

## FRUIT AND SEED MORPHOLOGY IN IRANIAN SPECIES OF *FRITILLARIA* SUBGENUS *FRITILLARIA* (*LILIACEAE*)

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### Abstract

Fruits and seeds of all Iranian taxa of *Fritillaria* subgenus *Fritillaria* were investigated by scanning electron and light microscopy. The fruit in *Fritillaria* is a three-valved loculicidal capsule, longitudinal dehiscence occurs down the centre of the outer walls of the three compartments or loculi. The capsule is wingless and the seeds are numerous in each capsule, flattened and  $\pm$  membranously-margined. They are often broadly ovate in outline. The testa cells have irregular shape with undulate margins.

### Introduction

The present paper is concerned with the documentation, of the fruit and seed morphology in Iranian species of *Fritillaria* subgenus *Fritillaria* by scanning electron microscopy (SEM) and light microscopy (LM). The genus *Fritillaria* s. lat. belongs to the tribe *Tulipeae* of the *Liliaceae*. It was established by Linnaeus (1753) and includes c. 100 species growing in temperate regions of the northern hemisphere (Stern, 1937; Turrill & Sealy, 1980; Corneae & Popescu, 1981; Rix, 1986; Zaharof, 1988; Basak 1991; Kamari, 1991), but is absent from eastern North America. According to Rix (1977), Iran is the centre of diversity of this genus above the species level, although it is relatively poor in species. Sixteen species of *Fritillaria* have been recorded from the country, two of which were recently described, *F. atrolineata* and *F. chlororhabdota* (Bakhshi Khaniki, 1997a, 1997b). Rix (1997) and Rechinger (1990) have placed all Iranian species in four subgenera: *Petilium*, *Rhinopetalum*, *Theresia* and *Fritillaria*, of which, subgenus *Rhinopetalum*, is mostly accepted as distinct genus under the same name (cf. Losina-Losinskaya 1935, Bakhshi Khaniki & Persson 1997). So far, on a comparative basis, relatively little work, and with respect to SEM studies none, has been done on fruits and seeds of this subgenus.

The present investigation was designed to give an overview of the variation of fruit seed in the genera, and also to examine whether fruit and seed features show any correlation with the latest classification of the genera and subgenera.

### Material and Methods

The material for this study was collected from Iran or obtained from cultivated plants in Göteborg Botanical Garden, Sweden (Table 1). Shape and size of the seeds and fruits were studied on fresh material by light microscope. Seeds were also fixed in FAA (5 vol. Formalin 40%; 5 vol. Acetic acid, glacial; 90 vol. Ethanol 50%) in the greenhouse. For SEM studies mature and well developed seeds were separated from the fruit and transferred to 70% alcohol for 2 days. After this, material was kept in 70% acetone and then dehydrated in a graded acetone series (90%, 95%; 15 min each) and

further dehydrated twice in 100% acetone (20 min each). The material was subjected to critical-point drying (BALZERS CPD 030) with liquid CO<sub>2</sub> as a transitional fluid and thereafter coated with gold (50 nm thick, BALZERS UNION 010). The material was studied using a Zeiss scanning electron microscope (SEM, ZEISS DSM 940).

**Table 1. Original source of material studied of *Fritillaria* subgenus *Fritillaria* (GBK= G. Bakhshi Khaniki).**

Taxa	Locality
<i>F. crassifolia</i> ssp. <i>kurdica</i>	Iran: Salmas, Ghooschi pass. 1900 m, GBK 67
<i>F. reuteri</i>	Iran: W. Azarbaijan, Urmiah, Kuh-e Sir, 2100 m, GBK 94
<i>F. straussii</i>	Iran: Kermanshah, Ghallajeh pass, 1700 m, GBK 51
<i>F. kotschyana</i> ssp. <i>kotschyana</i>	Iran: Tehran, Shemshak, Elborz mtns., 2800 m, GBK 98
<i>F. olivieri</i>	Iran: Hamadan, Kuh-e Elvand, 2500 m, GBK 60
<i>F. caucasica</i>	Iran: E. Azarbaijan, Tabriz to Ahar. 1800 m, GBK 70
<i>F. uva-vulpis</i> *	Iraq: Rowandooz, Haji Omran, TUBERGEN
<i>F. zagrica</i>	Iran: Arak, Soltanabad village, 1700-1900 m, GBK 33
<i>F. chlorantha</i>	Iran: Khoramabad, Oshtoran Kuh, 2400 m, GBK 88
<b><i>F. assyriaca</i>*</b>	Turkey: Agri, Tahir Da. pass, SØNDERHOUSEN 1106
<i>F. atrolineata</i>	Iran: W. Azarbaijan, Urmiah, Ghasemlu, 1500 m, GBK 63
<i>F. chlororhabdota</i>	Iran: W. Azarbaijan, Urmiah, Sir mtns., 1800 m, GBK 65

\*Material collected from cultivated plants in Göteborg Botanical Garden, Sweden.

## Results

The results of the studies on morphological features of the fruits and seeds are presented in Table 2. The fruit is a three-valved loculicidal capsule, that is longitudinal dehiscence occurs down the centre of the outer walls of the three compartments or loculi. The general shape of the capsule and the acute or obtuse, rounded or even slightly winged angles of the mature fruit are of taxonomic importance.

The seeds are numerous in each capsule, flattened and  $\pm$  membranously-margined. Generally, the shape of seeds are often ovoid to subglobose, and obtuse in borderlines. There are some differences in shape and size of testa cells among different species, but these differences do not seem to be taxonomically very important.

**The genus *Fritillaria* L.:** This genus is characterized by having actinomorphic flowers; nectary often flattish, usually linear to lanceolate or ovate; and pollen sculpture foveolate to reticulate.

***Fritillaria* subgen. *Fritillaria*:** As in other subgenera, except *Theresia*, in subgenus *Fritillaria* the bulb usually consists of 2, sometimes 3 or 4, fleshy, subglobose scales  $\pm$  tunicated by the marcescent remains of the scales of previous years. The stem bears 1, sometimes 2 or 3 flowers, rarely more (e.g., up to 8 flowers in *F. camschatcensis* and *F. olgae* and to 12 in *F. pluriflora*). This subgenus is morphologically classified into six complexes: the *F. crassifolia*, *F. kotschyana*, *F. graeca*, *F. meleagris*, *F. cirrhosa* and *F. caucasica* groups (Rix 1975, 1977, 1984, Rechinger 1990), three of which were studied here.

Table 2. Morphological features of the fruit and seed in taxa studied of *Fritillaria* subgenus *Fritillaria*.

Group	Taxon	Fruit			Seed		
		Shape	Size (cm)	Wing	Shape	Size (mm)	
A	<i>F. imperialis</i>	oblong to cylinder	2-3.5 (-4.5)	+	ovate-oblong	7-11 x 5.5-8	
A	<i>F. raddiana</i>	hexagonal-cylinder	2-3	+	ovate	11-14	
B	<i>F. persica</i>	obconical	1-3 x 1.2-2.5	+	broadly ovate.	5-6	
C	<i>F. crassifolia</i> ssp. <i>kurdica</i>	cylindrical	4-4.5	-	broadly ovate	5.5-6	
C	<i>F. reuteri</i>	cylindrical	4-5	-	broadly ovate	7-8	
C	<i>F. siraussii</i>	cylindrical	3-4.5 x 2.5	-	ovate	8.5-9 x 6	
C	<i>F. kotschyana</i> ssp. <i>kotschyana</i>	ovoid-cylindrical	1.6-2.2	-	ovoid-elliptic	6.5 x 5-5.5	
C	<i>F. olivieri</i>	cylindrical	4	-	broadly ovate	6-6.5 x 4.5	
C	<i>F. caucasica</i>	obovate	4-6	-	broadly ovate	5-6 x 4.5-5	
C	<i>F. uva-vulpis</i>	cylindrical	3.5 x 1-1.5	-	broadly ovate	5 x 4	
C	<i>F. chlorantha</i>	cylindrical	3.5 x 1-1.5	-	broadly ovate	5 x 4.5	
C	<i>F. zagrica</i>	cylindrical	3-4 (-5)	-	broadly ovate	8 x 6.5	
C	<i>F. assyriaca</i>	cylindrical	2-3	-	ovate and	6 x 4.5	
C	<i>F. atrolineata</i>	obovoid	2.5-3 x 1.5	-	ovate	4-5	
C	<i>F. chlororhabdota</i>	obovoid	2.5-3.5 x 1.5-2	-	ovate	3.5-5	

***Fritillaria crassifolia* group:** This complex is distinguished by having usually broadly campanulate flowers (narrowly campanulate in *F. poluninii*), generally nodding at maturity, and linear nectaries, half or more than half as long as the perianth segments and placed at 3–5 mm above their base. The nectaries are usually black-purplish at base, continuing and tapering toward the tepal apex by a narrow zone divided longitudinally by a channel. The basal part of the nectaries is apparently more active in nectar sugar secretion because that is usually filled with a watery fluid which seems to trickle along the median furrow i.e., downwards in the hanging flowers.

In *F. crassifolia* ssp. *kurdica* (Boiss. & Noë) Rix, the capsule is 4–4.5 cm long, obovoid, narrowly tapering at base, truncate at apex, and not winged. The seeds are 5.5–6 mm and ovate in outline. The testa cells have irregular shape with undulate margins (Fig. 1 a-b).

In the Iranian species *F. reuteri* Boiss., the capsule is 3.5–4.5 cm long, obovoid, tapering toward the base, and not winged. The seeds are 7–8 mm long and ovate in outline. The testa cells have irregular shape with undulate margins (Fig. 1c-d).

In *F. straussii*, known from N. W. Iran and S. E. Turkey, the capsule is 3–4.5 x 2.5 cm, obovoid, narrowly tapering toward the base and not winged. The seeds 8.5–9 x 6 mm, and ovate in outline. The testa cells have irregular shape with undulate margins (Fig. 1e-f).

***Fritillaria kotschyana* group:** This complex is characterised by having nodding, broadly campanulate flowers and lanceolate to ovate nectaries, less than half as long as the limb of the perianth segments, and located at the inflection of the bell (about 4–7 mm above the base of the tepals).

*F. kotschyana* Herbert ssp. *kotschyana*, which is endemic to Iran, has capsule with 16–22 mm long, obovoid, narrowly tapering toward the base and not winged. The seeds are 6.5 x 5–5.5 mm and ovate in outline. The testa cells have irregular shape with undulate margins (Fig. 2a-b).

In *F. olivieri* Boiss., an endemic species to Iran, the capsule is 4 cm long, obovoid, narrowly tapering toward the base and wingless. The seeds are 6–6.5 x 4.5 mm and ovate in outline. The testa cells have irregular shape with undulate margins (Fig. 2c-d).

***Fritillaria caucasica* group:** This group is morphologically characterised by species which have comparatively small and narrowly campanulate flowers, the nectaries are usually placed at the base or 0.5–1 (–2) mm above the base of the perianth segments.

In *F. caucasica* Adams, the capsule is 4–6 cm, obovoid, tapering toward the base and wingless. The seeds are 5–6 x 4.5–5 and ovate in outline. The testa cells have irregular shape with undulate margins (Fig. 2e-f).

*F. uva-vulpis* Rix is morphologically distinct. For a species in this group, its flowers are unusually rounded. The capsule is 3.5 x 1–1.5 cm, obovoid, narrowly tapering toward the base, truncate at apex and wingless. The seeds are 5 x 4.5 mm and ovate in outline. The testa cells have irregular shape with undulate margins, wingless (Fig. 3a-b). The seeds are 5 x 4 mm, and ovate in outline (Fig. 3b).

In *F. chlorantha* Hausskn. & Bornm., a species endemic to Iran, the capsule is 3.5–5 cm long, cylindrical, and wingless. The seeds are 5.5–6.5 x 5–6 mm, ovate to subcircular in outline. The testa cells have irregular shape with undulate margins (Fig. 3c-d).

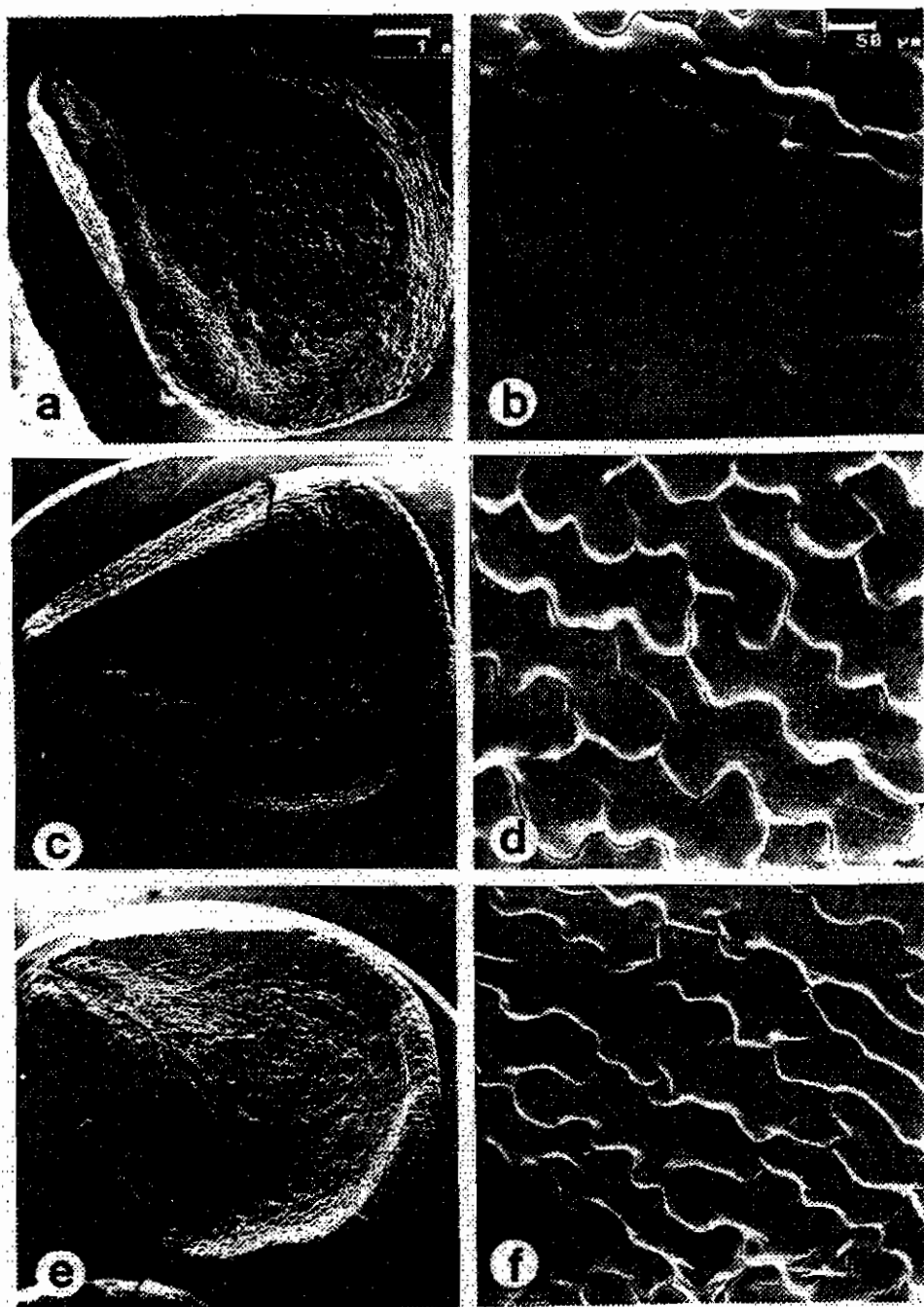


Fig. 1. (a-b) *F. crassifolia* ssp. *kurdica*. (a) seed; (b) testa cells. - (c-d) *F. reuteri*. (c) seed; (d) testa cells. - (e-f) *F. straussii*. (e) seed; (f) testa cells.  
Scales: a, c, e, 1 mm; b, d, f, 50 μm.

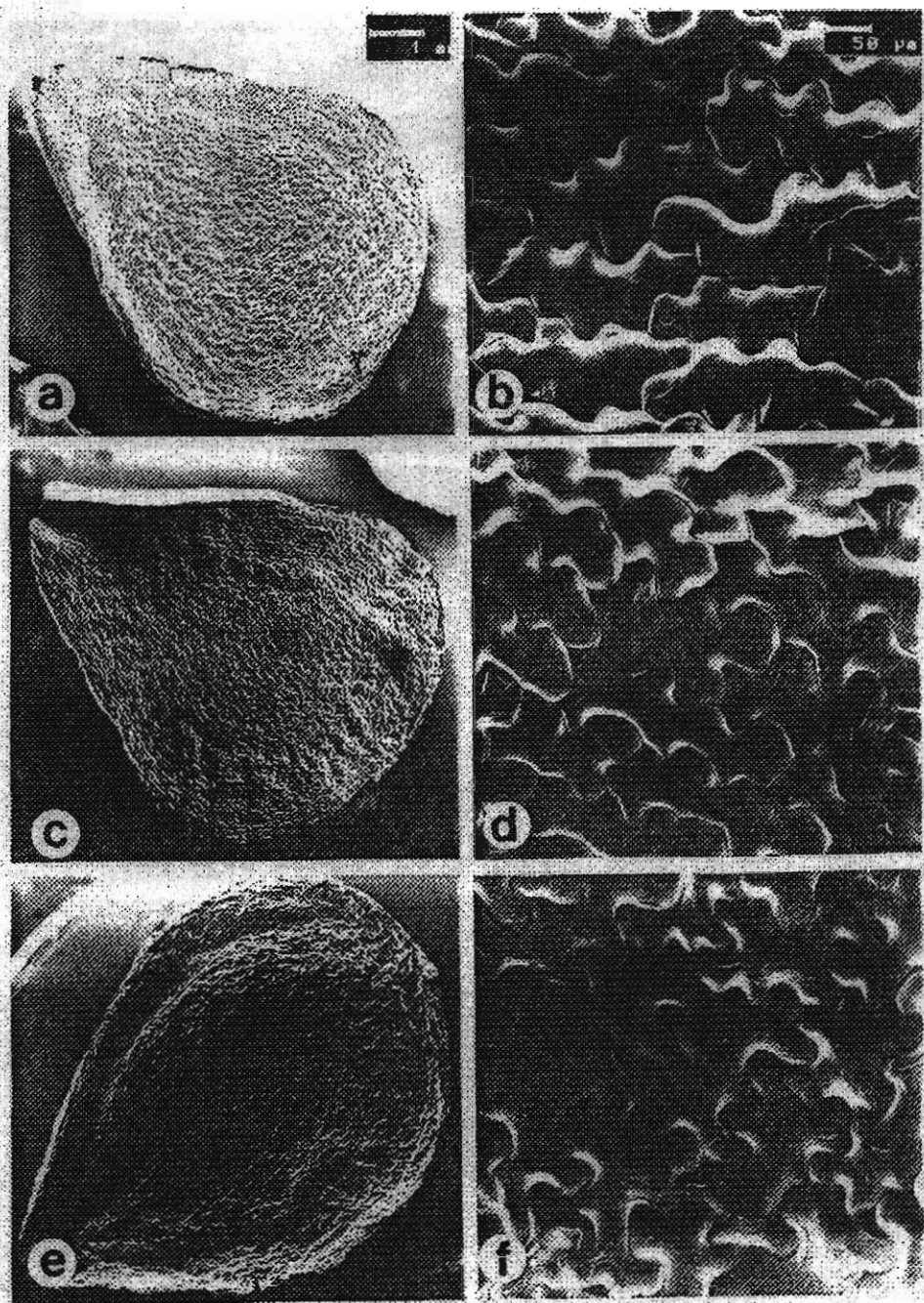


Fig. 2. (a-b) *F. kotschyana ssp. kotschyana*. (a) seed; (b) testa cells. - (c-d) *F. olivieri*. (c) seed; (d) testa cells. - (e-f) *F. caucasica*. (e) seed; (f) testa cells.  
Scales: a, c, e, 1 mm; b, d, f, 50 μm.

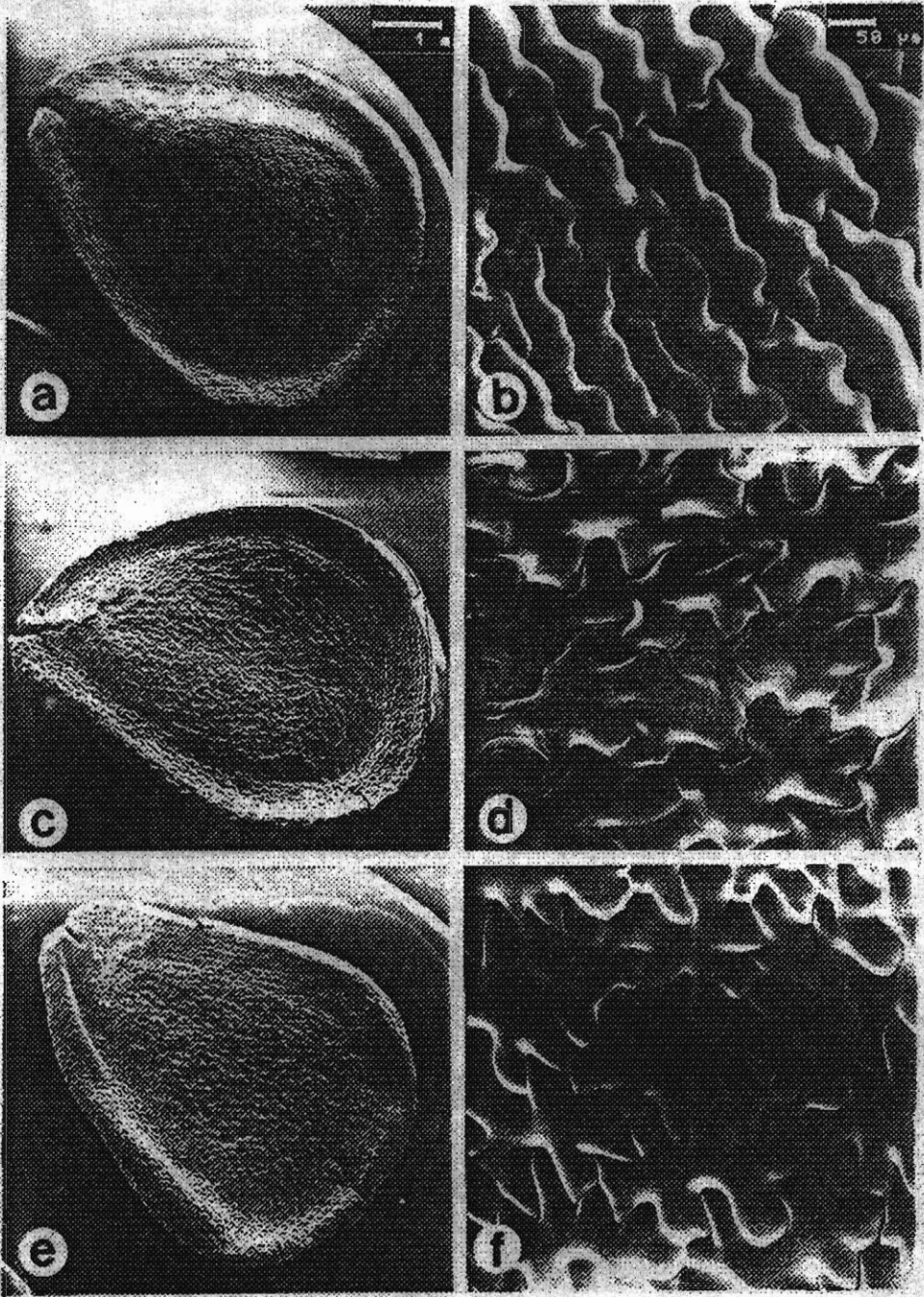


Fig. 3. (a-b) *F. uva-vulpis*. (a) seed; (b) testa cells. - (c-d) *F. chlorantha*. (c) seed; (d) testa cells. - (e-f) *F. zagrica*. (e) seed; (d) testa cells. Scales: a, c, e, 1 mm; b, d, f, 50 μm.

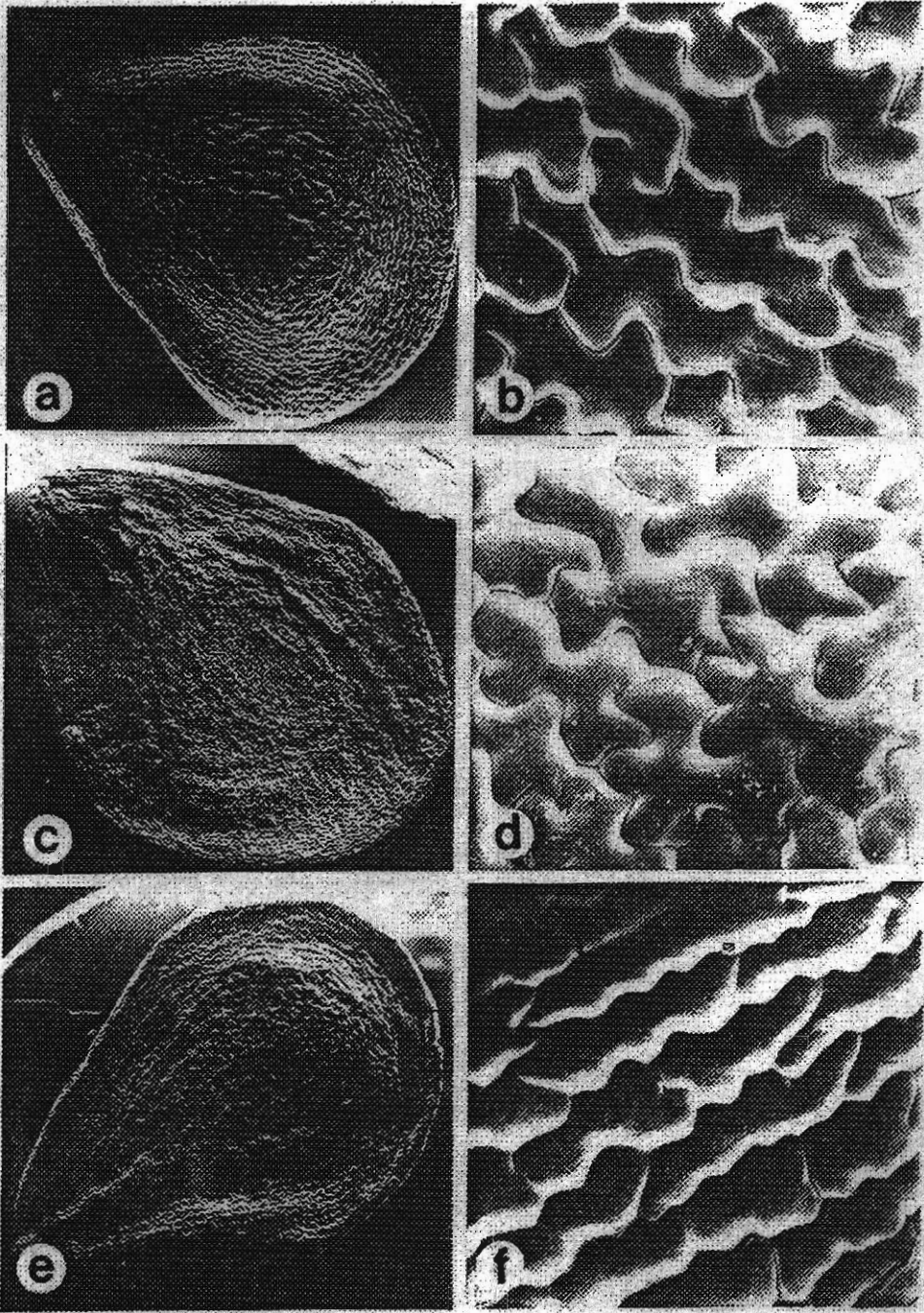


Fig. 4. (a-b) *F. assyriaca*. (a) seed; (b) testa cells. - (c-d) *F. atrolineata*. (c) seed; (d) testa cells. - (e-f) *F. chlororhabdota*. (e) seed; (f) testa cells. Scales: a, c, e, 1 mm; b, d, f, 50  $\mu$ m.



*F. zagrica* Stapf is also an Iranian endemic. The capsule is 3–4 (–5) mm long, obovoid, cylindrical, and wingless. The seeds are 8 x 6.5 mm and ovate in outline. The testa cells have irregular shape with undulate margins (Fig. 3e-f).

*F. atrolineata* Bakhshi Khaniki has been recently recorded by Bakhshi Khaniki (1997a). The capsule is 2.5–3 x 1.5 cm, obovoid, tapering toward the base, obtuse and not winged. The seeds are flat, ovate in outline and 4–5 mm long (Fig. 4c). The testa cells have irregular shape with undulate margins. The testa cells have irregular shape with undulate margins (Fig. 4d).

*F. chlororhabdota* Bakhshi Khaniki is recorded from Iran as new to science (Bakhshi Khaniki, 1997b). The capsule is 2.5–3.5 x 1.5–2 cm, obovoid, obtuse, tapering toward the base, and wingless. The seeds are 3.5–5 mm long and ovate in outline. The testa cells have irregular shape with undulate margins (Fig. 4e-f).

### Discussion

The seeds are numerous in each capsule, flattened and ± membranously-margined. Generally, the shape of seeds are often ovoid to subglobose, and obtuse in border lines. There are some differences in shape and size of testa cells among different species, but these differences are not significance and do not seem to be taxonomically very important. The fruit in *Fritillaria* is a three-valved loculicidal capsule, that is longitudinal dehiscence occurs down the centre of the outer walls of the three compartments or loculi. The general shape of the capsule and the acute or obtuse, rounded or even slightly winged angles of the mature fruit are of taxonomic importance. On general taxonomic criteria, and based on the fruit features obtained from the present investigation, the species of *Fritillaria* examined here can be put in 3 groups (A, B, C, see Table 2) which is equal to three subgenera of *Fritillaria*.

**Group A:** Table 2 contains species with capsules with 3–5 mm wide wings. This characters is found in *F. imperialis* and *F. raddeana*, both assigned to subgenus *Petilium* (Rix, 1977; Rechinger, 1990; Bakhshi Khaniki, 1998).

**Group B:** Table 2 contains species morphologically characterised by one-scaled bulbs, small, narrowly campanulate flowers arranged in ebracteate, many-flowered racemes. Similar with group A, the capsule is winged in group B but it has only 1.5–2 mm wide. These features comply with subgenus *Theresia*, which may be restricted to *F. persica*, a very variable species, especially in flower colour which partly affects nectary colour (Bakhshi Khaniki, 1998).

**Group C:** Table 2 contains species equivalent to subgenus *Fritillaria*, having broadly to narrowly campanulate flowers, linear, lanceolate or ovate nectaries, usually green, black or purplish, and placed from 0.5–1 to 3–7 mm above the base of the perianth segments. This group can be divided into four subgroups in SW Asia. The capsule is wingless in all species belong to this subgenus and this character is taxonomically useless for distributing the species into different formal groups of subgenus *Fritillaria*.

The present investigation proved that fruit morphology, particularly presence or absence of wing, is an important and useful character in deducing relationships between *Fritillaria* species only at subgeneric levels. The dispersion and arrangement of

examined species into different subgenera, based on fruit features are in agreement with much of the later classification of the south-west Asian fritillaries into three subgenera. Generally, the shape of seeds in most species of *Fritillaria* are ovoid. There are some differences in shape and size of testa cells among different species, but these differences do not seem to be taxonomically very important.

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