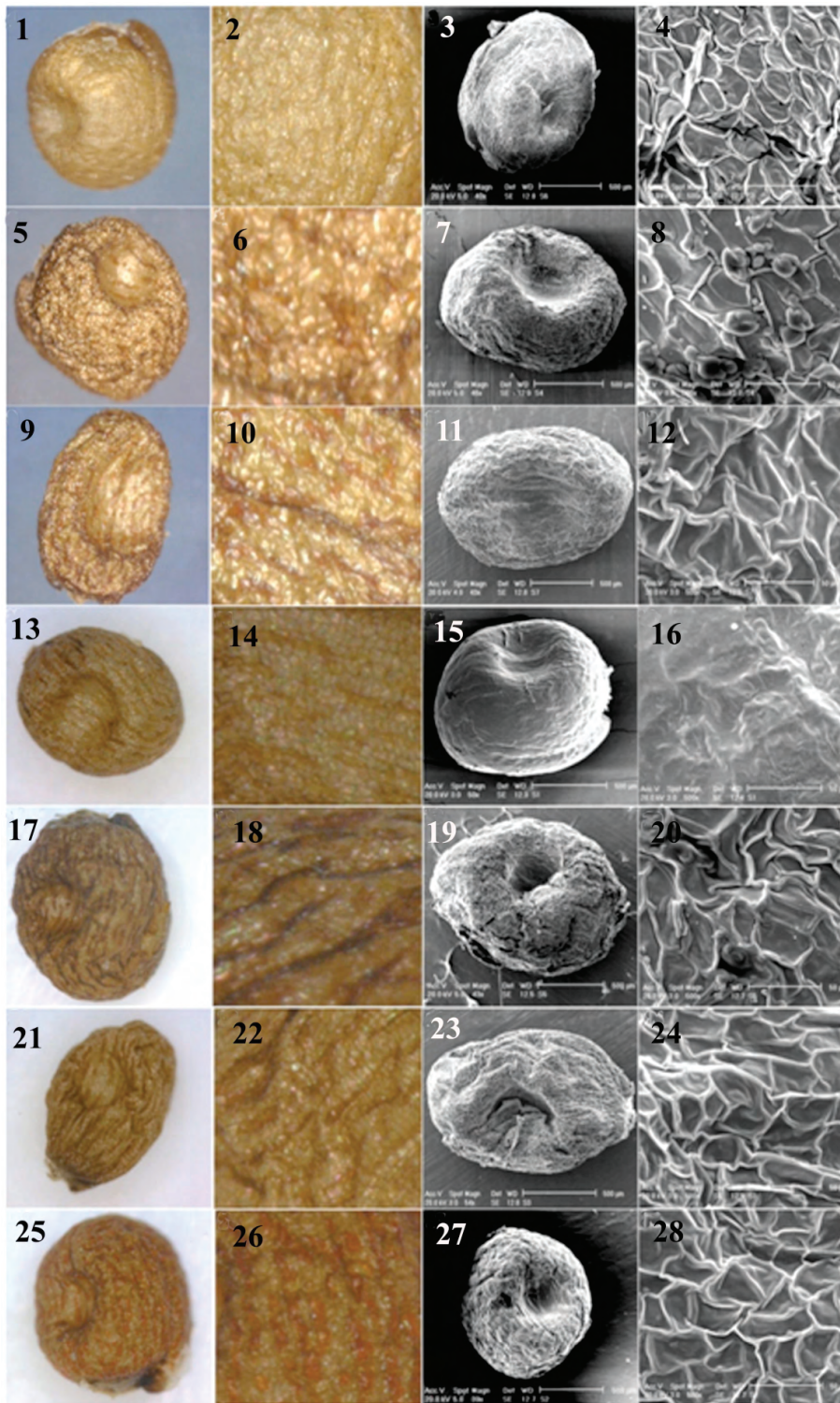


Figure 1. Stereomicroscope and scanning electron micrographs of *Fumaria* species seeds. 1 and 4- *F. asepala*, 5 and 8- *F. densiflora*, 9 and 12- *F. officinallis*, 13 and 16- Cheitgar population (*F. indica*), 17 and 20- Yazd population (*F. parviflora*), 21 and 24- Fassa population (*F. parviflora*), 25 and 28- *F. vaillantii*. Magnification of 1st column from left 170 \times and the 2nd column 230 \times .

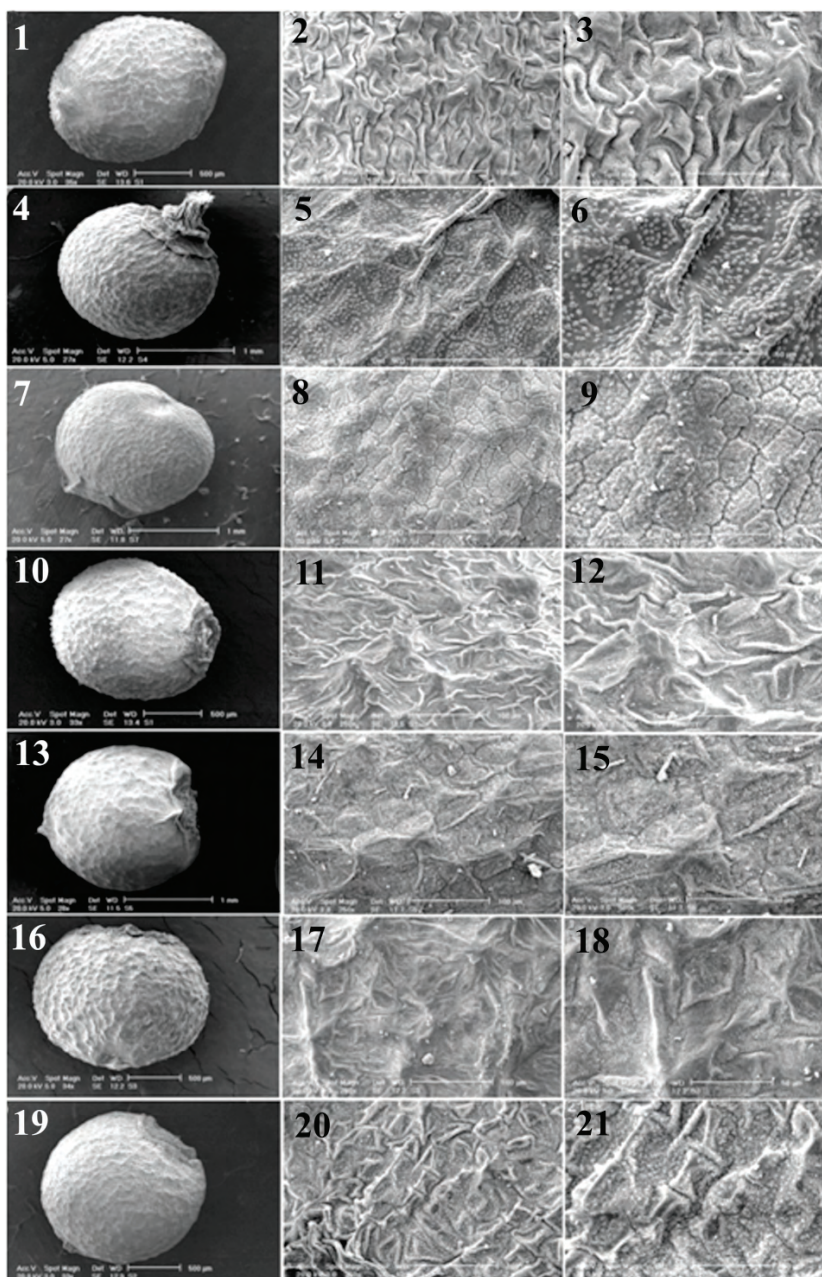


Figure 2. Scanning electron micrographs of *Fumaria* species fruit. 1 and 3- *F. asepala*, 4 and 6- *F. densiflora*, 7 and 9- *F. officinalis*, 10 and 12- Cheitgar population (*F. indica*), 13 and 15- Yazd population (*F. parviflora*), 16 and 18- Fassa population (*F. parviflora*), 19 and 21- *F. vaillantii*.

somehow more compact. *F. vaillantii* has a scabrate and wrinkled fruit surface. In this species, its ornamentalations with 500 magnification show a velvet texture on the fruit surface (Figure 2).

Results of statistical analysis

Statistical analysis by cluster analysis method (UPGMA) based on 7 qualitative and quantitative micro-morphological characters of the fruit and seed

surface (Figure 3) revealed the presence of 3 major clusters. *F. asepala* stands separate from the other species in the first cluster, while *F. densiflora* and *F. officinalis* comprise the second major cluster. The other species studied show similarity and form the third major cluster. *F. parviflora* takes an intermediate position between the members of second and third major clusters. In general, the closer affinity between *F. densiflora* and *F. officinalis* as well as *F. vaillantii* and *F. parviflora* is concordant with their general morphology. PCO plotting based on fruit and seed micro-morphological characters (Figure 4) also supports this clustering result.

Discussion

Our results support the taxonomic treatment of the genus in the *Flora Iranica* as species of *F. parviflora*, *F. indica*, and *F. vaillantii* have been considered close to each other and *F. asepala* and *F. densiflora* provide a separate position. *F. officinalis* is not mentioned in the *Flora Iranica*, and so our results about the position of this species cannot be evaluated with this reference.

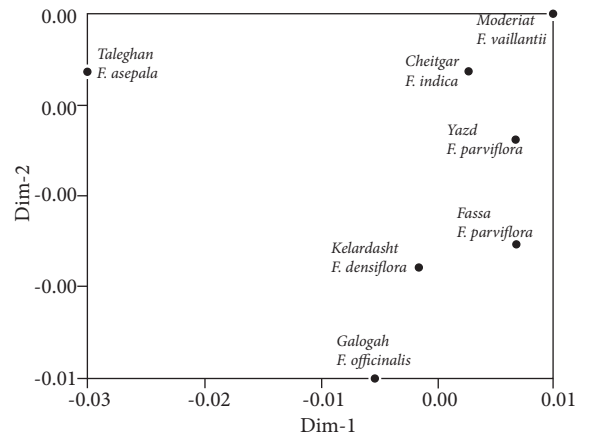


Figure 4. PCO ordination of the *Fumaria* species based on seed and fruit morphology.

The Cheitgar population of *F. indica* shows some differences in its seed and fruit surface with the other populations. Although there are a lot of similarities between these 2 taxa (*F. indica* and *F. parviflora*), it appears that seed and fruit surface ornamentation is a very useful tool in species separation. Jafri (1974) in the *Flora of Pakistan* mentioned that *F. indica* should be considered as a hybrid between *F. asepala*

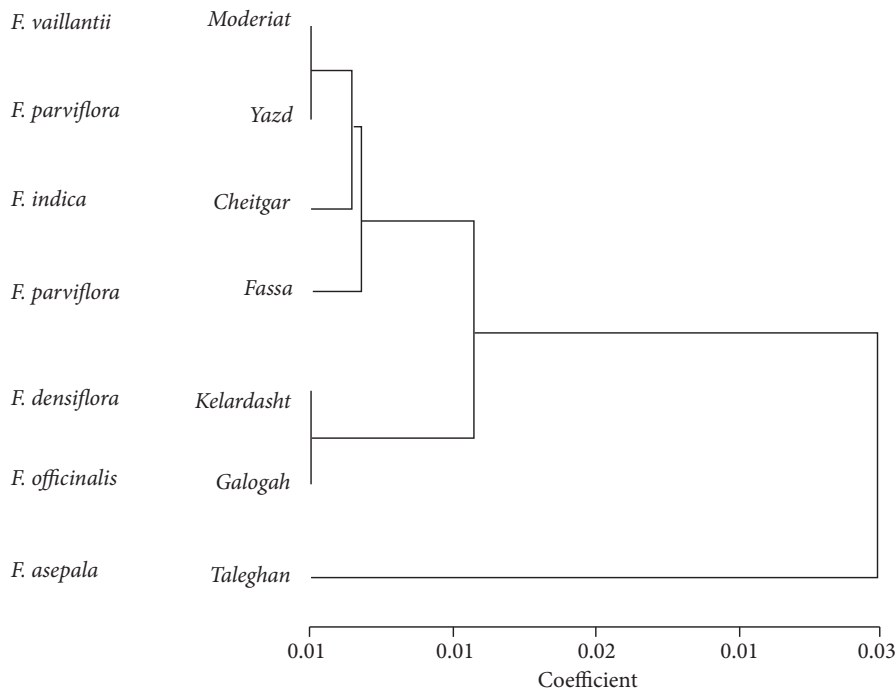


Figure 3. UPGMA dendrogram based on the seed and fruit morphology of *Fumaria* species.

and *F. parviflora*. It is morphologically very similar to *F. parviflora* (Wendelbo, 1974). Our previous palynological and morphological studies confirmed the separate position of the Cheitgar population as *F.*

indica. Due to the micro-morphological differences between the fruit and seeds of *F. parviflora* accessions in Iran, it seems that there are some subspecies in *F. parviflora*.

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