

SEED MICROMORPHOLOGY IN SOME SPECIES OF *ATOCION*, *IXOCA*, *MINJAEVIA* AND *VISCARIA* (SILENEAE, CARYOPHYLLACEAE)©2021 r. T. I. Kravtsova^{a,#} and V. O. Romanova^{a,##}^a Komarov Botanical Institute RAS
Prof. Popov Str., 2, St. Petersburg, 197376, Russia[#]e-mail: kraveleon@yandex.ru;^{##}e-mail: veronique71@mail.ru

DOI: 10.31857/S0006813621080056

Using scanning electron microscope, we studied seed morphology and seed coat micromorphology in seven species of the genera *Atocion*, *Minjaevia* (= *Atocion rupestre* (L.) Oxelman), and *Viscaria*, forming a separate clade *Viscaria* group (not corresponding to the traditional taxonomy) on the gene tree of Sileneae tribe, and in *Ixoca*, previously a member of this group. Seed characters, primarily the shape and orientation of exotesta cells, the presence and shape of tubercles on their outer periclinal wall, are found to be taxonomically and diagnostically important in the group. The results obtained confirmed the separate phylogenetic position of the genus *Ixoca* in the tribe Sileneae. In addition to the crown of hairs, their seeds differ from the seeds in the *Viscaria* group by disorderly located exotesta cells of an unusual amoeboid shape, glebulate (not granulate) secondary sculpture of their outer periclinal wall, a protruding roll around the hilum, and usually asymmetrical position of the hilum. Worthy of note is an exact duplication of the characteristic feature of *Ixoca* seeds – a crown of several rows of hard flat hairs – in some species of *Minuartia*, studied by Song et al. (2015), and Zaychenko and Zernov (2017). The study also confirmed a close relationship between *Atocion* and *Minjaevia*, revealed by molecular methods. Their seeds are very similar in the seed coat micromorphology; differences in seed thickness, the presence or absence of a groove on the dorsal side and large ribs on the periphery of the lateral seed sides may serve for the delimitation of these taxa. Our results do not corroborate, however, the molecular data on the sister relationships of these genera to the genus *Viscaria*. The peculiarity of the genus *Viscaria* is revealed: within the genus, two seed types (*V. alpina* and *V. viscosa*) exist which differ significantly in micromorphology. It is consistent with *Viscaria* subdivision into sections (Ikonnikov, 1987). In *V. alpina* type, the seeds are larger than in *V. viscosa*, usually less rounded in outline, somewhat asymmetrical, with a broad, flat or slightly convex back without a groove, the ribs are not pronounced; the surface throughout the seed is colliculate, exotesta cells are uniformly stellate. In *V. viscosa* type, the seeds are almost rounded in outline, more symmetrical and flat than in *V. alpina*, sometimes with a groove on the back; the surface is tuberculate with regular rows of tubercles. The exotesta cells differ in shape on different seed sides, and in different rows on the dorsal side. They are oblong with a rounded-conical tubercle on the lateral sides; oblong with a mamillate-conical tubercle in the outermost rows on the back; such tubercles on a stellate base with entire outer wall strongly elongated in two middle rows of the back. The both *Viscaria* seed types are markedly different from the seeds of *Atocion* and *Minjaevia*; they show similarities with *Lychnis* seeds in the shape of exotesta cells. We suggest that the discrepancy between morphological and molecular studies may be due to the revealed peculiarity of the genus *Viscaria*, which is manifested in the diversity of seed types in the studied species, as well as in the special fruit dehiscence (primarily loculicidal, according to Friman et al., 2013), which is not found in other genera of the tribe.

Keywords: Sileneae, *Viscaria* group, micromorphology, seed coat, seed, systematics, phylogeny

ACKNOWLEDGEMENTS

The authors thank for the help the curators of the herbaria LE and KW, from which the material was received, and many of our Russian colleagues for the provided material.

The present study was carried out within the framework of the institutional research project “Structural and functional bases of development and adaptation of higher plants” (no. AAAA-A18-118031690084-9) of the Komarov Botanical Institute RAS, St. Petersburg using equipment of the Core Facilities Centre “Cell and Molecular Technologies in Plant Science” at the Institute. We are grateful to

L.A. Kartseva, the head of scanning electron microscopy branch of the Core Facility Center, for a technical assistance in SEM studies.

REFERENCES

- Abdel-Maksoud H.S., Fawzi N.M. 2016. Seed morphology of some taxa of Caryophyllaceae. – Bull. Fac. Agric., Cairo Univ. 67 (3): 213–227.
- Aeschimann D. 1984. Étude biosystematique du *Silene vulgaris* s. l. (Caryophyllaceae) dans de domaine alpin. Morphologie de la graine. – Candollea. 39 (1): 135–149.

- Arabi Z., Ghahremaninejad F., Rabeler R.K., Heubl G., Zarre Sh. 2017. Seed micromorphology and its systematic significance in tribe *Alsineae* (Caryophyllaceae). – *Flora*. 234: 41–59.
<https://doi.org/10.1016/j.flora.2017.07.004>
- Arman M., Gholipour A. 2013. Seed morphology diversity in some Iranian endemic *Silene* (Caryophyllaceae) species and their taxonomic significance. – *Acta Biol. Szeged*. 57 (1): 31–37.
- Atazadeh N., Keshavarzi M., Sheidai M., Gholipour A. 2017. Seed morphology of *Silene commelinifolia* Boiss. complex (Caryophyllaceae Juss.). – *Modern Phytomorphology*. 11: 5–13.
<https://doi.org/10.5281/zenodo.34558>
- Barthlott W. 1981. Epidermal and seed surface characters of plants: systematic applicability and some evolutionary aspects. – *Nord. J. Bot.* 1 (3): 345–355.
- Barthlott W., Mail M., Bhushan B., Koch K. 2017. Plant Surfaces: Structures and Functions for Biomimetic Innovations. – *Nano-Micro Lett.* 9: 23.
<https://doi.org/10.1007/s40820-016-0125-1>
- Boissier E. 1867. *Flora Orientalis*. Geneve. Vol. 1. 1017 p.
- Bojňanský V., Fargašová A. 2007. Atlas of Seeds and Fruits of Central and East-European Flora: the Carpathian Mountains Region. Dordrecht: Springer Netherlands. 1046 p.
- Bozchaloyi S.E., Keshavarzi M. 2014. Micro- and macro-morphological study of *Stellaria* (Caryophyllaceae) and its closest relatives in Iran. – *Phytologia Balcanica*. 20 (2): 179–197.
- Camelia I. 2011. Aspects regulating seeds morphology and germination peculiarities at some taxa from *Silene* L. genera. – *J. Plant Develop.* 18: 5–10.
- Candáu P., Talavera S. 1978. Polen y semillas de las especies de *Silene*, sect. Erecto fractae Chowdhuri. – *Lagascalia*. 8 (2): 127–133.
- Chowdhuri P.K. 1957. Studies in the genus *Silene*. – *Notes Roy. Bot. Gard. Edinburg*. 22: 221–278.
- Dadandi, M.Y., Yildiz, K. 2015. Seed morphology of some *Silene* L. (Caryophyllaceae) species collected from Turkey. – *Turk. J. Bot.* 39: 280–297.
<https://doi.org/10.3906/bot-1307-35>
- Fawzi N., Fawzy A., Mohamed A. 2010. Seed morphological studies on some species of *Silene* L. (Caryophyllaceae). – *Int. J. Bot.* 6 (3): 287–292.
<https://doi.org/10.3923/ijb.2010.287.292>
- Frajman B., Eggens F., Oxelman B. 2009a. Hybrid origins and homoploid reticulate evolution within *Heliosperma* (Sileneae, Caryophyllaceae) – a multigene phylogenetic approach with relative dating. – *Syst. Biol.* 58 (3): 328–345.
<https://doi.org/10.1093/sysbio/syp030>
- Frajman B., Heidary N. et Oxelman B. 2009b. Phylogenetic relationships of *Atocion* and *Viscaria* (Sileneae, Caryophyllaceae) inferred from chloroplast, nuclear ribosomal and low-copy gene DNA sequences. – *Taxon*. 58 (3): 811–824.
<https://doi.org/10.1002/tax.583010>
- Frajman B., Thollesson M., Oxelman B. 2013. Taxonomic revision of *Atocion* and *Viscaria* (Sileneae, Caryophyllaceae). – *Botanical Journal of Linnean Society*. 173 (2): 194–210.
<https://doi.org/10.1111/boj.12090>
- Ghazanfar S.A. 1983. Seed characters as diagnostic in the perennial sections of the genus *Silene* L. (Family Caryophyllaceae) I. – *Pak. J. Bot.* 15 (1): 7–12.
- Gholipour A., Kuhdar F. 2014. Seed morphology diversity in the certain *Silene* species (Caryophyllaceae) from Iran and its taxonomic significance. – *Taxonomy and Biodiversity*. 6 (18): 107–118.
- Greuter W. 1995. *Silene* (Caryophyllaceae) in Greece: a subgeneric and sectional classification. – *Taxon*. 44 (4): 543–581. <https://doi.org/10.2307/1223499>
- Hong S.P., Han M.J., Kim K.J. 1999. Systematic significance of seed coat morphology in *Silene* L. s. str. (Sileneae – Caryophyllaceae) from Korea. – *J. Plant Biol. Korea*. 42: 146–150.
<https://doi.org/10.1007/BF03031023>
- Hoseini E., Ghahremaninejad F., Assadi M., Edalatyan M.N. 2017. Seed micromorphology and its implication in subgeneric classification of *Silene* (Caryophyllaceae, Sileneae). – *Flora*. 228: 31–38.
<https://doi.org/10.1016/j.flora.2017.01.006>
- Ikonnikov S.S. 1984. Notes on Caryophyllaceae. 7. – *Novosti Sist. Vyssh. Rast.* 21: 61–67 (In Russ.).
- Ikonnikov S.S. 1987. Notes on Caryophyllaceae. 8. – *Novosti Sist. Vyssh. Rast.* 24: 79–85 (In Russ.).
- Jafari F., Zare S., Gholipour A., Eggens F., Rabeler R.K., Oxelman B. 2020. A new taxonomic backbone for the infrageneric classification of the species-rich genus *Silene* (Caryophyllaceae). – *Taxon*. 69 (2): 337–368.
<https://doi.org/10.1002/tax.12230>
- Jeanmonod D. 1985. Révision de la section *Siphonomorpha* Oth du genre *Silene* L. (Caryophyllaceae) en Méditerranée occidentale V: Synthèse. – *Candollea*. 40 (1): 35–56.
- Keshavarzi M., Mahdavejad M., Sheidai M., Gholipour A. 2015. Seed and pollen morphology of some *Silene* species (Caryophyllaceae) in Iran. – *Phytologia Balcanica*. 21 (1): 7–12.
- Kovtonjuk N.K. 1995. Structure of seed surfaces of the *Gastrolychnis* (Caryophyllaceae) species from Siberia in connection with the systematics. – *Bot. Zhurn.* 80 (9): 98–101 (In Russ.).
- Kozhanchikov V.I. 1967. On morphological characteristics of seeds fam. Caryophyllaceae and possible ways of their evolution. – *Bot. Zhurn.* 52 (9): 1277–1286 (In Russ.).
- Kozhanchikov V.I. 1969. Morphological and geographical study of seeds in representatives of Caryophyllaceae Juss. of the European part of the USSR: Diss.... Kand. Biol. Sci. Leningrad. 293 p. (In Russ.).
- Kozhanchikov V.I. 1975. Izmenchivost morfologicheskikh priznakov semjan predstaviteley sem. Caryophyllaceae Juss. [Variability of morphological seed characters of representatives of the family Caryophyllaceae Juss.]. – In: *Voprosy sravnitelnoi morfologii semennykh rasteniy*. Leningrad. P. 108–138 (In Russ.).
- Kravtsova T.I., Bolotova Ya.V. 2019. Pericarp structure in some species in the tribe Sileneae DC. (Caryophyllaceae, *Viscaria* group). – *Botanica Pacifica*. 8 (2): 25–34.
<https://doi.org/10.17581/bp.2019.08211>
- Kuh M., Yildiz K., Minareci E. 2017. A taxonomic study of the *Silene* sections *Behenantha* and *Dichotomae*

- (Caryophyllaceae) in Turkey based on the micromorphology of their seed and pollen. — *Turk. J. Bot.* 41: 493–504. <https://doi.org/10.3906/bot-1610-23>
- Mahdavi M., Assadi M., Fallahian F., Nejadstattari T. 2012. The systematic significance of seed micromorphology in *Stellaria* L. (Caryophyllaceae) and its closest relatives in Iran. — *Iran J. Bot.* 18 (2): 302–310.
- Martynyuk V.O., Karpenko N.I., Tsarenko O.M. 2015. Some micromorphological features of *Atocion lithuanicum* (Zapał.) Tzvel. and *A. armeria* (L.) Raf. of Ukrainian flora. — *Biological Bull.* 5 (1): 8–23. <https://doi.org/10.7905/bbmspu.v5i1.901>
- Melzheimer V. 1977. Biosystematische revision einiger *Silene*-Arten (Caryophyllaceae) der Balkanhalbinsel (Griechenland). — *Bot. Jahrb. Syst.* 98 (1): 1–92.
- Melzheimer V. 1987. On the taxonomic position of *Silene thebana* (Caryophyllaceae). — *J. Plant Syst. Evol.* 155 (1/4): 251–256. <https://doi.org/10.1007/BF00936302>
- Melzheimer V. 1988. Caryophyllaceae. — In: *Flora Iranica*. 163: 341–508.
- Mikhailova Yu.V. 2016. Issledovanie DNK dlja reshenija voprosov sistematiki *Sileneae* DC. (Caryophyllaceae Juss.) [DNA study for *Sileneae* DC. (Caryophyllaceae Juss.) systematics]. — In: *Problemy botaniki Juzhnoy Sibiri i Mongolii: sbornik nauchnykh statey po materialam XV mezhdunarodnoy nauchno-prakticheskoy konferentsii*. Barnaul. P. 153–156 (In Russ.).
- 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 (3–4): 189–208. <https://doi.org/10.1007/s00606-006-0458-1>
- Murley M.R. 1951. Seeds of the Cruciferae of Northeastern North America. — *Am. Midl. Nat.* 46: 1–81. <https://doi.org/10.2307/2421948>
- Nersesian A.A. 1990. K izutcheniju poverchnosti semjan nekotorykh vidov roda *Silene* L. (Caryophyllaceae) flory Armenii [By studying the surface of the seeds of some species of the genus *Silene* L. (Caryophyllaceae) in flora of Armenia]. — In: *Trudy Leningr. Molodezhnoy konferentsii botanikov*. Leningrad. Vol. 1. P. 85–94 (In Russ.).
- Ocaña M.E., Juan R., Fernández I., Pastor J. 2011. Estudio morfológico de semillas de *Silene* (Caryophyllaceae) del suroeste de España. — *Lagacalia*. 31: 21–45.
- Oxelman B., Lidén M. 1995. Generic boundaries in the tribe *Sileneae* (Caryophyllaceae) as inferred from nuclear rDNA sequences. — *Taxon*. 44 (4): 525–542.
- Oxelman B., Lidén M., Berglund D. 1997. Chloroplast rps16 intron phylogeny of the tribe *Sileneae* (Caryophyllaceae). — *Plant Syst. Evol.* 206 (1–4): 393–410.
- Oxelman, B., Lidén M., Rabeler R.K. et Popp M. 2001. A revised generic classification of the tribe *Sileneae* (Caryophyllaceae). — *Nord. J. Bot.* 20 (6): 743–748. <https://doi.org/10.1111/j.1756-1051.2000.tb00760.x>
- Perveen A. 2009. Seed morphology of the genus *Silene*: Caryophyllaceae from Pakistan and Kashmir. — *Int. J. Biol. Biotech.* 6 (4): 219–227.
- Romanova V.O., Kravtsova T.I. 2016. Morphological peculiarities of seed hilar area in members of the tribe *Sileneae* (Caryophyllaceae). — *Bot. Zhurn.* 101 (2): 189–205 (In Russ.). <https://doi.org/10.1134/S0006813616020058>
- Romanova V.O., Kravtsova T.I. 2019. Morphology of epicuticular waxes on the seed coat surface in the tribe *Sileneae* (Caryophyllaceae). — *Turczaninowia*. 22 (1): 164–184 (In Russ.). <https://doi.org/10.14258/turczaninowia.22.1.16>
- Rorhbach P. 1868. Monographie der Gattung *Silene*. Leipzig. 249 p.
- Song J.-H., Kim J.-M., Ok M.-K., Hong S.-P. 2015. Comparative seed morphology of the tribe *Alsineae* (Caryophyllaceae) in Korea and its taxonomic implications. — *Korean J. Pl. Taxon.* 45 (4): 369–379. <https://doi.org/10.11110/kjpt.2015.45.4.369>
- Stern W.T. 2004. *Botanical Latin*. Fourth ed. Portland. 546 p.
- Tabaripour R., Koohdar F., Sheidai M., Gholipour A. 2013. Intra-specific variations in *Silene*: Morphometry and micromorphometry analyses. — *Afr. J. Biotechnol.* 12 (33): 5208. <https://doi.org/10.5897/AJB12.188>
- Tzvelev N.N. 2001. On genera of tribe smolevkovyh (*Sileneae* DC., Caryophyllaceae) in Eastern Europe [De generibus tribus *Sileneae* DC. (Caryophyllaceae) in Europa orientali]. — *Novosti Sist. Vyssh. Rast.* 33: 90–113 (In Russ.).
- Weberbauer A. 1898. Beiträge zur Anatomie der Kapsel-früchte. — *Botanisches Centralblatt*. 73: 54–59, 97–105, 135–142, 161–168, 193–202, 250–257, 296–302.
- Yildiz K. 2002. Seed morphology of Caryophyllaceae species from Turkey (North Anatolia). — *Pak. J. Bot.* 34 (2): 161–171.
- Yildiz K., Cirpici A. 1998. Seed morphological studies of *Silene* L. from Turkey. — *Pak. J. Bot.* 30 (2): 173–188.
- Zareh M.M. 2005. Seed diversity among certain species of Caryophyllaceae in Egypt. — *Pak. J. Biol. Sci.* 8 (5): 714–720. <https://doi.org/10.3923/pjbs.2005.714.720>
- Zaychenko S.G., Zernov A.S. 2017. Structural features of the seed coat in Caucasian representatives of *Minuartia* (Caryophyllaceae). — *Wulfenia*. 24: 205–220.