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Pollen Morphology on Some Taxa of Family Crassulaceae DC.

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CRASSULACEAE (orpine or stonecrop family) is a morphologically diverse and systematically complex Angiosperm family with a cosmopolitan distribution. A detailed description of the range of pollen morphological variation within the family has been presented, to resolve the taxonomic confusion between members of this family. palynological investigation of 19 species representing nine genera of Crassulaceae were studied using both light (LM) and scanning electron microscopy (SEM). The aim of the present study was to find out the taxonomic significance of palyno-morphological characteristics in family Crassulaceae. A comparative pollen analysis was accomplished based on pollen size, shape, polar and equatorial views, polar and equatorial diameter ratio (P/E ratio), aperture characters and exine features. Generally, the pollen grains were found to be monad, isopolar, radially symmetric, prolate-spheroidal, subprolate or prolate in equatorial view, triangular, tetragonal, or pentagonal in polar view. There are three different types of apertures encountered in the examined species. These types ranged from tricolporate, tetra- and penta- colporate pollen grains. Clear variation of tectum sculpture pattern was also observed, mostly rugulate/ foveolate and rarely striate. According to tectum sculpturing pattern, three major pollen types were recognized: *Crassula* type, *Echeveria* type and *Kalanchoe* type. Based on the overall characteristics of pollen grains, some combinations of pollen morphological characters can reliably delimitate genera, while others are unique to some species. Additionally, based on qualitative pollen morphological characters, an identification key for main pollen types was provided.

Keywords: Crassulaceae, Morphology, Pollen grains, SEM.

Introduction

Crassulaceae DC. is the largest family under order Saxifragales which is considered one of the taxonomically difficult families. It comprises 35 genera and 1400-1500 perennial species of either herbs or shrubs which are rarely aquatic tree-like with worldwide distribution (Thiede & Eggli, 2007). Many of its species have succulent leaves cultivated in gardens and borders for its attractive flowers (Berger, 1930; 't Hart, 1997; Thiede & Eggli, 2007; Gontcharova & Gontcharov, 2009; Mort et al., 2010). The traditional taxonomic classification done by Berger (1930) divided the family into six subfamilies *viz*., Crassuloideae, Cotyledonoideae, Kalanchoideae, Echeverioideae, Sedoideae, and Sempervivoideae on the basis of floral morphological characters. Thorne (2000) recognized three subfamilies in Crassulaceae *viz*., Crassuloideae, Kalanchoideae, and Sedoideae, whereas Van Ham & 't Hart (1998), recognized two subfamilies Crassuloideae and Sedoideae *sensu lato*. The infra-familial classification of Crassulaceae as well as the delimitation and the phylogenetic relationships among Crassulacean taxa was a matter of debate (Uhl, 1961, 1963; Carrillo-Reyes et al., 2009). Smith & Monro

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(2022) resolved the relation between the genera under both subfamilies: Crassuloideae and Kalanchoideae on the basis of the phylogenetyic aspect. Thus, the classification within the family is still under dispute because many of the species hybridize readily, both in wild and cultivated species (Uhl, 1961 & 1963; Bañares, 1990; 't Hart et al., 1993; Carrillo-Reyes et al., 2009).

Pollen morphology of different species of Crassulaceae has been described by Nair (1962) and Faegri & Iversen (1964). Family Crassulaceae was divided by Hideux (1981), into two subfamilies: Crassuloideae and Sedoideae, based on pollen morphological features. Parnell (1991) proved the significance value of the pollen morphological characters in the separation of the closely related species of genus *Sempervivum* from one another, and his result supported the view of Favarger et al. (1968) in the treatment of both *Jovibarba* and *Sempervivum* as two distinct genera. Jin-Hwan et al. (2002), investigated the pollen morphological features of Korean Crassulaceae. They conducted a palynotaxonomic study of the Korean Crassulaceae and observed differences in the morphology of the pollen grains of the species studied, particularly the presence or absence of the aperture margo and ornamentation of the exine. Karaer et al. (2010), revised the morphological, ecological and palynological characters of some species of *Sempervivum* and constructed an identification key based on pollen morphology. Minareci et al. (2012), examined morphological and palynological features of genus *Rosularia*. Qaiser et al. (2015), studied pollen morphology of 28 species representing nine genera *viz., Bryophyllum*, *Kalanchoe*, *Pseudosedum*, *Rhodiola*, *Rosularia*, *Hylotelephium*, *Sedum*, *Tillaea* and *Orostachys* of the family Crassulaceae from Pakistan. Recently, this has also been done by González-Mancera et. al. (2018) on the Mexican *Echeveria* species and found that their pollen grains are isopolar, symmetric, small with three, four or more compound apertures. However, Shahrestani & Faghir (2021) found the pollen characters within *Sedum* species can be of use in their discrimination. Accordingly, this work has been done to provide a comprehensive account on the pollen morphology of some taxa of Crassulaceae family and to evaluate the extent to which this character is useful in their classification.

Materials and Methods

Pollen grains of 19 species of Crassulaceae representing nine genera and six subfamilies of Crassulaceae (*sensu* Berger's system, 1930), were obtained from mature flowers of plants collected from various places (Table1). The identification of the ornamental species was done with the help of Bailey (1949), Jacobsen (1960) and Bailey & Bailey (1976), while *Umbilicus horizontalis* was identified according to Täckholm (1974) and Boulos (1999). Synonyms were derived from International Plant Names Index (IPNI; http://www.ipni.org/ipni/plantnamesearchpage.do) and Plants of the World Online (https://powo.science.kew.org/). The flowers were carefully opened to gather the anthers in test tubes, acetolyzed and mounted in unstained glycerol jelly for light microscope examination (Erdtman, 1952). At least 15-20 pollen grains per taxon were examined and measured using the Zeiss light microscope with an eye-piece micrometer. Polar axis length (P), equatorial diameter (E), and exine thickness were measured and the P/E values were calculated for each measured pollen grain. For SEM studies, non acetolyzed pollen grains were sputtered onto copper stubs coated for five minutes with a thin layer of gold in a JFC-1100E ion sputtering coating unit, examined at accelerating voltage of 15- 25kV., and then photographed by JED JSM-5300 SEM at the Electron Microscope Unit, Faculty of Science, Alexandria University. The terminology used for pollen grain description followed Erdtman (1952) and Punt et al. (2007).

Results

All the investigated taxa are eurypalynous with monad dispersal and heterogenous pollen grains. In examining the morphology of pollen grains particular emphasis was placed on the shape at equatorial and polar views, type of apertures and the tectum sculptural pattern. The taxa studied showed three pollen shapes as indicated by the P/E ratio: prolate-spheroidal (P/E> 1.1), sub-prolate (P/E> 1.2) and prolate (P/E≤ 1.2). Prolate is the most frequent shape among the studied species. The pollen amb varied between the studied taxa from the triangular to the circular. The pollen apertures are tri- tetra- or even penta- colporate with protected pores by exinous bridge. The tectum pattern sculpture of the pollen is significantly variable. The tectum pattern is mostly rugulate

or foveolate. Moreover, striated ornamentation tectum was only recorded in *Crassula perforate*. Variations in pollen morphological features as revealed by LM and SEM are presented in Table 2 and illustrated by Figs. 1-3. Based on the tectum surface sculpture pattern the pollen grains of the family has been divided into three main types *viz*., type I (*Crassula* type), type II (*Echeveria* type) and type III (*Kalanchoe* type).

Key to the pollen grain types:

1+ Tectum striate ……..…,,,,,,,,.. *Crassula* type
- Tectum not as above ……..... 2
2+Tectum faveolate……..... *Echeveria* type
- Tectum regulate ……..... *Khalanchoe* type

There follows a detailed description of the three pollen types with the names of taxa characterized by each type.

TABLE 1. List of species

No.	Genus	Species	Locality/ source
1	*Adromischus* Lem.	*A. cooperi* (Baker) A. Berger	Cactus International Farm, Kaliobeia, Egypt
2	*Aeonium* Webb & Berthel.	*A. decorum* Webb ex Bolle	//
3	*Crassula* L.	*C. perforata* Thunb.	Botanical Garden, Faculty of Agriculture., Kafr El-Sheikh University, Egypt
4	*Dudleya* Britton & Rose	*D. pulverulenta* (Nutt.) Britton & Rose	Orman Botanical Garden, Giza, Egypt
5	*Echeveria* DC.	*E. nodulosa* (Baker) Ed. Otto	//
6		*E. secunda* Booth ex Lindl.	Cactus International Farm, Kaliobeia, Egypt
7		*E. setosa* Rose & J. A. Purpus	//
8	*Graptopetalum* Rose	*G. paraguayense* (N.E.Br.) E. Walther	Orman Botanical Garden, Giza, Egypt
9	*Kalanchoe* Adans.	*K. beharensis* Drake	//
10		*K. blossfeldiana*	//
11		*K. daigremontiana* Raym. Hamet & H. Perrier	Botanical Garden, Faculty of Science, Ain Shams University, Egypt
12		*K. delagoensis* Eckl. & Zeyh.	//
13		*K. fedtschenkoi* Raym. Hamet & H. Perrier	//
14		*K. laciniata* (L.) DC.	Orman Botanical Garden, Giza, Egypt
15		*K. longiflora* Schltr.	//
16		*K. marmorata* Baker	//
17	*Sedum* L.	*S. adolphi* Raym. Hamet	Orman Botanical Garden, Giza, Egypt
18		*S. album* L.	Cactus International Farm, Kaliobeia, Egypt
19	*Umbilicus* DC.	*U. horizontalis* (Guss.) DC.	Burg El-Arab, MediterraneanCoastal Region (Brimley cave), Egypt

TABLE 2. Pollen morphological characters of the studied taxa (LM & SEM)

C. / T.	Pollen form	P/E	Shape		Apocolpia index	Apertures	Mesocolpia width (µm)	Colpi						Exine	
			Equatorial view	Polar view				Shape	Ends	Membrane	Margo	Tenuimar-ginate	Length P %	Sculpture	Thickness
1	Mono-morphic	1.56	Prolate	Triangular	0.26	3-plan-colporate	7.47- 7.77 (7.62± 0.15)	Oblong	Rounded	Ornamented	Absent	Absent	80	Rugulate	0.82- 1.14 (0.94± 0.14)
2	//	1.64	//	//	0.23	3-angul-colporate	2.98- 3.22 (3.13± 0.11)	//	//	//	Present	Present	69.65	//	0.87- 1.26 (0.97± 0.19)
3	//	1.17	Subprolate	//	0.51	//	2.59- 2.97 (2.78± 0.18)	Fusiform	Acute	//	Absent	//	80.27	Striate	0.71- 0.93 (0.79± 0.10)
4	//	1.04	Prolate-spheroidal	//	0.38	//	3.94- 4.37 (4.17± 0.19)	//	//	//	Present	//	94.88	Rugulate	1.18- 1.39 (1.27± 0.09)
5	Di-morphic	1.29	Subprolate	Tetra- (penta-) gonal	0.58	4-(5-) colpate	3.43- 3.67 (3.55± 0.10)	//	//	//	//	//	74.98	Foveolate	1.45- 1.86 (1.65± 0.17)
6	Poly-morphic	Variable (1.21-1.30)	//	Tri-(tetra- penta-hexa-) gonal	0.56	3-(4-5-6-) colpate	Variable 3.61- 4.03 (3.85± 0.18)	Oblong	Rounded	Absent	Absent	Absent	Variable (80.12-80.28)	//	1.31- 1.96 (1.60± 0.28)
7	Mono-morphic	1.28	//	Triangular	0.25	3-angul-colporate	3.77- 4.05 (3.89± 0.12)	//	//	//	Present	Present	71.25	//	1.24- 1.49 (1.39± 0.11)
8	//	1.49	Prolate	//	0.48	//	2.98- 3.24 (3.11± 0.11)	//	//	//	Absent	//	85.67	Rugulate	1.28- 1.65 (1.43± 0.18)
9	//	1.05	Prolate-spheroidal	//	0.24	//	4.88- 5.16 (5.00± 0.13)	//	//	//	Present	//	89.74	//	0.93- 1.24 (1.08± 0.14)

TABLE 2. Cont.

C. / T.	Pollen form	P/E	Shape		Apocolpia index	Apertures	Mesocolpia width (µm)	Colpi						Exine	
			Equatorial view	Polar view				Shape	Ends	Membrane	Margo	Tenuimar-ginate	Length P %	Sculpture	Thickness
10	//	1.72	Prolate	//	0.25	3-plan-colporate	3.15- 3.41 (3.28± 0.13)	//	//	//	Absent	Absent	84.50	//	0.91- 1.17 (1.02± 0.12)
11	//	1.01	Prolate-spheroidal	//	0.36	3-angul-colporate	3.43- 3.69 (3.56± 0.12)	//	//	//	Present	Present	76.05	//	1.05- 1.34 (1.18± 0.12)
12	//	1.82	Prolate	//	0.00	3-angul-syncolporate	4.51- 4.82 (4.66±0.13)	Fusiform	Acute	//	Absent	//	100	//	1.11- 1.36 (1.26± 0.11)
13	//	1.35	//	//	0.25	3-angul-colporate	4.73- 4.98 (4.89± 0.11)	//	//	//	//	//	87.84	//	0.92- 1.17 (1.02± 0.11)
14	Di-morphic	1.53	//	Tri- (tetra-) gonal	0.23	3-(4-) colporate	4.23- 4.65 (4.44± 0.22)	//	//	//	//	//	87.06	//	1.41- 2.04 (1.69± 0.26)
15	Mono-morphic	1.75	//	Triangular	0.39	3-angul-colporate	4.19- 4.47 (4.33± 0.12)	Oblong	Rounded	//	Absent	//	79.35	//	1.71- 2.09 (1.88± 0.16)
16	//	1.43	//	//	0.27	//	9.09- 9.35 (9.23± 0.11)	//	//	//	//	//	85.64	//	1.93- 2.48 (2.18± 0.27)
17	//	1.17	Subprolate	//	0.45	//	3.85- 4.26 (4.04±0.18)	//	//	//	Present	//	85.39	//	1.20- 1.32 (1.27± 0.05)
18	//	1.64	Prolate	//	0.28	//	3.74- 4.05 (3.88± 0.14)	//	//	//	Absent	//	69.65	//	1.07- 1.35 (1.21± 0.11)
19	//	1.30	//	//	0.33	//	2.72- 2.96 (2.82±0.10)	//	//	//	//	Absent	89.51	Foveolate	0.57- 0.72 (0.61± 0.08)

(C.); Character, **(E);** Equatorial diameter, **(P);** Polar axis, **(T.);** Taxa, **(//);** as previous.

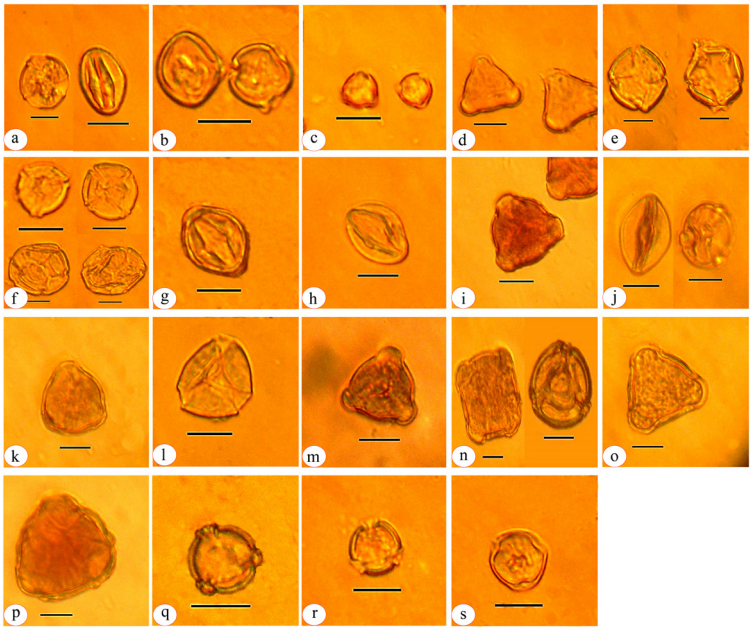

Fig. 1. LM micro-photographs of pollen morphology of the studied taxa showing different categories of pollen shapes and apertures (scale bar 10µm). (a), ***Adromischus cooperi***; (b), ***Aeonium decorum***; (c), ***Crassula perforata***; (d), ***Dudleya pulverulenta***; (e), ***Echeveria nodulosa***; (f), ***E. secunda***; (g), ***E. setosa***; (h), ***Graptopetalum paraguayense;*** (i), ***Kalanchoe beharensis***; (j), ***K. blossfeldiana***; (k), ***K. daigremontiana***; (l), ***K. delagoensis***; (m), ***K. fedtschenkoi***; (n), ***K. laciniata***; (o), ***K. longiflora***; (p), ***K. marmorata***; (q), ***Sedum adolphi***; (r), ***S. album***; (s), U***mbilicus horizontalis***

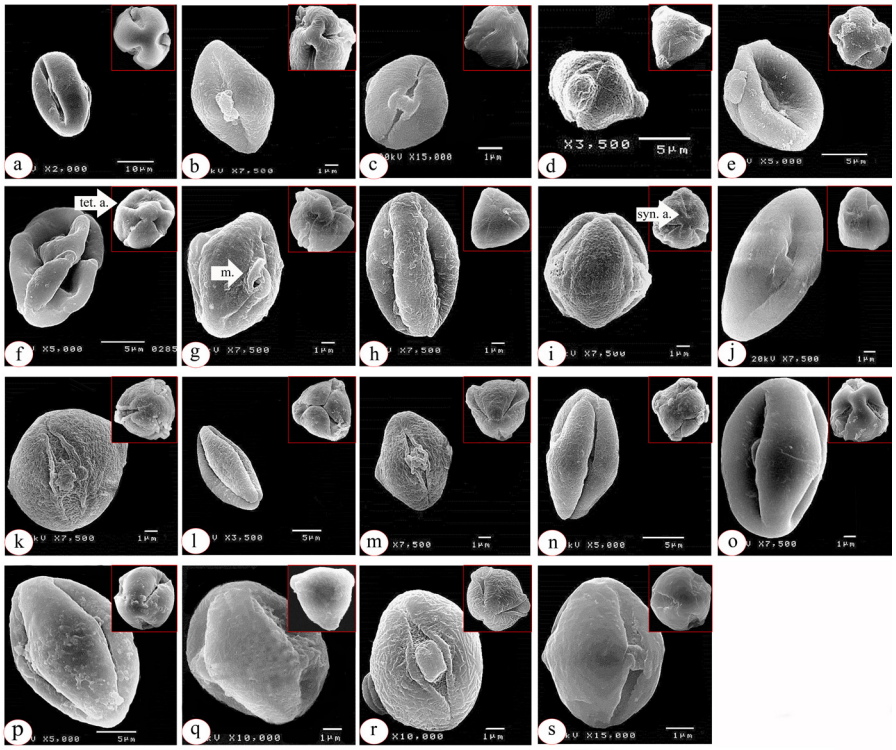

Fig. 2. SEM micro-photographs of pollen morphology of the studied taxa. (a), ***Adromischus cooperi***; (b), ***Aeonium decorum***; (c), ***Crassula perforata***; (d), ***Dudleya pulverulenta***; (e), ***Echeveria nodulosa***; (f), ***E. secunda***; (g), ***E. setosa***; (h), ***Graptopetalum paraguayense;*** (i), ***Kalanchoe beharensis***; (j), ***K. blossfeldiana***; (k), ***K. daigremontiana***; (l), ***K. delagoensis***; (m), ***K. fedtschenkoi***; (n), ***K. laciniata***; (o), ***K. longiflora***; (p), ***K. marmorata***; (q), ***Sedum adolphi***; (r), ***S. album***; (s), U***mbilicus horizontalis***. **(m.): margo; (Syn. a.): syncolpate amb; (tet. a.): tetracolpate amb.**

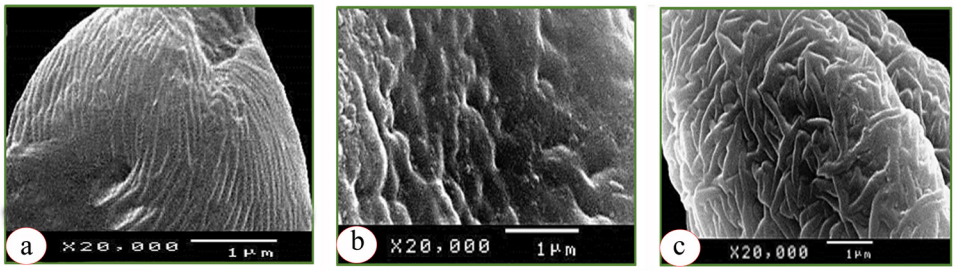

Fig. 3. SEM micro-photographs showing major exine surface sculptures of pollen grains of the studied taxa (a), *Cassula perforata,* striate pattern; (b), *Echveria glauca,* foveolate pattern: (c), *Kalancho longiflora,* rugulate pattern

Type I (*Crassula* type): Pollen grains monad, small, isopolar and radially symmetric, subprolate in equatorial view; triangular in polar view; Length of polar axis (P)= (3.41- 4.06) µm and equatorial diameter (E)= (2.89- 3.41) µm; P/E= 1.17. Apocolpium index (0.51). Aperture tri-angul-colporate; colpi long; fusiform with acute ends and ornamented membrane and tenuimarginate (thin margin aperture). The ora covered with bridge like operculum. Exine sculpture striate (Fig. 3, a) and its thickness (0.71- 0.93) µm. This pollen type characterizes *Crassula perforata* (Figs 1, 2 c).

Type II (***Echeveria* type):** Pollen grains monad; small; isopolar; radially symmetric. They are subprolate to prolate in equatorial view, with a length of (P) axis ranging from 5.05- 14.41 µm and (E) diameter ranging from 3.94- 10.91 µm. The P/E ratio ranges from 1.21- 1.30. The apertures are variable, ranging from tri- to penta-colporate, and the colpi are long and oblong/ fusiform with acute to round ends. The apocolpium index ranges from 0.25- 0.58. The tectum ornamentation displays a foveolate pattern (Fig. 3 b), and the exine thickness ranges from 1.31- 1.45 µm. This type of pollen characterizes four species: *Echeveria nodulosa*, *E.secunda*, *E.setosa*, and *Umbilicus horizontalis*. (Figs.1 & 2 e, f, g, s).

Type III (***Kalanchoe* type):** This particular type of pollen grains is the largest and contain 14 species, accounting for about 74% of all species. These species are generally characterized by rugulate tectum sculpture pattern (Fig. 3 c) and significant differences in pollen shape classes, and the presence/ absence of aperture margo (a delimited area around ectocolpus) as well as apocolpium index. The pollen grains are monad, isopolar, small and radially symmetric, mostly prolate shapes, sometimes prolate-spheroidal or sub-prolate. The apocolpium index ranges from 0.00- 0.48, and the apertures are mostly tricolporate. The length of the (P) axis ranges from 7.31- 24.98µm, while the (E) diameter ranges from 4.72- 15.45µm, and P/E ranges from 1.04- 1.82. The colpi are long, oblong, or fusiform, with round to acute ends, and the aperture membrane is ornamented. Exine thickness ranges from 0.82- 2.48µm.

The species included in this type are *Adromischus cooperi*, *Aeonium decorum*, *Dudleya pulverulenta*, *Graptopetalum paraguayense*, *Kalanchoe beharensis*, *K. blossfeldiana*, *K. daigremontiana, K. delagoensis*, *K. fedtschenkoi*, *K. laciniata*, *K. longiflora*, *K. marmorata*, *Sedum adolphi*, and *S. album* (Figs. 1 & 2 a, b, d, h, i, j, k, l, m, n, o, p, q, r). *Kalanchoe delagoensis* can be delimited from the rest of species by having tri-syncolporate pollen grains (Figs. 1 & 2 i). Certain combinations of pollen morphological characteristics, such as shape classes and the presence/ absence of the aperture margo, can be used to delimit the species included in this pollen type.

Key to the pollen Kalanchoe type

1+ Pollen grains prolate spheroidal..... (*Dudleya pulverulenta*, *Kalanchoe beharensis* & *K. daigremontiana)*
- Pollen grains not as above..... 2
2+ Pollen grains subprolate.....*Sedum adolphi*
- Pollen grains prolate 3
3+ Margo absent..... (*Aeonium decorum, Graptopetalum paraguayense, Kalanchoe blossfeldiana, K. longiflora, K. marmarota*& *Sedum album*)
- margo present.....4
4+ Pollen grain polarly tri -syncolporate .....*Kalanche delagoensis*
- Pollen grain not as above..... (*Adromischus cooperi, Kalanchoe fedtschenkoi* & *K. laciniata*)

Discussion

Crassulaceae is a morphologically diverse and systematically complex family. It exhibits highly complex cytological and chromosomal variations (Uhl, 1948; Mort et al., 2010). The morphology of pollen grain is one of the most stable diagnostic criteria in the identification and classification of flowering plants (Walker & Doyle, 1975; EL-Atroush et al., 2015).

The pollen morphology of the studied species showed considerable variations in their measurable characters *viz*., polar axis, equatorial diameter, colpi length, and mesocolpia distance. Erdtman (1952) and Faegri & Iversen (1964), described Crassulaceae as europalynous family. The current investigation identified three types of pollen shapes: prolate-spheroidal, subprolate, and prolate. The most frequent pollen shape among the species studied is prolate. Moreover, the sculpturing pattern of the tectum is diverse and is considered as a key pollen character of the family Crassulaceae. This finding corroborated with that of Erdtman (1952), Hideux (1981) and Qaiser et al. (2015), who indicated the taxonomic value of tectum ornamentation pattern in the family Crassulaceae. In the current study the predominantly tectum ornamentation is rugulate besides being foveolate which rarely has striated sculpture pattern. Based on tectum sculpture pattern and pollen shape classes, three main pollen types were identified: *Crassula* type, *Echeveria* type and *Kalanchoe* type.

Crassula perforata can be clearly distinguished from the other species investigated by having a striated tectum sculpture pattern. This result coincides with that reported by Erdtman (1952, 1986). The separation of *Crassula* in a distinct group is in accordance with most infra-familial classification systems of the famiy, *viz*., Berger (1930), Thiede & Eggli (2007) and Thorne & Reveal (2007) among others, since they placed *Crassula* species in a separate subfamily, Crassuloideae. Moreover, based on morphological and molecular analysis, Karakish et. al. (2016) and Salim et al. (2019), supported the treatment of genus *Crassula* in a distinct subfamily Crassuloideae.

Pollen morphology of *Echeveria nodulosa*, *E. secunda* and *E. setosa* showed considerable variation within species, within a single inflorescence and even within a single flower. This result agrees with those of Kim (1994) and González-Mancera et al. (2016 & 2018), who pointed out the variations in pollen morphology within the same inflorescence of Crasulaceaen taxa. The recorded basic pollen aperture type for *Echeveria* species is tri-colporate (*E. setosa*). However, both tetra- and penta-colporate grains have been recorded in the pollen grains of *E. nodulosa and E. secunda*. The variation in pollen aperture is often associated with heterostyle or zygomorphy which is associated with reproductive systems or pollination strategy (Punt & Nienhuis, 1976; Mignot et al., 1994; Barrett, 2002).

The *Kalanchoe* type is the largest pollen type which contains the most studied Crassulacean species. Species included in this pollen type can be further classified based on the pollen shape, class, and the presence or absence of aperture margo. *Dudleya pulverulenta*, *Kalanchoe beharensis*, and *K. daigremontiana* are characterized by prolate-spheroidal pollen shape, tricolporate with prominent margo and rugulate tectum. *Sedum adolphi* can be distinguished from the remaining species of the *Kalanchoe* type by the subprolate grains. The present findings are consistent with the general pollen morphology of Crassulaceae family reported by Qaiser et al. (2015) and Shahrestani & Faghir (2021). Pollen grains aperture showed differences among the species included under *Kalanchoe* type, most of which having tri-angul-colporate grains. *Kalanchoe laciniata* can be delimited from the rest of the studied species by three to tetra- colporate grains. This finding was previously reported by Payne (1972) and Kim (1994).

Jin-Hwan et al. (2002) studying the pollen morphology of Korean Crassulaceae, stressed the taxonomic relevance of the presence/ absence of aperture margo in determining the generic boundaries. In the present study, pollen grains with margo along the colpus delineated *Adromischus cooperi, Kalanchoe delagoensis, K. fedtschenkoi, K lacinata* and *Sedum album* from the other examined species, which helped to distinguish between *Sedum album* and *Sedum adolphi*. Thiede & Eggli (2007), emphasized the importance of margo aperture in the family Crassulaceae. Based on morphological features described by Baldwin (1938), Uhl (1948), and Karakish et al. (2016) as well as molecular traits by Mort et al. (2010) and Salim et al. (2019), a tight link between the

Adromischus and *Kalanchoe* genera has been revealed.

Conclusion

The studied Crassulacean species showed considerable variations in the pollen morphological characteristics, notably shape, class, number of apertures and tectum ornamentation. Based on overall characteristics of pollen grains, some combinations of pollen morphological characters can reliably delimitate genera, while others are unique to some species. Regardless of the limited range of taxa considered, the present study corroborated to some extent with the classification systems of the family into three subfamilies. Nonetheless, a more comprehensive study encompassing more taxa and using other parameters appears to be required in a bid to achieve a reliable relationship between the Crassulacean species.

Conflict of interests: The authors report no conflicts of interest regarding this work.

Authors' contributions: Azza Shehata, Mona Shiha supervised the practical work and wrote the manuscript, Safa Mohamed gathered the specimens, did the practical work, Wafaa Taia participated in the manuscript revision and Mohamed Salim shared in the specimen's collection, writing the manuscript, designed the plates and responded to journal reviewers.

Ethical approval: Not applicable.

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الشكل الظاهري لحبوب اللقاح لبعض وحدات الفصيلة الكراسيولية

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تعتبر العائلة الكراسيولية إحدى عائلات كاسيات البذور الواسعة الانتشار والمتنوعة مورفولوجيا. قدمت الدراسة وصفا للصفات الظاهرية الدقيقة لحبوب اللقاح لتسعة عشر نوعا تمثل تسعة أجناس من العائلة الكراسيولية بمصر بواسطة كل من المجهر الضوئي والمجهر الإلكتروني الماسح. هدفت الدراسة إلى تقييم الأهمية التصنيفية لصفات حبوب اللقاح في الفصل بين الأنواع ومدى مساهمتها في فهم الالتباس التصنيفي للأنواع المنتمية إلى العائلة. أظهرت صفات حبوب اللقاح تباينا بين الأنواع المدروسة من حيث الشكل فقد سجلت الدراسة ثلاثة أشكال prolate-spheroidal, subprolate or prolate كما أوضحت الدراسة تباينا في فتحات الإنبات حيث تراوحت بين ثلاثة واربعة وخمسة فتحات إنبات مركبة بيضاوية الشكل. بدراسة السطح الخارجي لحبوب اللقاح تبين وجود أنماط مختلفة من الزركشة منها striate , foveolate ,regulate. اعتمادا على نمط زركشة السطح الخارجي لحبوب اللقاح تم تقسيم الأنواع المدروسة إلى ثلاثة مجاميع هي: Crassula type, Echeveria type, Kalanchoe type. تم تصميم مفتاح تعريفى لأنواع حبوب اللقاح والأنواع التابعة لكل مجموعة من المجاميع الثلاثة اعتمادا على شكل حبوب اللقاح ونمط زركشة السطح الخارجي.