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Seed Morphology and Germination Capacity of some Species in the *Sedoideae* subfamily (Crassulaceae family)

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ABSTRACT

This paper provides seed anatomy, morphology and germination capacity analysis of some species in the subfamily *Sedoideae* cultivated in Siberian Botanical Garden of Tomsk State University. The research helped us identify the morphological characteristics of seeds in 21 species and 2 subspecies. We measured the main morphometric parameters as well as described the shape, coloration and surface type of seeds. The internal structure of seeds was analyzed and their germination capacity was determined after three months of storage.

Key words: *Sedoideae*, seeds, morphology, germination capacity.

INTRODUCTION

The family Crassulaceae DC is a vast group of plants comprising over 30 genera and 1,500 species [1]. About 600 of these species belong to the subfamily *Sedoideae* Berger. Species of the family are found in virtually all parts of the world but some deserts, continental Antarctic and islands of the Pacific Ocean [2]. The centers of their diversity are Mexico, South Africa, Macaronesia, the Mediterranean region and Eastern Asia [3]. The life forms of the Crassulaceae representatives include herbs, semi-shrubs and sub-shrubs with different adaptations to dry growing conditions. A number of species are valuable medicinal, nectariferous and ornamental plants and their introduction is of particular interest.

Introduction research is generally aimed at enriching the gene pool of cultivated plants with new valuable taxa. By creating collections of wild flora species, we can resolve some issues associated with researching and maintaining biodiversity as well as using beneficial plant species.

In Siberian Botanical Garden of Tomsk State University, we did an open-air trial of various representatives of the subfamily *Sedoideae*: 9 species of the genus *Phedimus* Raf., over 20 species of the genus *Sedum* L., 13 specues of the genus *Hylotelephium* H. Ohba, 3 species of the genus *Orostachys* Fisch., and 10 species of the genus *Rhodiola*. Many of these have successfully passed introduction tests and are recommended for practical use [4].

Seed coat characters are stable, conservative, and almost unaffected by the environment, which gives them high taxonomic value [5, 6]. Therefore, the analysis of *Sedoideae* seed morphological traits is quite valuable for species identification, and studying germination parameters helps evaluate the reproductive capabilities of the species.

This research was aimed at analyzing the seed anatomy, mophology and germination capacity of some representatives of the subfamily *Sedoideae*.

Objects and methods

The laboratory research took place in 2008-2013. The objects of this research were 21 species and 2 subspecies of the subfamily *Sedoideae*: *Hylotelephium erythrostictum* (Miq.) H. Ohba, *H. ewersii* (Ledeb.) H. Ohba, *H. populifolium* (Pallas) H. Ohba, *H. telephium* subsp. *fabaria* (W.D.J. Koch) H. Ohba, *H. telephium* subsp. *maximum* (L.) H. Ohba, *H. triphyllum* (Haw.) Holub, *Orostachys spinosa* (L.) Sweet, *Phedimus aizoon* (L.) 't Hart, *Ph. florifer* (Praeger) 't Hart, *Ph. hybridus* (L.) 't Hart, *Ph. kamtschaticus* (Fisch.) 't Hart, *Ph. middendorffianus* (Maxim.) 't Hart, *Ph. obtusifolius* (C.A. Mey.) 't Hart, *Ph. spurius* (M. Bieb.) 't Hart, *Ph. stolonifer* (J.F. Gmel.) 't Hart, *Rhodiola algida* Fisch. & C.A. Mey., *Rh. rosea* L., *Sedum acre* L., *S. album* L., *S. hispanicum* L., *S. reflexum* L., *S. sexangulare* L.

The papers by Artyushenko [7], Danilova [8], Gontcharova [3], Brouwer and Staehlin [9] were used as reference to describe the seed morphology, which was inspected under MSP-1 stereoscopic microscope (Lomo, Russia) at ×16 and ×32 magnification. Being more practical, this approach is valuable for express diagnostics of seeds in crop seed lots. Seed cross sections were prepared on the MZ-2 freezing microtome (Tochmedpribor, Ukraine). Seed anatomy was assessed under Axio Lab A1 light microscope (Carl Zeiss, Germany) at ×50 and ×100 magnification. The images were received, processed and analyzed by means of Axio Vision 4.8 software.

The seed weight was measured on DX-200 electronic scale (A&D, Japan) graduated in 0.001 g. 500 seeds were weighted in triplicate. The data obtained were extrapolated to 1,000 seeds.

The seed coloration was described by comparing it with the scale developed by Bondartsev [10] for biological objects.

After 3 months of storage, the seed germination capacity was studied under laboratory conditions. The seeds were sprouted in Petri dishes on wet filtered paper, 100 pieces at a time, in triplicate, in TSO-1/80 thermostat (Smolenskoye SKTB SPU, Russia) at 24°C. The experiment was held both in the light and in the dark.

Fig. 1: Seeds of some representatives of the subfamily *Sedoideae*

Table 1. Seed morphology in some representatives of the subfamily *Sedoideae*

#	Species	Seed dimensions		Weight of 1,000 seeds, g	Coloration	Surface type	Shape
		length, mm	width, mm				
1	*Hylotelephium erythrostictum*	1.20±0.05	0.44±0.04	0.088±0.004	bister	longitudinally corrugate-reticulate	oblong, oblanceolate
2	*H. ewersii*	0.91±0.03	0.32±0.03	0.073±0.005	bister	longitudinally corrugate	oblong
3	*H. populifolium*	0.92±0.04	0.38±0.02	0.078±0.006	bister, brown	longitudinally corrugate	oblong-obovate, oblanceolate
4	*H.telephium* subsp. *fabaria*	1.06±0.05	0.32±0.02	0.063±0.002	dark brownbister	longitudinally corrugate-reticulate	oblong, oblanceolate
5	*H. telephium* subsp. *maximum*	1.36±0.07	0.50±0.01	0.093±0.005	dark brown	longitudinally corrugate-reticulate	oblong, oblanceolate
6	*H. triphyllum*	1.53±0.06	0.47±0.01	0.118±0.007	bister, snuffy brown	longitudinally corrugate-reticulate	oblanceolate, oblong
7	*Orostachys spinosa*	0.65±0.03	0.29±0.02	0.029±0.002	ocher yellow, sand	weakly reticulate	ovate-oblong
8	*Phedimus aizoon*	1.09±0.07	0.48±0.05	0.084±0.004	dark brown	longitudinally corrugate	obovate
9	*Ph. florifer*	0.81±0.01	0.31±0.03	0.087±0.005	dark brown	longitudinally corrugate	obovate
10	*Ph. hybridus*	0.82±0.02	0.37±0.05	0.069±0.003	dark brown, bister	longitudinally corrugate	obovate
11	*Ph. kamtschaticus*	0.94±0.04	0.40±0.02	0.079±0.006	dark brown	longitudinally corrugate	oblong-obovate, obovate
12	*Ph. middendorffianus*	0.88±0.03	0.42±0.06	0.079±0.004	dark brown	longitudinally corrugate	obovate, sickle-shaped
13	*Ph. obtusifolius*	0.69±0.05	0.41±0.01	0.086±0.007	dark brown	longitudinally corrugate	obovate
14	*Ph. spurius*	0.98±0.06	0.42±0.06	0.085±0.005	dark brown	longitudinally corrugate	obovate, oblong-obovate
15	*Ph. stolonifer*	0.68±0.04	0.31±0.01	0.045 ±0.003	dark brown	longitudinally corrugate	obovate
16	*Rhodiola algida*	2.62±0.36	0.60±0.04	0.133 ±0.009	chestnut brown	reticulate	oblong, oblanceolate
17	*Rh. rosea*	1.44±0.12	0.46±0.01	0.086±0.006	dark brown	longitudinally corrugate	oblanceolate
18	*Sedum acre*	0.79±0.04	0.35±0.03	0.059±0.002	brown	alveolate	obovate
19	*S. album*	1.01±0.09	0.33±0.02	0.064±0.003	bister	longitudinally corrugate	oblong, oblong-obovate
20	*S. hispanicum*	0.51±0.04	0.29±0.02	0.052±0.002	dark brown	longitudinally corrugate	obovate
21	*S. reflexum*	1.15±0.08	0.44±0.03	0.089±0.007	dark brown	longitudinally corrugate	oblong-obovate, oblong
22	*S. sexangulare*	0.60±0.04	0.29±0.03	0.030±0.002	brown	colliculate	ovate, obovate

RESULTS AND DISCUSSION

Among the representatives of the family Crassulaceae, seeds are generally numerous, small, ovate or oblong, and often spindle-shaped. The seed surface can be shiny or dull, reticulate, verrucate, longitudinally striate or corrugate [8].

Studies of the *Sedoideae* seed morphology have shown that the seeds in the species under study are small, 0.65 to l.78 mm long and 0.29 to 0.48 mm wide. The smallest and lightest seeds were found in *Orostachys spinosa* (0.025 g/ 1000 pcs) and the biggest and heaviest ones, in *Rhodiola algida* (0.133 g/1000 pcs).

Most of the species studied have obovate-shaped seeds. Also, *Sedoideae* seeds are typically oblong, oblong-obovate, oblanceolate and oblong-ovate in shape. The *Phedimus middendorffianus* seeds are also sickle-shaped. There is often a raphe in the shape of a narrow thin ridge located along the seed from the micropyle to chalaza. The seed coloration of the species under study is ocher yellow, bister, brown, dark brown, snuffy brown (Table 1, Figure 1). According to our observations as well as Gontcharova's data [3], there are rugose or wing-like spermoderm projections at the chalazal end in the species of the genus *Rhodiola* and *Hylotelephium*. These are most likely adaptations for sind dissemination.

Table 2: Embryo area in some *Sedoideae* representatives in longitudinal section

#	Species	Embryo area, mm^2
1	*Hylotelephium triphyllum*	0.264±0.044
2	*Orostachys spinosa*	0.172±0.021
3	*Phedimus aizoon*	0.276±0.033
4	*Ph. spurius*	0.207±0.025
5	*Rhodiola rosea*	0.396±0.051
6	*Sedum acre*	0.196±0.022
7	*S. reflexum*	0.269±0.032

Sedoideae seed coat sculpture differs depending on the genus and even species. Gontcharova [3, 11] identifies 4 main seed surface types as illustrated by *Sedoideae* of the Russian Far East (longitudinally costate, reticulate, multipapillate, and colliculate). Orlova [12] singles out the following seed surface types for the representatives of *Sedoideae* introduced in the south-west of the Black Earth Region: colliculate, alveolate, corrugate, and corrugate-alveolate.

When describing the seed surface types, we were guided by the earlier developed approaches used for characterizing seed morphology and made some contributions to these approaches.

Thus, we have subdivided the *Sedoideae* species under study into the following groups by the seed surface type:

Longitudinally corrugate surface (corrugations are pronounced, reticulate pattern is hardly, if at all, noticeable): *Hylotelephium ewersii,*

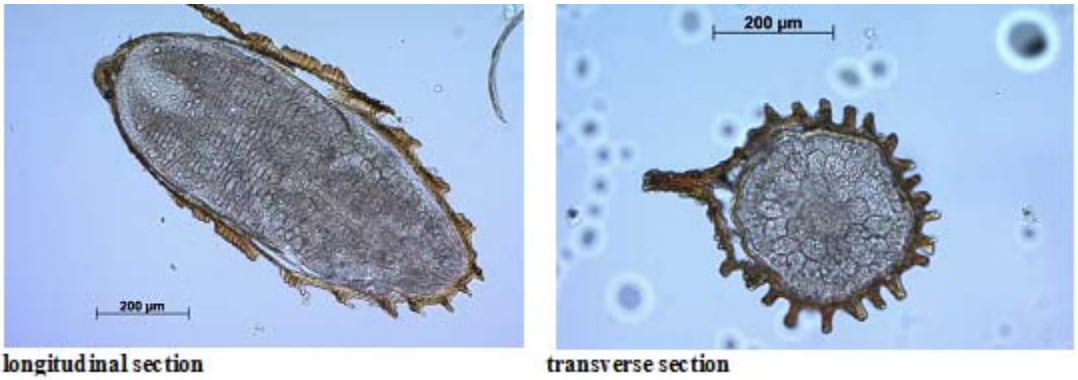

Fig. 2: *Phedimus aizoon* seed section

H. populifolium, Phedimus aizoon, Ph. florifer, Ph. hybridus, Ph. kamtschaticus, Ph. middendorffianus, Ph. obtusifolius, Ph. spurius, Ph. stolonifer, Rhodiola rosea, Sedum album, S. hispanicum, S. reflexum.

Longitudinally corrugate-reticulate surface (corrugations and reticulation between them are well-marked): *Hylotelephium erythrostictum, H. telephium* subsp*. fabaria, H. telephium* subsp*. maximum, H. triphyllum.*

Reticulate (or weakly reticulate) surface: *Orostachys spinosa, Rhodiola algida.*

Alveolate surface: *Sedum acre.*

Colliculate surface: *Sedum sexangulare*.

Sedoideae seed anatomy has uniform structure. The embryo is large and occupies almost the entire inner space of the seed; the endosperm is monolayer and almost absent or unstructured in most species at maturity. The spermoderm is composed of two double-layer coats [13, 14, 3]. The findings of morphological and anatomical research into the seeds of the model species in different genera of the subfamily *Sedoideae* also confirm literature data.

The research has established that the spermoderm pattern of most species studied has projections of different shape and length. The most prominent spermoderm pattern is observed in *Phedimus aizoon* (Figure 2), projections in *Orostachys spinosa* are not prominent. The seed coat thickness varies from 0.019 to 0.031 mm. Embryo size also varies over a wide range in the specimens studied, which directly correlates with the overall seed size. The largest embryo is observed in *Rhodiola rosea* (0.396 mm^2) and the smallest one, in *Orostachys spinosa* (0.172 mm^2) (Table 2).

The seeds of most species under study have high germinating property during the first year of storage [15]. After long-term storage, however, the germination capacity plummets, which,

Table 3: Seed germination capacity of some *Sedoideae*

#	Species	Germinated seeds	
		in the light, %	in the dark, %
1	*Hylotelephium erythrostictum*	60	16
2	*H. ewersii*	89	0
3	*H. populifolium*	100	68
4	*H.telephium* subsp*. fabaria*	68	32
5	*H. telephium* subsp*. maximum*	96	0
6	*H. triphyllum*	100	98
7	*Orostachys spinosa*	84	12
8	*Phedimus aizoon*	96	72
9	*Ph. florifer*	92	84
10	*Ph. hybridus*	84	68
11	*Ph. kamtschaticus*	100	12
12	*Ph. middendorffianus*	84	44
13	*Ph. obtusifolius*	68	4
14	*Ph. spurius*	40	12
15	*Rhodiola rosea*	23	-
16	*Sedum acre*	88	0
17	*S. album*	60	36
18	*S. hispanicum*	77	2
19	*S. reflexum*	34	0

according to Gontcharova and Abankina [16], is due to the seed having undeveloped monolayer endosperm actively used by the large embryo.

We have established that, of all the *Sedoideae* studied, the following species have the highest germination performance after three months' storage: *Hylotelephium ewersii, H. populifolium, H. telephium* subsp*. maximum, H. triphyllum, Orostachys spinosa, Phedimus aizoon, Ph. florifer, Ph. hybridus, Ph. kamtschaticus, Ph. middendorffianus, Sedum acre* (84-100%). Poor germination performance is observed in the seeds of *Phedimus spurium, Rhodiola rosea* and *Sedum reflexum* (23-40%) (Table 3). Kim [17] argues that poor germination performance of *Rhodiola rosea* seeds results from their thick seed coat inhibiting the access of oxygen and water to the embryo.

The seeds of most of the species under study are light-sensitive. The dark-germination percentage of many of the species studied is significantly lower. Seeds of some *Sedoideae* species tested do not germinate at all (*Hylotelephium ewersii, H. telephium* subsp*. maximum, Sedum acre*, *S. reflexum*). With *Hylotelephium triphyllum, Phedimus aizoon, Ph. florifer* and *Ph. hybridus*, light has no significant effect on seed germination (Table 3).

CONCLUSION

We have established that the seeds of *Sedoideae* species are small or very small, 0.65-l.78 mm long and 0.29-0.48 mm wide. Seed shape varies from obovate to oblong. Seed coloration ranges from ocher yellow to dark brown. In terms of seed surface types, the *Sedoideae* species studied are subdivided into the following groups: longitudinally corrugate, longitudinally corrugate-reticulate, reticulate, alveolate, and colliculate. The largest embryo is observed in *Rhodiola rosea* and the smallest one, in *Orostachys spinosa.* The seeds of most of the species under study retain their high germination capacity after 3 months of storage; however, they are light-sensitive. Low germination rates were only observed in seeds of *Phedimus spurius, Rhodiola rosea* and *Sedum reflexum*.

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