THE SYSTEMATIC SIGNIFICANCE OF SEED MICRO-MORPHOLOGY IN STELLARIA L. (CARYOPHYLLACEAE) AND ITS CLOSEST RELATIVES IN IRAN

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In this study, seed micro-morphology of eight species of *Stellaria* and two of its closest relatives were examined by scanning electron microscope. High variation was found in seed coat micromorphology and four distinc cell patterns were observed. Shape of testa cells is defined as elongated polygonal, broad polygonal, interlaced polygonal and irregular polygonal. The variation in ornamentation of testa cells as well as their size and shape may provide useful diagnostic characters for separating taxa at the generic and specific level. Seeds of the *Myosoton aquaticum* are reniform with rounded polygonal cells that are convex on the surface, having papillae on outer periclinal walls and V-shape anticlinal walls. This cell pattern is very similar to *Stellaria media* and *S. pallida*. Seeds shape of *Mesostemma* are cubical-spherical and the surface of seeds are arranged in irregular polygonal cell, irregular zip-shape margin and corrugated in periclinal wall. These are very different with exomorphology of the seeds of the *Stellaria* species. Seed micro-morphological data suggest that *Myosoton aquaticum* belongs to *Stellaria* and is better to be included as a synonym of it, but this data provides some support at least for the separation of *Mesostemma kotschyanum* from *Stellaria*.

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Key words. Caryophyllaceae, *Stellaria* L., seed micro-morphology, taxonomic significance.

اهمیت سیستماتیکی میکرو-مورفولوژی دانه در جنس .Stellaria L و نزدیکترین خویشاوندانش (Caryophyllaceae) در ایران

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در این مطالعه، میکرو- مورفولوژی ۸ گونه از جنس *Stellaria* و دو جنس از نزدیکترین خویشاوندانش، توسط میکروسکوپ الکترونی نگاره بررسی شدند. تنوع زیادی در میکرومورفولوژی پوشش دانه یافت شد و ٤ الگوی سلولی متفاوت مشاهده شد. شکل سلول‌های پوششی به صورت چند ضلعی کشیده، چند ضلعی پهن، چند ضلعی درهم تنیده و چند ضلعی نامنظم تعیین شدند. تنوع در تزیینات سلول‌های پوششی به خوبی اندازه و شکل آنها می‌تواند صفات تشخیصی مفیدی را برای جدا کردن تاکسون‌ها در سطح گونه و جنس فراهم کند. دانه‌ها در *Myosoton aquaticum* کلیوی شکل هستند و با سلول‌های چند ضلعی پهنی که سطح بیرونی آن ها محدب، دارای زگیل و حاشیه آنها V شکل می‌باشد، آراسته شده است. این الگوی سلولی، بسیار شبیه به دانه‌های *Stellaria media* و *S. pallida* است. شکل دانه‌ها در *Mesostemma kotschyanum* مکعبی- کروی است و سطح دانه‌ها با سلول‌های چند ضلعی نامنظمی که حاشیه zip شکل و سطح چروکیده‌ای دارند، مرتب شده است. این وضعیت با اگزومورفولوژی دانه‌های *Stellaria* بسیار متفاوت است. داده‌های میکرو- موروفولوژی دانه پیشنهاد می‌کند که *M. aquaticum* متعلق به *Stellaria* است. اما این داده‌ها، جدایی *M. kotschyanum* از *Stellaria* را حمایت می‌کنند.

INTRODUCTION

Stellaria L. belongs to the family *Caryophyllaceae* (subfamily *Alsinoideae*), with approximately 150-200 species worldwide. These annual to perennial herbs are distributed mainly in Eurasia, with a centre of distribution in the mountains of E Central Asia, some species in Afromontane of Africa, some species with cosmopolitan distribution (Bittrich 1993). Most of the species prefer humid mountainously slopes, but some grow in deserts.

The genus is represented by 9 species in Iran (Rechinger 1988); *S. nemorum* L., *S.media* (L.) Vill., *S. pallida* (Dumort) Pire, *S. holostea* L., *S. graminea* L. *and S. persica* Boiss. in sect. *Stellaria, S. alsinoides* Boiss. & Buhse. in sect. *Pseudalsine* Boiss. and *S. blatteri* Mattf., *S. scaturiginella* Rech.f. in uncertain section. The morphological study of some *Stellaria* species and *Myosoton aquaticum* (L.) Moench show their high similarities, as *M. aquaticum* sometimes treated as *Stellaria aquatica* (L.) Scop., this subject is an indication of close relationships between the two genera. Recent studies on the molecular phylogeny of *Caryophyllaceae* strongly show that *M. aquaticum* nested within a clade *Stellaria.*

On the other hand, *Mesostemma kotschyanum* (Fenzl in Boiss.) Vved. is the basionym of *Stellaria kotschyana* Fenzl in Boiss. and was referred to section *Oligosperma* by Boisser (1867). But, Rechinger (1988) included this species in the genus *Mesostemma* Vved. with two new species (*Mesostemma perfoliatum, M. platyphyllum*). *M. kotschyanum* is fairly a robust perennial from Iran, northern Iraq, and eastern Turkey with a stiffly erect habit and many flowers.

Seed micro-morphology by scanning electron microscopy (SEM) has been applied in systematic studies about different genera of *Caryophyllaceae* for example, *Arenaria* L. (Wofford 1981, Wyatt 1984), *Gypsophila* L. (Amini et al. 2011), *Minuartia* L. (Celebioglu et al. 1983), *Moehringia* L. (Minuto et al. 2006 & 2011), *Paronychia* Miller (Ocana et al. 1997, Kaplan et al. 2009), *Sagina* L. (Crow 1979), *Silene* L. (Hong et al. 1997, Fawzi et al. 2010) and *Velezia* L. (Yildiz 2010). But few studies carried out on seed morphology of few *Stellaria* species (*S. media:* Minuto et al. 2006, *S. holostea:* Yildiz 2002, *S. cuspidata:* Volponi 1993) and there are no data about seed morphology of other *Stellaria* species, *Myosoton* and *Mesostemma*.

The present study aims to examine seed micro-morphological characters of *Stellaria* species distributed in Iran using scanning electron microscopy (SEM), comprehensive study of seed coat micro-morphology of *Stellaria* species and its relatives and to provide new insights into its potential taxonomic value.

MATERIALS AND METHODS

The nine *Stellaria* taxa included in the study were selected according to Rechinger's work in Iran (1988), with the exception of *S. scaturiginella* for lack of adequate material. One species of *Myosoton aquaticum* and also two subspecies of *Mesostemma kotschyanum* were added.

Seeds were collected from the field or herbarium specimens deposited in TARI (herbarium of Research Institute of Forests and Rangelands) and IAUH (herbarium of Islamic Azad University, Science & Research Branch). The list of specimens are shown in table 1.The seeds were taken only from dehiscent capsules and were observed at first using a stereomicroscope to ensure that they were normal in size and development. At least three populations were studied for each taxon in order to calculate the mean and to ensure the constancy of characters. Seeds were mounted on aluminum stabs and were sputter coated with a thin layer (ca. 25 nm) of gold-palladium. The specimens were observed and photographed by a sc**a** ning electronic microscope (SEM), model LEO 440I (in the Islamic Azad University, Research and Sciences Branch) at an accelerating voltage of 10-15 KV.

The terminology to describe seed coat surface sculpturing follows previous studies on *Caryophyllaceae* seeds such as Amini et al. (2011), Barthlott (1981), Minute et al. (2006 & 2010) and Yildiz (2002).

RESULTS

Stellaria nemorum L. was cited by Rechinger (1988) in Flora Iranica based on a specimen in TARI (Wendelbo & Shirdelpour 14877). This specimen was studied, it has flowers with 5 styles and petals not exceed the sepals whereas *S. nemorum* are defined by 3 styles and petals are twice as long as sepals. Thus, the specimen is really *Myosoton aquaticum* (L.) Moench. and *Stellaria nemorum* was incorrectly recorded from Iran.

Morphological features of the seeds such as size, colour, shape and testa cell are very various within *Stellaria* species and species of *Myosoton* and *Mesostemma*. A set of relevant characters that were found distinctive for the species is reported in table 2. Selected SEM micrographs of the seed and their surface are shown in Figs. 1-20.

Seed size

According to the table 2, the largest seeds occur in *Mesostemma kotschyanum* subsp. *afghanicum* (3.54 mm in length and 2.57 mm in width). The smallest seeds are found in *Stellaria alsinoides* (0.78 mm in length and 0.73 mm in width).

Table 1. List of *Stellaria* species and relative genera examined in this study, their localities and voucher numbers. Sections are according to Rechinger (1988).

Species	Section	Voucher specimen
Stellaria media (L.) Vill.	*Stellaria*	Gilan: Bandar Anzali, 0 m, Mozaffarian 65156 (TARI) Azerbaijan: Arasbaran protected area, east Makidi, 2400 m, Assadi & Maassoumi 20217 (TARI) Mazandaran: south Ramsar, east Javaher deh, 1800 m, Runemark & Moussavi 20816 (TARI)
S. pallida (Dumort.) Pire.	*Stellaria*	Khuzestan: Haft Tape, railway station, 80 m, Mozaffarian 62812 (TARI) Khuzestan: Masjed- Solayman, 400 m, Foroughi 3165 (TARI) Fars; 18 km from Kazeroun to Dalaki, 800 m, Runemark & Mozaffrian 26765 (TARI)
S. holostea L.	*Stellaria*	Mazandaran: Pol-e-Sefid, Sang-deh, Ashak, 1600-2600 m, Assadi 73630 (TARI) Semnan: Shahroud, Kuh-e-Abr, Kuh-e-Ghatri, 2300-2500 m, Wendelbo & Foroughi 12897 (TARI) Gilan: Damash, east Roudbar, 1900 m, Wendelbo & An Alla 18181 (TARI)
S. graminea L.	*Stellaria*	Azerbaijan: Ardebil, 42 km west Neur, Lisar protected area, 2450 m, Foroughi & Assadi 13753 (TARI) Tehran: Karaj, Chalus road, Kandovan north slopes, 2750-2850 m, Mahdavi 1379 (IAUH)
S. persica Boiss.	*Stellaria*	Tehran: Karaj, Chalus road, Kandovan north slopes, 2750-2850 m, Mahdavi 1380 (IAUH)
S. alsinoides Boiss. & Buhse	*Pseudalsine* Boiss.	Mazandaran: Haraz road to Ab-e-Garm, 2250 m, Assadi & Mozaffarian 33162 (TARI) Mazandaran: Haraz road, Emam Zad-e- Hashem, 2750-2850 m, Mahdavi 1377 (IAUH) Tehran: Mountain of Tuchal, near fifth Station of Tuchal Telecabin, 2930 m, Mahdavi 1378 (IAUH)
S. blatteri Mattf.		Yazd: Ardakan, Tout and Anjiran, 1800 m, Mozaffarian 77402 (TARI) Balouchestan: Mountain of Taftan, Tamendan village, 2300-2500 m, Mozaffarian 53175 (TARI) Tehran: Kavir protected area, Kuh-e-Talhe, west central region, 1100-1250 m, Runemark, Foroughi and Assadi 19508 (TARI)
Mesostemma kotschyanum (Fenzl in Boiss.) Vved. subsp. *kotschyanum*		Azerbaijan: Oroumieh,Targovar,1580 m, Zehzad, Kuhafkan & Rogers 7112 (TARI) Fars: north mountain Dena, near Ab Malakh, 2800-3600 m, Assadi & Mozaffarian 31474 (TARI)
M. kotschyanum (Fenzl in Boiss.) Vved. subsp. *afganicum* Rech. f.		Semnan:15 km north Shahroud, Nekarman, 2500 m, Assadi & Maassoumi 21045 (TARI)
Myosoton aquaticum (L.) Moench		Gilan: Talesh (Hasht Par) Lisar Valley, 50 m, Roshan 6195 (TARI) Gilan: 4 km from Asalem to Khalkhal, 2000-2500 m, Zehzad, Pakravan & Taheri 67325 (TARI)

Seed colour

Most *Stellaria* seeds show a brown and dull surface (table 2). This condition was also observed in *Myosoton aquaticum* and *Mesostemma kotschyanum*. An exception was observed in *S. media, S. blatteri* and *S. alsinoides*. The seeds of *S. media* and *S. blatteri* were dark brown, but they were yellow and sub shiny in *S. alsinoides.*

Table 2. Seed micro-morphological pattern in studied species of *Stellaria* and relative genera. Abbreviations: DB/D dark brown and dull, B/D brown and dull, Y yellow and sub shiny, Conv: convex, Pap: papillae, RD rough dots, SMS secondary micro-sculpture.

Taxon	Length (mm)	Width (mm)	Colour	Shape	Shape of testa cell	Margin of testa cell	Outer periclinal wall	Ornamentation of testa cell	Figure
Stellaria* sect. *Stellaria									
S. media	1.16	1.06	DB/D	Reniform-Rounded	Rounded	V-shape	Conv, Pap	RD, SMS	1, 2
S. pallida	0.81	0.73	B/D	Reniform-Rounded	Rounded	V-shape	Conv, Pap	RD, SMS	3, 4
S. holostea	2.38	2.00	B/D	Reniform	Rounded	V-shape	Conv, large Pap	SMS	5, 6
S. graminea	0.94	0.74	B/D	Reniform	Interlaced	V-shape	Conv	SMS	7, 8
S. persica	1.12	0.84	B/D	Reniform	Interlaced	V-shape	Conv	SMS	9, 10
S.* sect. *Pseudalsine									
S. alsinoides	0.78	0.73	Y/SS	Pyriform	Elongate	Undulate	Flat, Pap	SMS	11, 12
S. blatteri	1.20	0.94	DB/D	Reniform	Elongate	Zip-shape	Flat	SMS	13, 14
Mesostemma									
M. kotschyanum subsp. *kotschyanum*	2.87	2.34	B/D	Cubical-Spherical	Irregular	Irregular, Zip shape	Corrugate	SMS	15, 16
M. kotschyanum subsp. *afghanicum*	3.54	2.57	B/D	Cubical-Spherical	Irregular	Irregular, Zip shape	Corrugate	SMS	17, 18
Myosoton									
M. aquaticum	0.96	0.79	B/D	Reniform	Rounded	V-shape	Conv, Pap	SMS	19, 20

Seed shape

The seeds shape within *Stellaria* are reniform, but some of them seem to be intermediate between reniform and rounded (*S. media* and *S. pallida*). The seeds shape in *Myosoton aquaticum* are also reniform. In *S. alsinoides* seeds are pyriform (Fig. 11) and have different shape from other *Stellaria* species.

Mesostemma kotschyanum seeds shape are cubical-spherical (Fig 15, 17).

Seed coat cells

The exomorphology of seed coat varies among studied species. The seed ornamentations of some species, such as *Stellaria media, S. pallida, S. holostea* and *M. aquaticum* are rounded polygonal. But they are interlaced polygonal in *S. graminea* and *S. persica* (Figs. 8, 10). Seed coat cells of *S. alsinoides* and *S. blatteri* are elongated polygonal (Figs. 12, 14).

Seeds surface of *Mesostemma kotschyanum* is arranged with irregular polygonal cells (Figs. 16, 18) and different from the other species.

The testa cell contours of most studied taxa are V-shape, but in few species, they are zip-shape (*S. blatteri*), undulate (*S. alsinoides*) or irregular (*M. kotschyanum)*. Most examined species is formed by convex epidermal periclinal wall and having papillae. But seed surface of some species are flat and lacking papillae. Exception was observed in *M. kotschyanum* seeds feature that were corrugate.

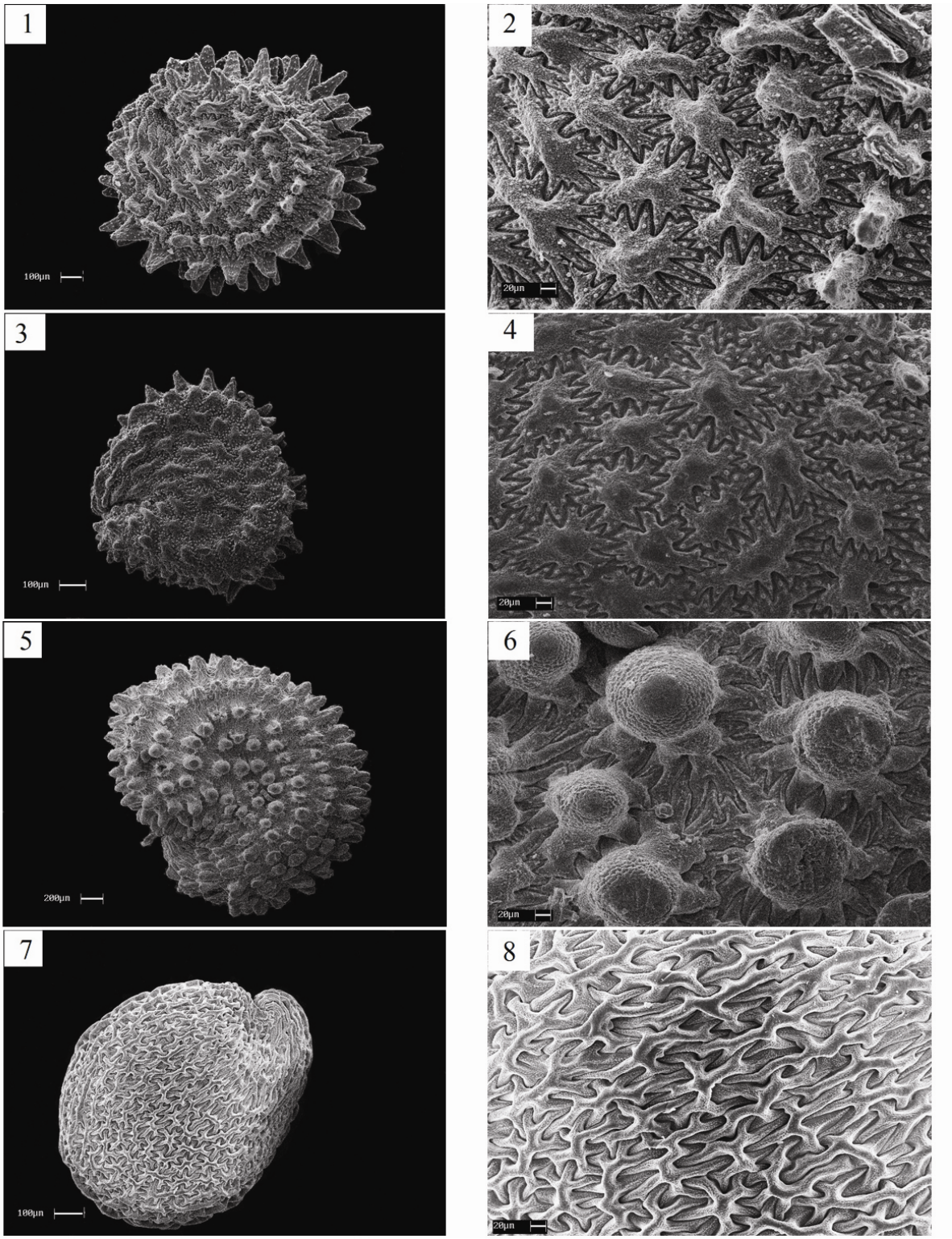
The cell pattern was covered in all studied species with secondary micro sculpture. In addition, *Stellaria media* and *S. pallida* cells show a more evident secondary sculpture forming rough dots in cell margin (Figs. 2, 4).

DISCUSSION

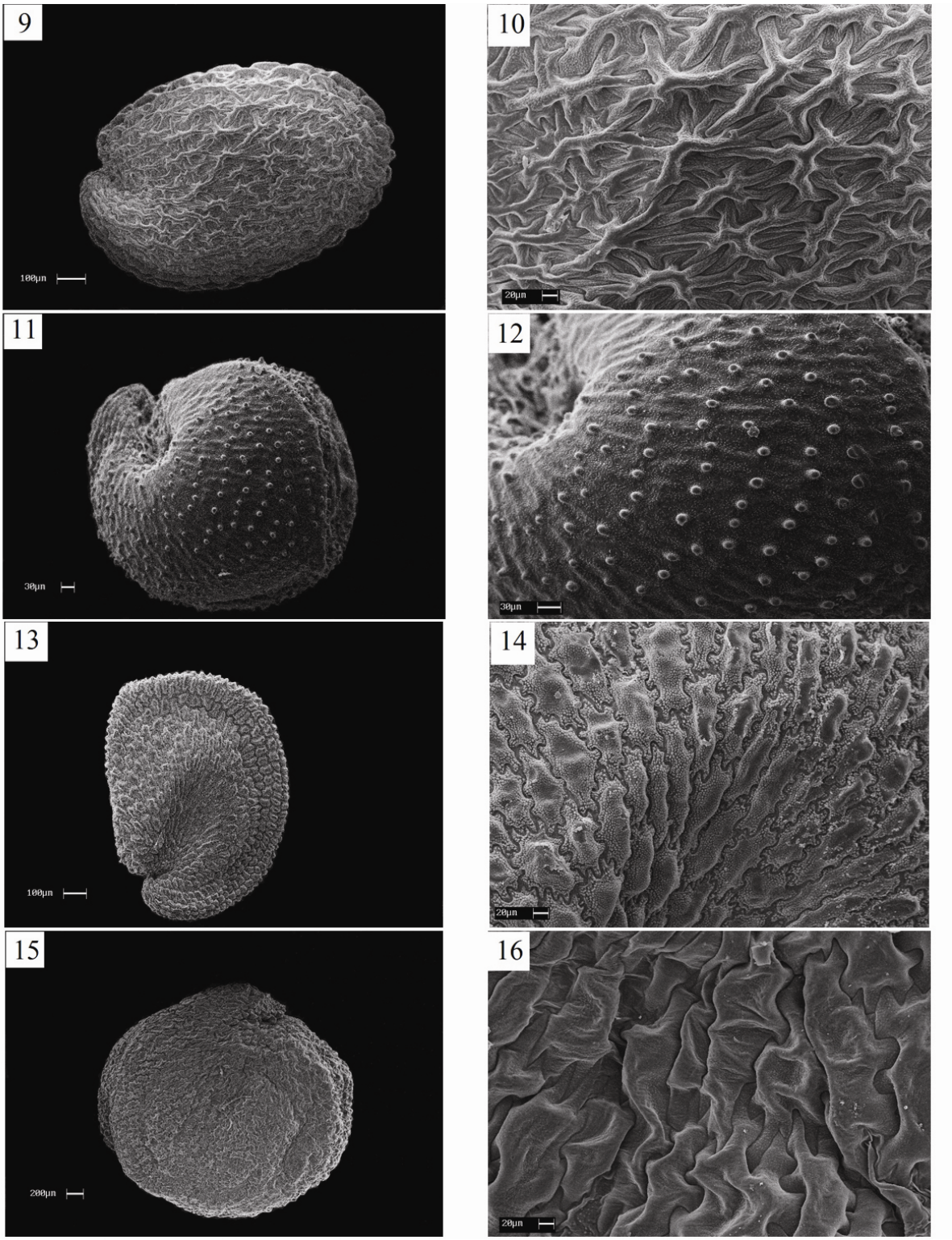
The use of the Scanning Electron Microscopy (SEM) of the seed surface of *Stellaria* and the closest relatives has revealed a great variation in seed coat micro-morphology and allowed the description of a number of novel morphological features. A comparison with seed of allied genera has provided their potential taxonomic value.

Seed morphology of the most examined species are reniform or reniform-rounded, but pyriform (*Stellaria alsinoides*) and cubical-spherical (*Mesostemma kotschyanum*) shape are characteristic for some species. Moreover, the seed colour is in most studied taxa brown or dark brown, only *S. alsinoides* seeds are yellow. Results suggest that shape and colour parameters do not have much importance in evaluating relationships within *Stellaria* species and its closest relatives. It seems that testa cell pattern is the most valuable character. One of the most striking aspects is the shape of testa cell that shows the most variation within studied taxa, as much as variation in size, shape of lobed margins and protuberances of cell provide evidence useful in delimitation of the taxa.

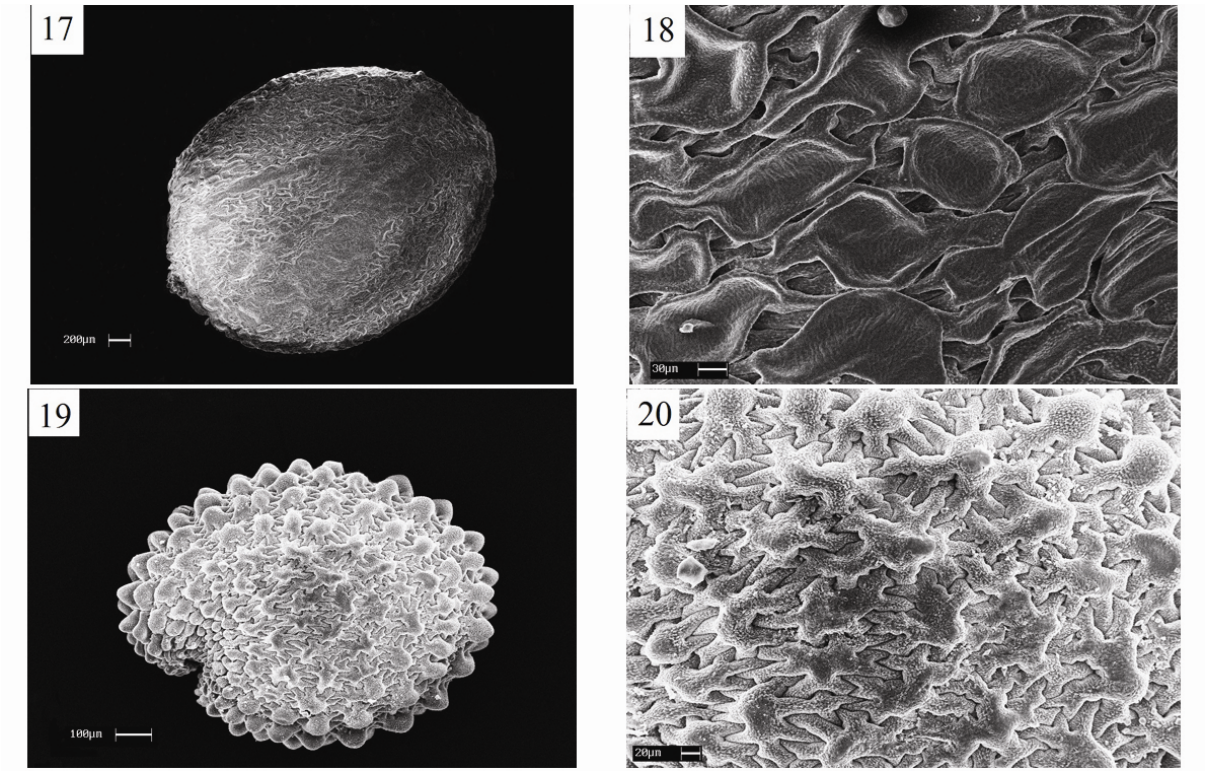
We examined the Iranian species of the genus *Stellaria* only. More of these species have placed in sect.



Figs. 1-8. Scanning electron micrographs of seed surface *Stellaria*. For each species the first micrograph shows seed general shape and the second micrograph is seed surface. 1, 2: *S. media* (Scale bars: 1=100 µm, 2=20 µm), 3, 4: *S. pallida* (Scale bars: 3=100 µm, 4=20 µm), 5, 6: *S. holostea* (Scale bars: 5=200 µm, 6=20 µm), 8: *S. graminea* (Scale bars: 7=100 µm, 8=20µm).



Figs. 9-16. SEM of seed surface *Stellaria* and *Mesostemma.* For each species the first micrograph shows seed general shape and the second micrograph is seed surface. 9, 10: *S. persica* (Scale bars: 9=100 µm, 10=20 µm), 11, 12: *S. alsinoides* (Scale bars: 11=30 µm, 12=30 µm), 13, 14: *S. blatteri* (Scale bars: 13=100 µm, 14=20 µm), 15, 16: *Mesostemma kotschyanum* subsp. *kotschyanum* (Scale bars: 15=200 µm, 16=20 µm).



Figs. 17-20. SEM of seed surface *Mesostemma* and *Myosoton*. For each species the first micrograph shows seed general shape and the second micrograph is seed surface. 17, 18: *M. kotschyanum* subsp. *afghanicum* (Scale bars: 17=200 µm, 18=30 µm), 19, 20: *Myosoton aquaticum afghanicum* (Scale bars: 19=100 µm, 20=20 µm).

Stellaria. The species of this section occur in humid places and mostly grow on mountains. five sepals and petals, mostly 3, rare 2 or 4-5 styles, capsule poly-or few seeds characterize the species of this section (Rechinger 1988).

Stellaria media and *S. pallida* are very closely related, so that morphological characters separating them have minor variation (Rechinger 1988). Seed micro-morphology provides some evidence in delimitation of these species. Although, both species show the rounded polygonal cell with the anticlinal wall V-shape, secondary micro sculpture with convex and papillae in outer surface seed testa, but seeds colour in *S. media* is dark brown and in *S. pallida* is brown. On the other hand, seeds size in the *S. pallida* is smaller than seeds of *S. media* (table 2). Therefore, it seems that seed micro-morphological characters could separate these species.

Presence of cylindrical protuberances on testa cell in *Stellaria holostea* is its most important characteristic features in terms of seed micro-morphology (Figs. 5, 6).

Stellaria graminea shows many morphological similarities to *S. persica* and it is difficult to distinguish them from each other. The entire bracts and having petals longer than the sepals in *S. persica* seem to be the best diagnostics characters (Coode 196ϳ . The seed micro-morphology studies in both species show reniform seeds, interlaced polygonal cell pattern with secondary micro-sculpturing and V-shape margin. The periclinal wall in both species is convex and lacking papillae. Only the seeds size of the *S. persica* are larger than *S. graminea* seeds and testa cells of *S. persica* are more elongated than *S. graminea* (Figs. 7-10). They do not show any difference in seed surface micro-sculpturing indicating the constancy of surface patterns in these species. Thus, these species need to be examined with other biosystematics studies, especially molecular studies.

Section *Pseudalsine* is characterized by 4 sepals and petals, 4 stamens, 4-6 ovules in the ovary and is a monotypic section (Rechinger 1988). *Stellaria alsinoides* belongs to this section and is very different from the species of the sect. *Stellaria*. The smallest size, pyriform shape and yellow colour of seed with elongated polygonal cells, flat periclinal wall and undulate anticlinal wall as well as morphological characters separate this section from sect. *Stellaria*.

Stellaria blatteri is morphologically distinct from the other species of the *Stellaria*, based on 5 petals and

sepals, 2 styles and 10 stamens. Although Mattfeld (1933) refers the species to section *Oligosperma* and relates it to *Stellaria kotschyana*, the two species are not particularly similar (Mc Neill 1973). *S. blatteri*, has more numerous ovules (8-12) most of which develop into seeds (*S. kotschyana* has 1- or 2- seeds), foliaceous lower bracts, linear to oblanceolate rather than narrowly triangular to lanceolate stem leaves and smaller flowers. But, Rechinger (1988) transferred S. *kotschyana* from *Stellaria* to *Mesostemma* and placed *S. blatteri* in uncertain section. The study of seeds of *S. blatteri* show the reniform shape, elongated polygonal with zip-shape margin of the testa cells, secondary micro-sculpture surface and flat in periclinal wall (Figs. 13, 14). These characters place *S. blatteri* into a new section.

The species of *Myosoton aquaticum* and *Mesostemma kotschyanum* (*Stellaria kotschyana*) are most closely related to *Stellaria*. All of three genera have several morphological synapomorphies such as petals deeply cleft (rarely jagged) or rarely absent and capsules dehiscing by twice as many valves as styles. Separation of *Mesostemma* from *Stellaria* and distinguishing *Myosoton* from *Stellaria* is much more a matter of doubt. On the other hand, one of the genera within the *Alsinoideae* that was shown to be paraphyletic is *Stellaria* (Harbuagh et al 2010, Greenberg et al 2011, Mahdavi et al. unpublished).

Seeds of *Myosoton aquaticum* show reniform shape, rounded polygonal cells with V-shaped anticlinal wall, outer surface of testa cell were formed by convex and having papillae, were covered with secondary micro-sculpture (Figs. 19, 20). This cell pattern is very similar to the *S. media* and *S. pallida*, only lack rough dots. It seems that the shape of the seed as well as the type of seed surface micro-sculpturing suggest that *M. aquaticum* is more closely related to *Stellaria*. Although having 5 styles and capsule dividing to 5 bluntly bi-dentate teeth considered as morphological evidence supporting the separation of these genera. Based on the recently published phylogeny of *Caryophyllaceae*, *M. aquaticum* (sometime treated as *Stellaria aquatica*) nested within a sub clade *Stellaria* and they are sister groups (Harbuagh et al 2010, Greenberg et al 2011, Mahdavi et al. unpublished). Seed micro-morphology supports these relationships. Based on morphological and seed micro-morphological and molecular data it seems that *M. aquaticum* belongs to the genus *Stellaria* and is better to be included in it.
Seed shape of *Mesostemma* is cubical-spherical and seeds surface composed of irregular polygonal cells with irregular and zip-shaped margin, corrugate in periclinal wall and forming by secondary micro-sculpture. Morphological study of *M. kotschyanum* subsp. *kotschyanum*, which is mostly distributed in Turkey Iraq and Iran, have shorter pedicels, leaves broadest at or near the base, distinctly triangular or lanceolate, whereas *M. kotschyanum* subsp. *afghanicum* Rech. f. from eastern Iran and Afghanistan have long pedicles and often more or less linear leaves. Seeds coat micro-morphology of the two subspecies show also few differences. Testa cells shape of *M. kotschyanum* subsp. *kotschyanum* are elongated irregular polygonal, but they are broad cells in other subspecies (Figs. 15-18). These are very different with seeds surface of the *Stellaria* species. Therefore the seed micro-morphology provides some support for the separation of *M. kotschyanum* from *Stellaria*.

Consequently, seed micro-morphological data of studied species indicate that the separation of most species is real, but for some do not provide important diagnostic characters for their delimitation. Seed coat characters support the separation of *Stellaria* and *Mesostemma*, but disagree with recognition of *Myosoton* as a genus distinct from *Stellaria.* The relationships in these genera need to be revised based on evidence from different sources.

REFERENCES

Amini, E., Zarre, S. & Assadi, M. 2011: Seed micro-morphology and its systematic significance in Gypsophila (Caryophyllaceae) and allied genera. -Nord. J. Bot. 29: 660-669

Barthlott, W. 1981: Epidermal and seed surface characters of plants: systematic applicability and some evolutionary aspects. -Nord. J. Bot. 1: 345-355.

Bittrich, V. 1993: Caryophyllaceae. In: Kubitzki, K., Rohwer, J. & Bittrich, V. (eds.) The families and genera of vascular plants. Vol. 2, Magnoliid, Hamamelid and Caryophyllid families. -Springer, Berlin, pp. 206-236

Celebiog˘lu, T., Favarger, C. & Huynh, K. L. 1983: Contribution a` la micromorphologie de la testa des graines du genre Minuartia (Caryophyllaceae). I. Sect. Minuartia. -Adansonia 4: 415-435.

Coode, M. J. E. 1967: Stellaria L. In: Davis, P. H., Mill, R.R. & Tan, K. (eds.), Flora of Turkey and East Aegean Islands. Vol. 2: 69-72. -Edinburgh University Press.

Crow, G. E. 1979: The systematic significance of seed morphology in Sagina (Caryophyllaceae) under scanning electron microscopy.- Brittonia 31: 52-63.

Fawzi, N. M., Fawzy, A. M. & Mohamed, A. A. 2010: Seed morphological studies on some species of Silene L. (Caryophyllaceae). -Inter. J. Bot. 6: 287-292.

Fior, S., Karis, P. O., Casazza, G., Minuto, L. & Sala,

F. 2006: Molecular phylogeny of the Caryophyllaceae (Caryophyllales) inferred from chloroplast *mat*K and nuclear rDNA ITS sequences. -Amer. J. Bot. 93: 399-411.

Greenberg, A. K. & Donoghue, M. J. 2011: Molecular systematics and character evolution in Caryophyllaceae. - Taxon 60 (6): 1637–1652.

Harbaugh, D. T., Nepolroeff, M., Rabeler, R. K., Mc Neill, J., Zimmer, E. A. & Wagner, W. L. 2010: A new lineage-based tribal classification of the family Caryophyllaceae. -Int. J. Plant Sci. 171: 185-198.

Hong, S. P., Han, M. J. & Kim, K. J. 1999: Systematic significance of seed coat morphology in Silene L. s. str. (Silenenae-Caryophyllaceae) from Korea. -J. Plant Biol. 42: 146-150.

Kaplan, A., Colgecen, H. & Buyukkartal, H. N. 2009: Seed morphology and histology of some Paronychia taxa (Caryophyllaceae) from Turkey. -Bangladesh. J. Bot. 38: 171-176.

Mc Neill, J. 1973: Gypsophila and Stellaria*:* An unexpected problem in generic delimitation. -Notes from Roy. Bot. Gard. 32:389-395.

Minuto, L., Fior, S., Roccotiello, E. & Casazza, G. 2006: Seed morphology in Moehringia L. and its taxonomic significance in comparative studies within the Caryophyllaceae. -Plant Syst. Evol. 262: 189-208.

Minuto, L., Roccotiello, E. & Casazza, G. 2011: New seed morphological features in Moehringia L. (Caryophyllaceae) and their taxonomic and ecological significance. –Plant Biosys. 145: 60-67.

Ocan˜a, M. E., Fernandez Gonzalez I. & Pastor, J. 1997: Fruit and seed morphology in Paronychia Miller from southwest Spain. -Lagascalia 19: 521-528.

Rechinger, K. H. 1988: Stellaria L. In: Rechinger, K. H. (ed), Flora Iranica no. 163: 60-76. Akad. Druck- und Verlagsanstalt.

Rechinger, K. H. 1988: Myosoton Moench. In: Rechinger, K. H. (ed), Flora Iranica no. 163: 84-85. -Akad. Druck- und Verlagsanstalt.

Rechinger, K. H. 1988: Mesostemma Vved. In: Rechinger, K. H. (ed), Flora Iranica no. 163: 76-84. -Akad. Druck- und Verlagsanstalt.

Smissen, R. D., Clement, J. C., Garnock-Jones, P. J. & Chambers, G. K. 2002: Subfamilial relationships within Caryophyllaceae as inferred from 5'-*Ndhf* sequences. -Am. J. Bot. 89: 1336-1341.

Volponi, C. R. 1993: Stellaria cuspidata (Caryophylaceae) and some related species the Andes. –Willdenowia 23:193-209.

Wofford, B. E. 1981: External seed morphology of Arenaria (Caryophyllaceae) of the southeastern United States. -Syst. Bot. 6: 126-135.

Wyatt, R. 1984: Intraspecific variation in seed morphology of Arenaria uniflora (Caryophyllaceae). -Syst. Bot. 9: 423-431.

Yildiz, K. 2002: Seed morphology of Caryophylaceae species from Turkey (northern Anatolia). -Pakistan J. Bot. 34: 161-171.

Yildiz, K. 2010: Pollen and Seed morphology of Velezia L. (Caryophylaceae) genus in Turkey. -Turk. J. Bot. 34: 179-190.