

Seed Morphology and Seed Coat Sculpturing of 32 Taxa of Family Brassicaceae

Kasem, W.T.¹, Ghareeb, A.² and Marwa, E.²

¹ Botany and Microbiology Department, Faculty of Science, Al-Azhar University, Cairo, Egypt (Now Associate Prof. in Jazan University, Faculty of Science, Kingdom of Saudi Arabia)

² Botany Department, Faculty of Science, Zagazig University, Cairo, Egypt

ataawael@yahoo.com

Abstract: Seed exomorphic characters of 32 taxa of Brassicaceae were investigated by LM and SEM. The diagnostic characters at the generic and specific level are, seed shape, dimensions, colour, epidermal cells, and seed coat surface and aspect of anticlinal and periclinal walls. Seed shape among the studied taxa showed wide range of variations. LM revealed most of the studied seeds vary from globose to oblong-ellipsoid or elongate. Most of the seeds have no wings except *Farsetia aegyptia*. SEM investigation at higher magnifications revealed main six types of seed surface sculpture; reticulate, ocellate, foveate, papillate, stellate and domate. The seed exomorphic criteria obtained from LM and SEM were analyzed by the STATISCA program package using the UPGMA clustering method. Produced data facilitate the construction of a dendrogram between the studied taxa. Two groups are represented from the first group included the taxa of Tribe Arabideae, Lepidieae, Matthioleae, Sisymbrieae, Alysseae, Chamireae, Schizopetaleae, Stenopetaleae, Drabeae, Euclidieae, Lunariae, and Streptantheae. The second group included the most commonly known genera of the tribe Brassiceae.

[Kasem, W.T., Ghareeb, A. and Marwa, E. Seed Morphology and Seed Coat Sculpturing of 32 Taxa of Family Brassicaceae. Journal of American Science 2011;7(2):166-178]. (ISSN: 1545-1003).

<http://www.americanscience.org>.

Keywords: Brassicaceae (Cruciferae); Seed coat sculpture; LM; SEM; numerical taxonomy

1. Introduction

The Brassicaceae, which currently includes 3709 species and 338 genera (Warwick *et al.* 2006), is one of the ten most economically important plant families (Rich, 1991). In Brassicaceae, much attention was paid to the general anatomy of the seed coat and its taxonomic use particularly in species of economic value (Berggren, 1962). Discrimination between Brassicaceae seeds is very difficult with the naked eye or lens. On the other hand, Heywood, 1993 stated that the cruciferae is classified into 13 tribes, Arabideae, Hesperideae, Lepidieae, Matthioleae, Sisymbrieae, Alysseae, Brassiceae, Chamireae, Schizopetaleae, Stenopetaleae, Helphiteae, Cremolobeae, Drabeae, Euclidieae, Lunariae, and Streptantheae only two tribes, the Brassiceae and Lepidieae can be regarded as natural. It is the reason why micromorphological structures have been observed on the surface of the seeds (Bernard, 2000). Most systematists agree that data concerning the macro-and microstructure of seeds are very significant for the classification of Angiosperm taxa. In *Brassica* species, relatively numerous reports concerning the seed coat structure have been published (Mulligan and Bailey, 1976; Buth and Roshan, 1981; Setia and Richa, 1989 and Ren and Bewley, 1998). In Egypt, Täckholm (1974) reported 61 genera and 106 species and El-Hadidi & Fayed (1995) reported 55 genera and 108 species. Several recent studies of different seed coat characters have employed scanning electron microscopy (SEM). For example,

Vaughan and Whitehouse (1971) studied the macro and micromorphological characters of approximately 90 genera and 200 species of Brassicaceae and paid special attention to the relationships between structure and existing taxonomy. The exo-and endomorphic characters of Brassicaceae seeds have been studied by Musil (1948), Murley (1951), Berggren (1962), Corner (1976), Jonsell (1986), El-Naggar (1987, 1996), Fayed and El-Naggar (1988, 1996), El-Naggar and El-Hadidi (1998). Koul *et al.* (2000) gave detailed descriptions of seed morphology in 44 species of the subtribes Brassicinae, Raphaninae and Moricandiinae, and elucidated the phylogenetic relationships between taxa. More recently, Tantawy, *et al.* (2004) studied the macro and micromorphological characters of approximately 22 genera, 30 species of Brassicaceae. The present work concern with the exomorphic studies of certain Brassicaceae seeds by using LM and SEM to emphasize seed surface structure considered as a distinguished taxonomic character.

2. Materials and Methods

Seeds of 32 taxa representing 18 genera, 30 species, 1 ssp. and 2 varieties of Brassicaceae were obtained from the Royal Botanic Gardens at Kew, London, UK, and from different localities in Egypt. Studied local taxa were identified according to Täckholm (1974) and Boulos (1999). The studied taxa are given in Table 1.

Table 1. Localities of the studied taxa of the Brassicaceae.

No.	Characters Taxa	Serial Number	Location	Collection Date
1	<i>Brassica oleracea</i> S.I.L	0070498	England	1988
2	<i>B. oler. var. capitata</i> L.	---	Egypt	2009
3	<i>B. oler. var. botrytis</i> L.	---	Egypt	2009
4	<i>B. rapa</i> L	0020747	Switzerland	1974
5	<i>B.nigra</i> (L.) koch	0070395	England	1988
6	<i>B. tournefortii</i> Gouan	0184696	Egypt	2002
7	<i>Cardamine flexuosa</i>	1071	England	1988
8	<i>Cardamine hirsuta</i>	387109	Brukina-Faso	2007
9	<i>Capsella bursa-pastoris</i> DC.	---	Egypt	2009
10	<i>Coronopus didymus</i> (L.) Sm.	0076065	England	1989
11	<i>Descurainia sophia</i> (L.) Webb	0497413	Jordan	2008
12	<i>Diplotaxis erucoides</i> (L.)DC	0113946	Jordan	1996
13	<i>D.harra</i> (forssk) Boiss.	---	Egypt	2009
14	<i>D. tenuifolia</i> (L.)DC	064824	England	1986
15	<i>Eruca Sativa</i> Miller	---	Egypt	2010
16	<i>Erysimum cheiri</i> (L.) Crantz	0026716	France	----
17	<i>Farsetia aegyptia</i> Turra	---	Egypt	2010
18	<i>Hirschfeldia incana</i> (L.) Lagr. Fossat	0115249	Lebanon	1996
19	<i>Lepidium sativum</i> L.	0071831	Oman	1987
20	<i>Raphanus sativus</i> L.	---	Egypt	2010
21	<i>R. raphanistrum</i> L.	0071853	Oman	1989
22	<i>Moricandia sinaica</i> (Boiss.) Boiss.	---	Egypt	2010
23	<i>Matthiola longipetala</i> (Vent) DC. spp. <i>incana</i> (L.) R.Br	---	Egypt	2010
24	<i>Sinapis alba</i> L.	200095	Jordan	2003
25	<i>S. arvensis</i> L.	0115272	Lebanon	1996
26	<i>S. allionii</i> Jacq.	---	Egypt	2010
27	<i>Sisymbrium orientale</i> L.	0158808	Jordan	2001
28	<i>S. altissimum</i> L.	0175935	Belgium	1989
29	<i>S. irio</i> L.	---	Egypt	2009
30	<i>S. officinale</i> (L.) Scop	0053257	England	1984
31	<i>Schouwia thebaica</i> Webb.	---	Egypt	2010
32	<i>Thlaspi perfoliatum</i> L	0113876	Jordan	1996

The dry mature seeds were cleaned, and examined by light microscope to show the different exomorphic parameters viz. shape, dimensions, colour and seed surface texture. Five to ten seeds for each taxon were taken to cover the range of variations. For SEM investigation, the seeds were dried and fixed to specimen stubs with an adhesive and placed on the revolving discs of Joel fine coat ion sputter (Joel, JFC 1100). Each seed was uniformly coated with gold. Specimens stubs were then fixed to the specimen holder of Scanning Electron Microscope (Joel JSM 350) maintained at accelerating potential voltage of 15 Kv. and

photomicrographs were taken at different magnifications in Unit of at the Scanning Electron Microscopy Unit in Alexandria University (Egypt). This study is dependent upon the application of a total of 28 comparative seed exomorphic characters and their states as a binary character (0 & 1), on each taxa. The characters and states have been subjected to numerical analysis under an program using similarity and dissimilarity assessment percentage method (Rohlf, 1993). The method applied is based on cluster analysis by using an UPGMA (unweighted pair-group method with arithmetic means).

3. Results and Discussion

***Brassica oleraceae*:** Globose seeds, brownish-black with globrous surface. Seed size 1.5×2.0 mm, seed wing absent. Seed coat ornamentation revealed the anticlinal walls are identical and showed ferrucate pattern, in addition flakes of wax-like structure of various size are seen over the seed surface. Crakes are found on their surface (Fig.1).

***B. oler. var. capitata*:** Globose seeds and black, globrous surface. Seed size 1.0 ×1.3 mm, seed wing absent. SEM revealed the anticlinal walls are identical and showed regulate ornamentation, randomly reticulate surface pattern with weakly outlined polygonal cells found (Fig. 2).

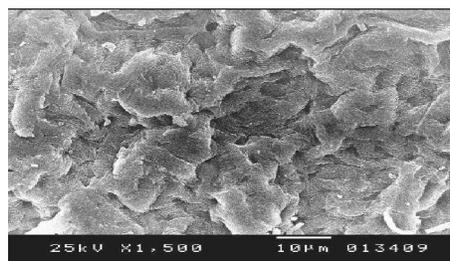
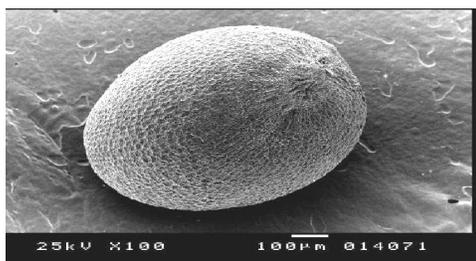
***B. oler. var. botrytis* :** Globose seeds, black with globrous surface. Seed size 1.0×1.5 mm, seed wing absent. The seed coat showed; seed surface pattern is identical and regulate in addition irregular reticulate

sculpture with peripheral particles (colliculate) of various size and number (Fig.3).

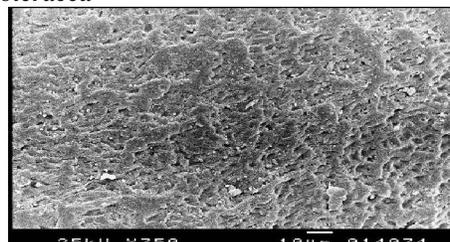
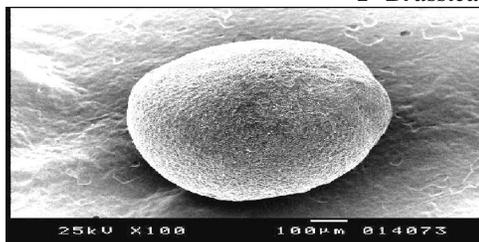
***B. rapa*:** Globose seeds are found, black in color and globrous in texture. Seed size 1.0 ×1.5 mm, seed wing absent. Seed coat which examined by SEM revealed seed surface pattern is identical and showed regulate ornamentation, polygonal pits of outer periclinal cell wall (Fig.4).

***B. nigra*:** Seeds are globose black in color with globrous texture. Seed size 1.0 ×1.5 mm, seed wing absent. SEM revealed seed surface pattern is identical. Polygonal pits of outer periclinal cell wall are found on their surface (Fig.5).

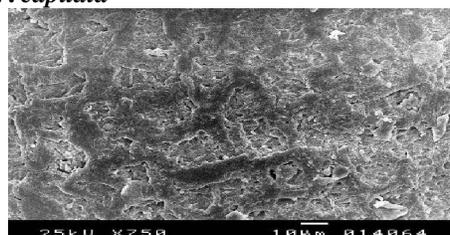
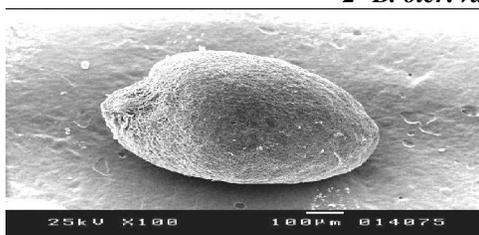
***B. tournefortii*:** Globose seeds and dark brown with globrous texture. Seed size 1.0 ×1.2 mm, seed wing absent. The examinations of seed coat revealed papillate structure; anticlinal walls are more or less broad and smooth and the periclinal walls are deeply depressed smooth (Fig.6).



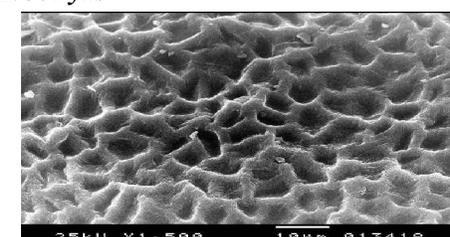
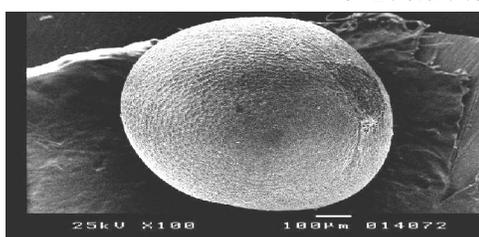
1- *Brassica oleracea*



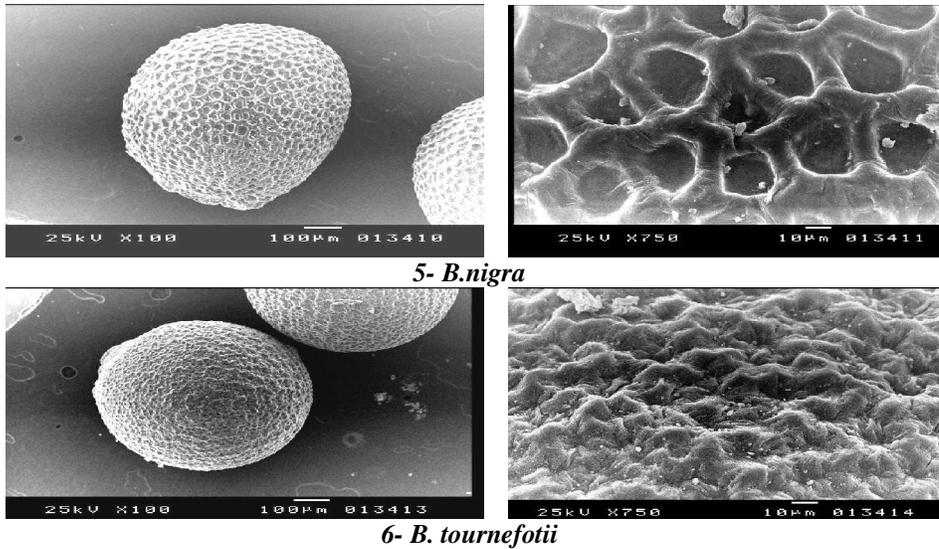
2- *B. oler. var. capitata*



3- *B. oler. var. botrytis*



4- *B. rapa*

5- *B. nigra*6- *B. tournefortii*

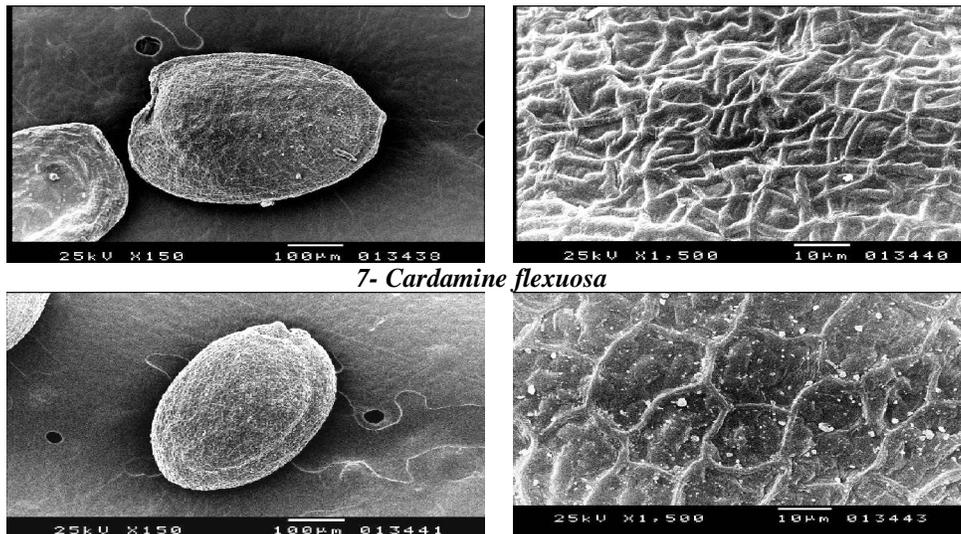
***Cardamine flexuosa*:** Oblong-ellipsoid seeds and reddish brown with globrous texture. Seed size 1.0×0.5 mm, seed wing absent. SEM revealed presence of undulate pattern in which unregulated structures are present (Fig.7).

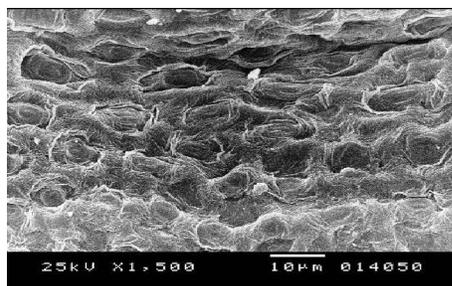
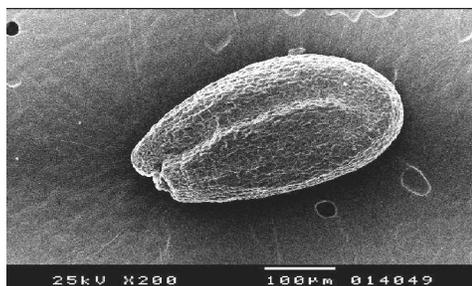
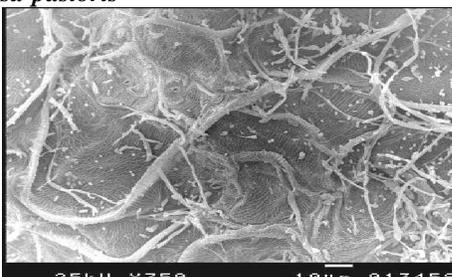
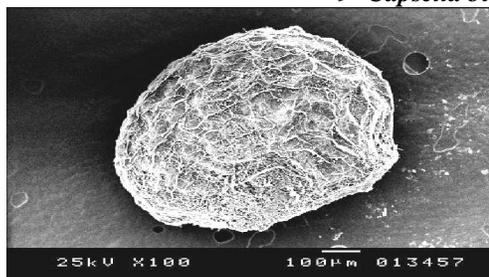
***Cardamine hirsute*:** kidney shape seeds and shiny brown with globrous texture. Seed size 0.8 ×1.0 mm, seed wing absent. SEM revealed microreticulate structure. The periclinal cell wall with sunken central portion found (Fig. 8).

***Capsella bursa-pastoris*:** Oblong-ellipsoid seeds, and reddish brown with globrous texture. Seed size is

small 1.0×0.5 mm, seed wing absent. SEM showed reticulate-papillate patterns in which irregular periclinal cell wall has been noticed (Fig.9).

***Coronopus didymus*:** Seeds are small in size, kidney shaped, and shiny brown with globrous texture. Seed size 0.8 ×1.0 mm, seed wing absent. SEM revealed the smooth surface and stellate-like structure has been noticed. Epidermal cell shape irregular polygonal cells. Anticlinal boundaries raised-channelled, straight to sinuous; smooth to fine folds periclinal cell wall slightly concave smooth to medium folds (Fig.10).

7- *Cardamine flexuosa*8- *Cardamine hirsute*

9- *Capsella bursa-pastoris*10- *Coronopus didymus*

Descurainia Sophia: Kidney in shape, and shiny brown in color with globrous texture. Seed size 0.8 ×1.0 mm, seed wing absent. SEM revealed bright dull spherical particles are regularly cover all seed surface or completely sunken in the epidermal cells. (Fig.11).

Diplotaxis eruroides: Seeds kidney, and yellowish with globrous texture. Seed size 1.0 ×0.5 mm, seed wing absent. SEM revealed outer periclinal cell wall with irregularly formed pits. In addition compactly wax-like materials are present on their surface (Fig. 12).

D.harra: Seeds are oblong, subglobose in shape, brown in color with globrous in texture. The seed size 0.8 ×1.2 mm, seed wing absent. SEM revealed rugose-striate sculpture on their seed surface (Fig.13).

D. tenuifolia: Seeds are oblong in shape brown in color with globrous in texture. Seed size 0.2×1.0 mm, seed wing absent. SEM revealed reticulate patterns, absence of particles on their surface (Fig.14).

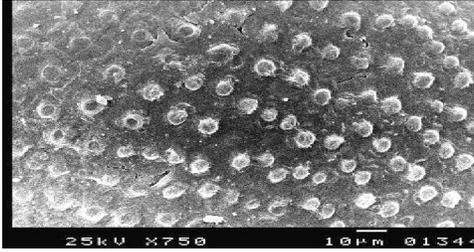
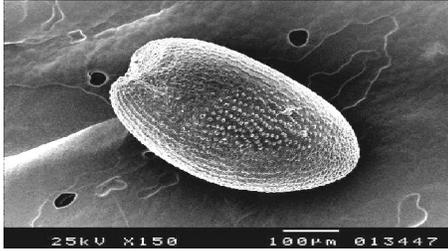
Eruca Sativa: Subglobose seeds, brown and globrous texture. The seed size 1.7×1.4 mm, seed wing absent. SEM revealed epidermal cell shape isodiametric, 5-6 gonial, elongate in one direction Anticlinal boundaries raised, straight to slightly sinuous; smooth to fine folds. In addition periclinal cell wall concave with medium striate structure (Fig.15).

Erysimum cheiri: Oblong ovate seeds, orange-brown in color with globrous texture. The seed size 3.0×1.3 mm, seed wings present. SEM revealed ocellate structure in which flat central portion; periclinal isodimetric and polygonal cell wall smooth to folded are present (Fig.16).

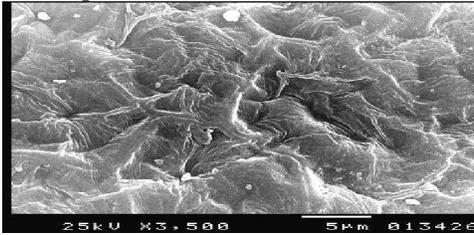
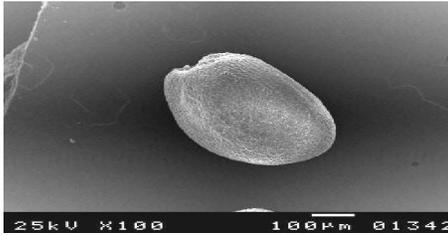
Farsetia aegyptia: Seeds small in size, kidney shaped, brown -orange with globrous texture. Seed size 3.6×5.0 mm, small seed wings present. Seed exomorphic by SEM revealed reticulate ornamentation, epidermal cells patterns show tetra, pentagonal and nearly isodimetric forming a network form. A very small particles are scattered on their surface (Fig.17).

Hirschfeldia incana: Seeds are kidney, and shiny brown with globrous texture. Seed size 0.8×1.0 mm, seed wing absent. SEM revealed reticulate patterns, small particles present. Anticlinal boundaries cell are highly raised in one direction; straight to sinuous; periclinal cell wall flat to concave structure (Fig.18).

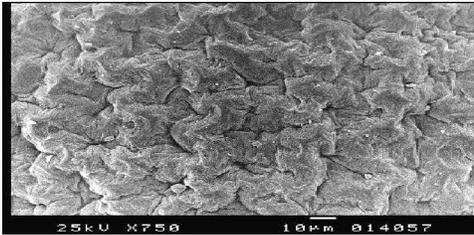
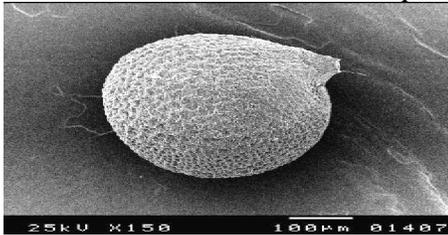
Lepidium sativum : Obliquely ovate seeds, brown with globrous texture. Seed size 1.0×2.5 mm, seed wing absent. SEM revealed epidermal cell shape isodiametric, elongate in one direction, 4-5-6 gonial. Anticlinal boundaries highly raised, straight with smooth form (Fig.19).



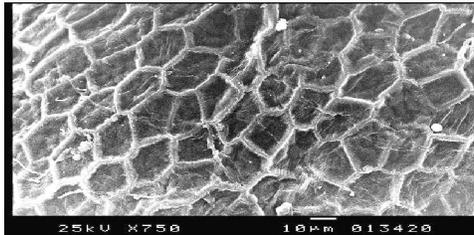
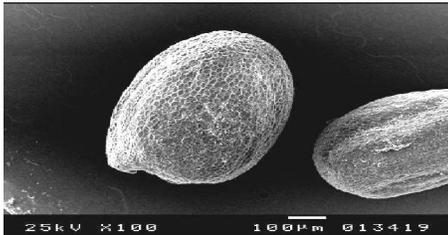
11- Descurainia Sophia



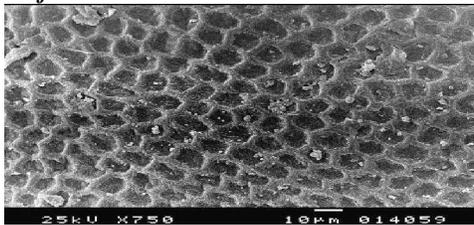
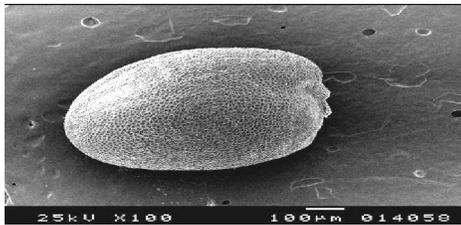
12- Diplotaxis eruroides



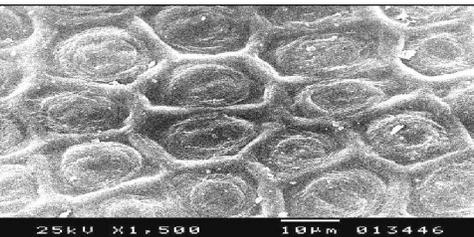
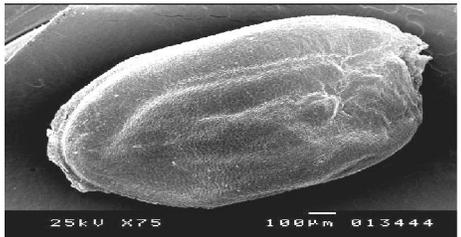
13- D.harra



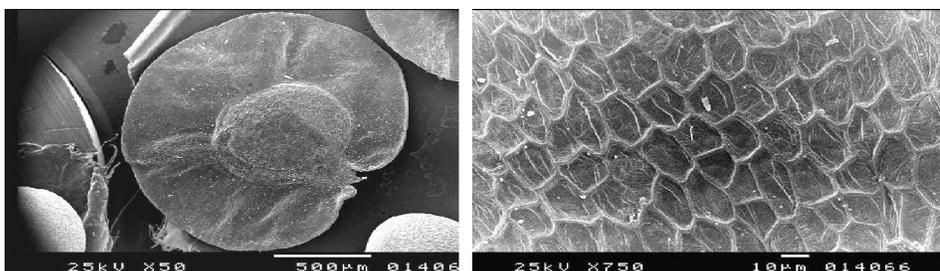
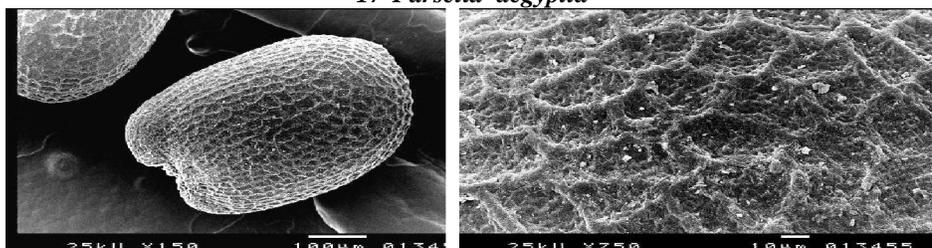
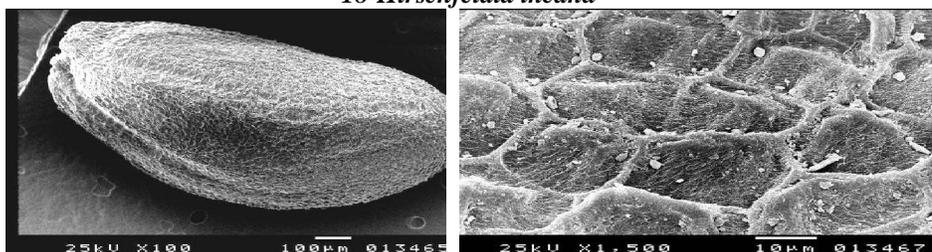
14- D. tenifolia



15- Eruca Sativa



16- Erysimum cheiri

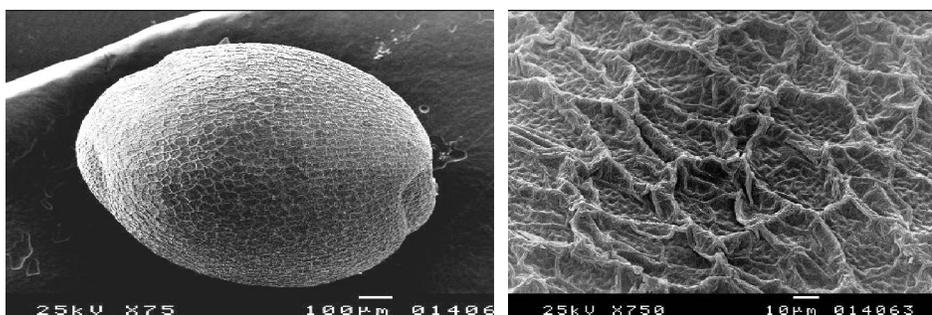
*17-Farsetia aegyptia**18-Hirschfeldia incana**19-Lepidium sativum*

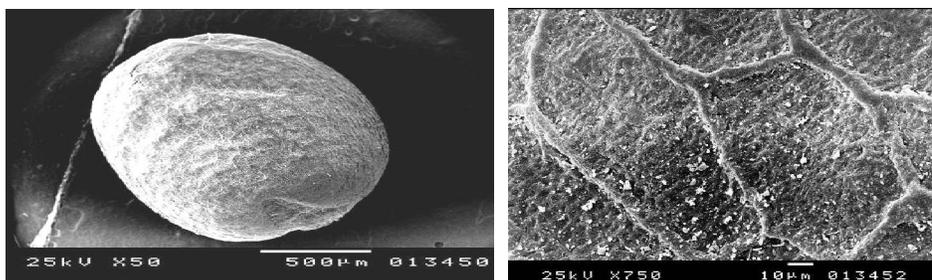
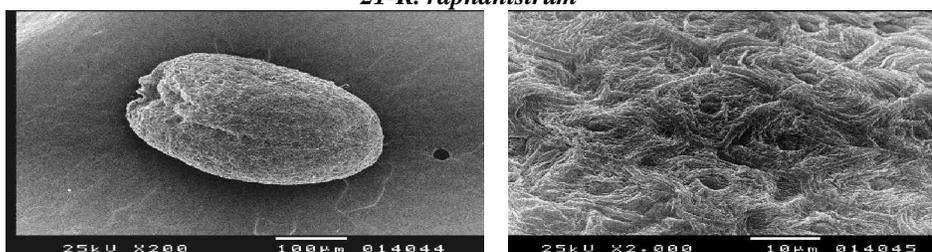
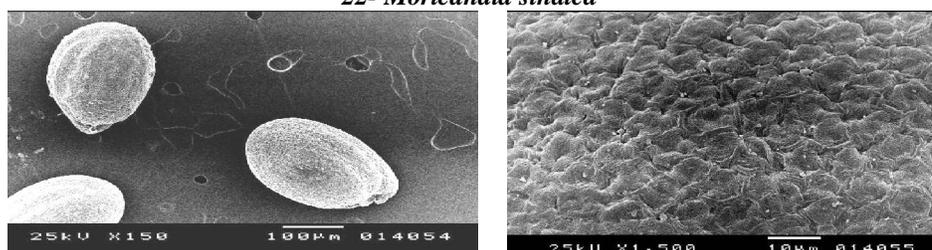
Raphanus sativus: Seed are kidney and shiny brown with globrous texture. Seed size 0.8×1.0 mm, seed wing absent. SEM revealed reticulate ornamentation, epidermal cells patterns show tetra, pentagonal and nearly isodimetric. A small particles are scattered on their surface (Fig.20).

R. raphanistrum : kidney shaped seeds, and shiny brown with globrous texture. Seed size 0.8×1.0 mm, seed wing absent. SEM revealed reticulate seed coat pattern showing isodiametric polygonal cells (Fig.21).

Moricandia sinaica : Seeds are oblong-ellipsoid in shape, and orange with globrous texture. Seed size 0.2×0.5 mm, seed wing absent. SEM revealed reticulate with spherical particles are completely sunken in the epidermal cells and interwoven appearance were recorded on their surface (Fig.22).

***Matthiola longipetala* (Vent) DC. spp. incana**: Globose seeds, and yellowish in color with globrous texture. The seed size 1.5×0.2 mm, seed wing absent. SEM revealed flat to slightly concave; fine to coarse folds is present (Fig.23).

*20-Raphanus sativus*

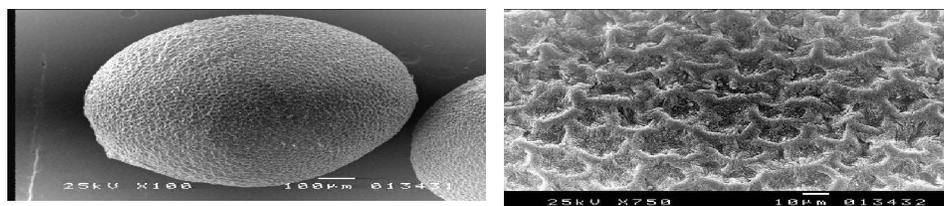
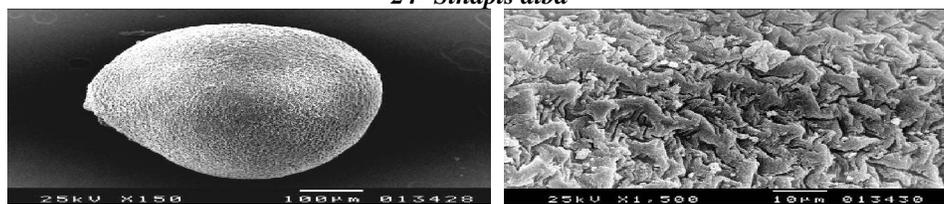
**21-*R. raphanistrum*****22-*Moricandia sinaica*****23-*Mathiola longipetala* spp. *incana***

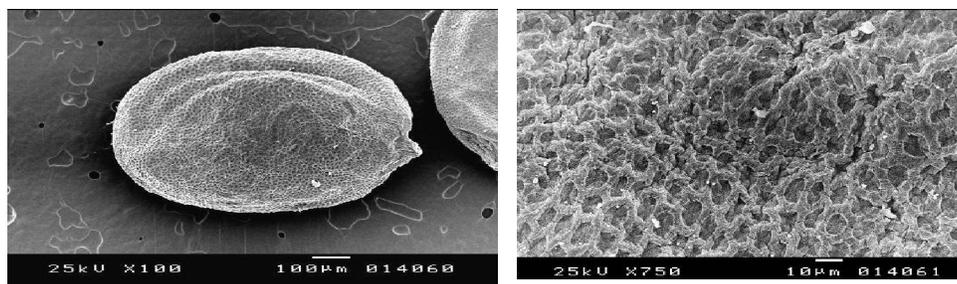
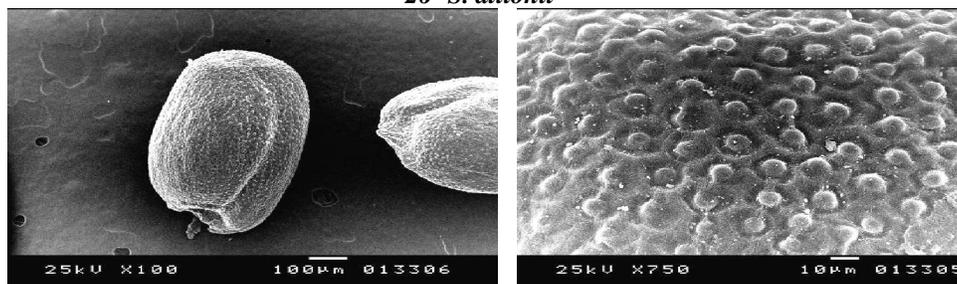
Sinapis alba: Globose in shape, and brown in color with globrous in texture. The seed size 2.0×3.0 mm, seed wing absent. SEM revealed irregular reticulate patterns (Fig.24).

S. arvensis: Globose seeds, and dark brown with globrous texture. The seed size 1.0× 0.5 mm, seed wing absent. SEM revealed rugae show folds on their walls, giving the appearance of stellate structures. Thin long cracks radiating from the pleurogram are seen on the seed surface (Fig.25).

S. allionii : Globose seeds, orange brown with globrous texture. The seed size 0.8 ×1.0 mm, seed wing absent. SEM revealed reticulate seed coat pattern. testa cells with highly raised anticlinal cell boundaries (Fig.26).

Sisymbrium orientale: Oblong seeds, yellowish with globrous texture. Seed size 1.0×0.5 mm, seed wing absent. SEM revealed smooth to folded ocellate epidermal cell shape present; domate cell wall with globular central papillae (Fig.27).

**24-*Sinapis alba*****25-*S. arvensis***

26- *S. allionii*27- *Sisymbrium orientale*

S. altissimum: Seeds are oblong-ellipsoid in shape, and reddish brown in color with globrous in texture. The seed size 1.0×0.5 mm, seed wing absent. SEM revealed ocellate pattern; periclinal cell wall with sunken central papilla present (Fig.28).

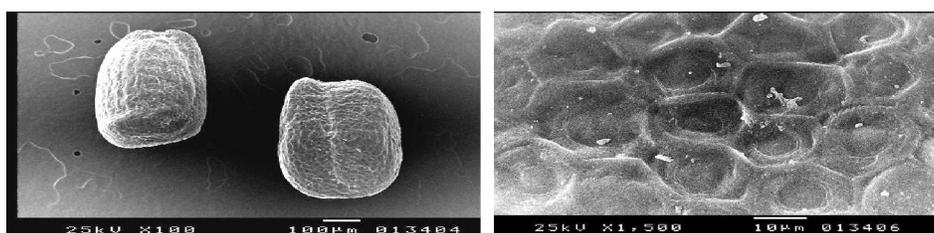
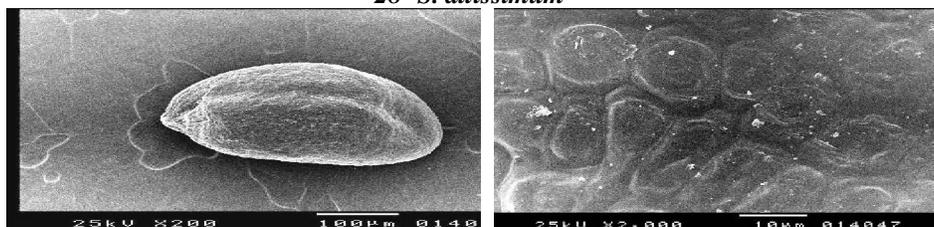
S. irio: Small in size, oblong in shape, and yellowish with globrous in texture. Seed size 1.0×0.5 mm in width, seed wing absent. SEM revealed epidermal cell shape isodiametric, polygonal, anticlinal channeled straight to sinuous, periclinal cell wall appear flat or concave with central position radiate-striate (Fig.29).

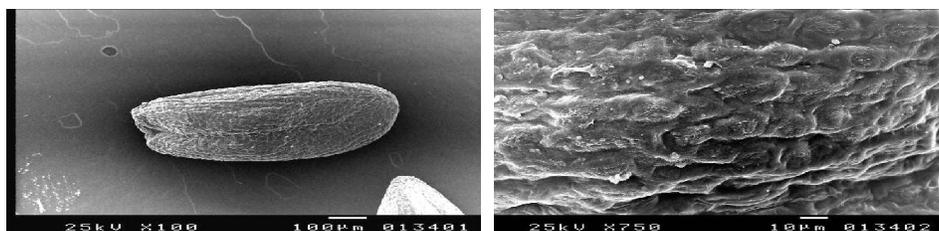
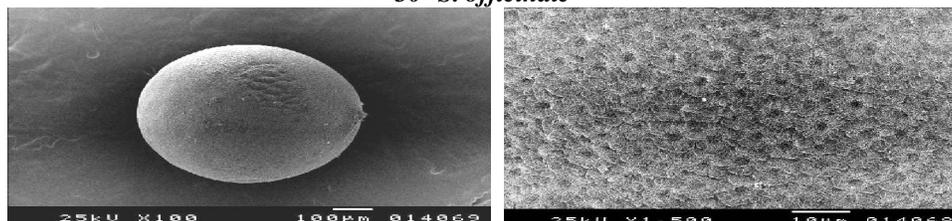
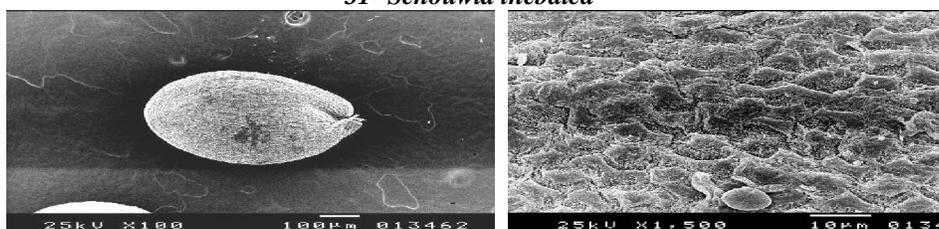
S. officinale: Seeds are oblong in shape, and dark brown in color with globrous in texture. The seed size

1.0×1.5 mm, seed wing absent. SEM showed that periclinal cell wall with little sunken central papilla (Fig.30).

Schowia thebaica: Seeds are circular in shape, brown in color with globrous in texture. The seed size 1.5×2.5 mm, seed wing absent. SEM revealed ocellate pattern with several sunken central papilla on their structure (Fig.31).

Thlaspi perfoliatum: Seeds are globose in shape, yellow in color with globrous in texture. Seed size 1.0×0.5mm, seed wing absent. SEM revealed sinuous cell wall; periclinal cell wall convex and micro-papillate (Fig.32).

28- *S. altissimum*29- *S. irio*

30- *S. officinale*31- *Schouwia thebaica*32- *Thlaspi perfoliatum*

The dendrogram produced from the cluster analysis between the 32 taxa based on the seed exomorphic characters is represented in Fig 33. From the dendrogram; the taxa are separated at taxonomic level of 100.0%. Two groups are represented; the first group included the studied taxa of Tribe Arabideae, Lepidieae, Matthioleae, Sisymbrieae, Alysseae, Chamireae, Schizopetaleae, Stenopetaleae, Drabeae, Euclidieae, Lunariae, and Streptantheae. The second group included the most commonly known genera of the tribe Brassiceae such as the six species of genus *Brassica*, *Diplotaxis*, *Raphanus* and *Hirschfeldia*) this is in accordance with work of Al-Shehbaz, *et al.* 2006. Within the second group, the three species of *Sinapis* are separated at taxonomic level of 17.0%. On the other hand, *Schouwia thebaica* is separated at single taxonomic level of 78.0%.

The seed shape among the taxa showed wide range of variations. Most of the seeds vary from globose to oblong-ellipsoid or elongate. However, they are globose in the six species of genus *Brassica*, three species of *Sinapis* and *Thlaspi perfoliatum*. Kidney shape in *Coronopus didymus*, *Descurainia* and *Cardamine hirsuta* and *Diplotaxis erucoides*, circular in *Farsitea aegyptiaca* Obliquely ovate in *Raphanus sativus*, oblong in the three species of *Sisymbrium* (*orientale*, *irio* & *officinale*). The seed shape as observed in the present study seems to be diagnostic at the generic level. Most of the

investigated seeds have no wings, but in *Farsetia aegyptia* wing is present and may be apical (small) or marginal (largely expanded). Presence or absence of wing to be of diagnostic value in distinguishing between the studied taxa. Our data showed marked similarities with earlier studies of Kapil *et al.* (1980) and Abdel Khalik *et al.* (2002). Seed size vary greatly between the present taxa. However, the largest seed size of 3-4×1.3-1.5 *Farsetia aegyptia* and *Erysimum cheiri*, relatively large (range from 1.2-2.0 mm) in 5 taxa, (*Brassica oleraceae*, *Mathiola longipetalae*, *sinapis alba*, *Schouwia thebaica* and *Eruca sativa*). The smaller size was found in the studied taxa of *Diplotaxis tenifolia* and *Moricandia sinaica*. Several studied taxa are shared in size of 0.8×1.0; these taxa are *Cardamine hirsute*, *Coronopus didymus*, *Hirschfeldia incana*, the two species of *Raphanus* and *Sisymbrium allionii*.

In similar, the seed size of 1.0×0.5 were noticed in several taxa such as the four taxa of *Sisymbrium*, *Capsella bursa-pastoris*, *Cardamine flexus* and *Diplotaxis erucoides* and *Sinapis arvensis*. The seed size as a variable criterion is considered diagnostic for some extent. This is in accordance with the work of Aniszewski *et al.* (2001) and El-Tantawy *et al.*, 2004. On the other hand, seed surface in all taxa, is glabrous and to be unreliable criterion to use at the generic and specific level.

Table 2. The seed morphological characters as seen by LM and SEM between taxa of the family.

N o.	Characters Taxa	L×W	Shape	Texture	Color	Anticlinal cell wall	Periclinal cell wall	Seed Surface
1	<i>Brassica oleracea</i>	1.5×2.0	Globose	glabrous	brown	raised	concave	wax like materials
2	<i>B. oler. var. capitata</i>	1.0 ×1.3	Globose	glabrous	black	straight	concave	randomly reticulate
3	<i>B. oler. var. botrytis</i>	1.0 ×1.5	Globose	glabrous	brown	raised	concave	Reticulate-foveate
4	<i>B. rapa</i>	1.0 ×1.5	Globose	glabrous	brown	raised	depressed	Foveate pattern
5	<i>B. nigra</i>	1.0 ×1.5	Globose	glabrous	black	raised	concave	microreticulate
6	<i>B. tournefortii</i>	1.0 ×1.2	Globose	glabrous	dark -brown	Highly-raised	domate	papillate
7	<i>Cardamine flexuosa</i>	1.0×0.5	oblong-ellipsoid	glabrous	reddish brown	sunken	concave	undulate
8	<i>Cardamine hirsuta</i>	0.8 ×1.0	kidney	glabrous	Pale-brown	Slightly raised	concave	microreticulate
9	<i>Capsella bursa-pastoris</i>	1.0×0.5	oblong-ellipsoid	glabrous	orange brown	raised	sunken	ocellate
10	<i>Coronopus didymus</i>	0.8 ×1.0	kidney	glabrous	shiny - brown	Raised-cannelled	folded	stellate-like
11	<i>Descurainia sophia</i>	0.8 ×1.0	kidney	glabrous	Shiny-brown	raised	sunken	dull spherical
12	<i>Diplotaxis erucoides</i>	1.0 ×0.5	kidney	glabrous	yellow	broad raised	deeply depressed	reticulate
13	<i>D. harra</i>	0.8 ×1.2	subglobose	glabrous	brown	broad raised	deeply depressed	rugose-striate
14	<i>D. tenuifolia</i>	0.2×1.0	subglobose	glabrous	Brown	raised	concave	reticulate
15	<i>Eruca Sativa</i>	1.7×1.4	oblong	glabrous	Brown	Raised	Flat to convex	reticulate
16	<i>Erysimum cheiri</i>	3.0×1.3	Oblong	glabrous	orange-brown	raised	Flat to convex	ocellate
17	<i>Farsetia aegyptia</i>	3.6×5.0	circular	glabrous	Brown	slightly raised	slightly concave	reticulate
18	<i>Hirschfeldia incana</i>	0.8×1.0	kidney	glabrous	Brown	raised	pitted	reticulate patterns
19	<i>Lepidium sativum</i>	1.0×2.5	kidney	glabrous	brown	raised	pitted	microreticulate
20	<i>Raphanus sativus</i>	0.8×1.0	Obliquely ovate	glabrous	Shiny-brown	slightly raised	flatted	reticulate
21	<i>R. raphanistrum</i>	0.8×1.0	kidney	glabrous	shiny - brown	raised	pitted	reticulate
22	<i>Moricandia sinaica</i>	0.2×0.5	oblong-ellipsoid	glabrous	orange	raised	pitted	reticulate
23	<i>Matthiola longipetala spp. incana</i>	1.5×0.2	globose	glabrous	yellow	raised	clumped	domate
24	<i>Sinapis alba</i>	2.0×3.0	globose	glabrous	brown	raised	depressed	reticulate
25	<i>S. arvensis</i>	1.0× 0.5	globose	glabrous	dark brown	raised	depressed	Stellate
26	<i>S. allionii</i>	0.8 ×1.0	globose	glabrous	orange-brown	Raised	Convex	reticulate
27	<i>Sisymbrium orientale</i>	1.0×0.5	oblong	glabrous	yellow	Raised	papillate	ocellate
28	<i>S. altissimum</i>	1.0×0.5	oblong-ellipsoid	glabrous	orange-brown	Raised	papillate	ocellate
29	<i>S. irio</i>	1.0×0.5	oblong	glabrous	yellow	sinuous	domate	domate
30	<i>S. officinale</i>	1.0×1.5	oblong	glabrous	Dark- brown	domate	sinuous	papillate
31	<i>Schouwia thebaica</i>	1.5×2.5	Circular	glabrous	brown	raised	depressed	ocellate
32	<i>Thlaspi perfoliatum</i>	1.0×0.5	Globose	glabrous	yellow	raised	depressed	micro-papillate

Table 3. The resulted 29 binary characters of the studied spp. (Characters & States are symbolized for numerical analysis).

Taxa	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32		
Stat Recognized																																		
Seed colour																																		
1-Black 1/ Yellow 0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2- Brown 1, reddish brown 0	1	0	1	1	0	1	0	0	0	1	1	0	1	1	1	0	1	1	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	
3- orange 1/ orange brown 0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	1		
Seeds Surface																																		
4-globrous 1/ rough 0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
L/W																																		
5- 1.0 x1.5 1/ 1.0 x1.5 0	0	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	1	0	1	1	1	0	0	1	1	1	1	1	1	1	0	0		
Seed Shape																																		
6- globose 1/ sub globose 0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0		
7- kidney 1/ heart 0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	
8- ovate 1/ obliquely ovate 0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1		
9- shiny 1/ shiny brown 0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1		
10- oblong 1/ oblong-ellipsoid 0	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1		
Anticlinal cell wall																																		
11- raised, 1/ sunken, 0	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1		
12- slightly raised 1/ high raised 0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		
13- sinuous 1 /domate 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		
periclinal cell wall																																		
14- depressed 1 /deeply depressed 0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1		
15- concave 1/ convex 0	1	1	1	0	1	0	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
16- flattened 1 /sinous 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		
Seed coat pattern																																		
17-Reticulate	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0		
18-microreticulat	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0		
19- Reticulate- foveate	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
19-undulate	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
20-ocellate	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1		
21-foveate	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
22-domate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		
23-Reticulate- foveolate	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
24-Wax-like materials	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
25-papillate	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		
27-micropapillate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		
28-rugose-striate	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

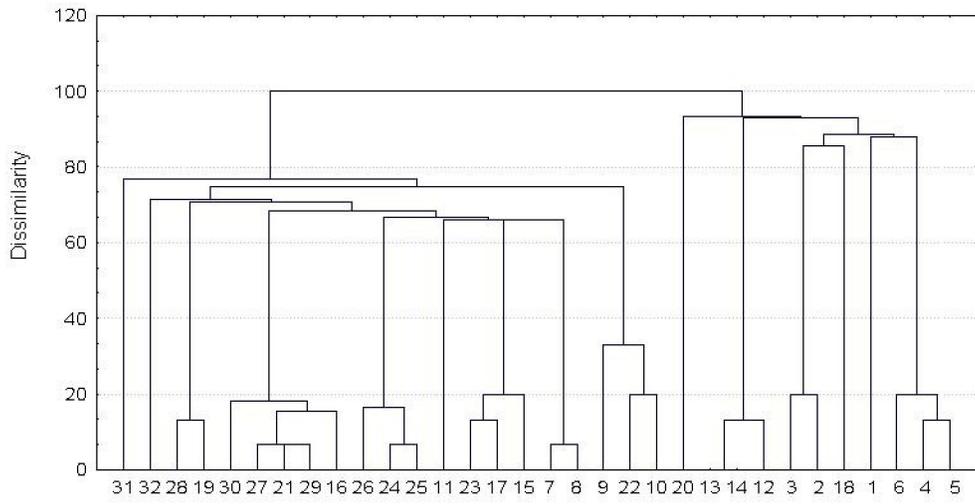


Figure 33. UPGMA dendrogram based on seed characters between the studied taxa of the family.

Seed colour varies from brown, dark brown, pale brown black, orange-brown to shiny brown (Table 2). Seed colour is diagnostic at the generic and specific level for some extent. The data of seed colour is compatible with that mentioned before by Dahlgren and Clifford (1982) and Barthlott (1984).

SEM investigation revealed main six types of seed sculpture; reticulate, ocellate, rugose, papillate, stellate and domate. The reticulate seed surface pattern

is the basic type in the majority of the studied taxa (15 taxa). The separation between them based on the aspects of anticlinal and periclinal walls. Ocellate type was recorded in *Capsella bursa-pastoris*, *Erysimum cheiri*, *Sisymbrium orientalen*, *S. altissimum* and *Schouwisia thebaica*. Papillate form was noticed in *B.tournefortii*, *Sisymbrium officinale* and *Thlaspi perfoliatum*. Stellate structure was found in *Coronopus didymus* and *S. arvensis* and domate structure was

found in only two species *Mathiola longepetalae* and *Sisymbrium irio*. From the SEM data, it was noticed that: the seed surface sculpture, aspects of the anticlinal and periclinal walls can serve as good diagnostic parameters at the generic and specific level in the studied Brassicaceae. This is in accordance with the work of Barthlott (1981, 1984), Fayed and El-Naggar (1996) and Abdel Khalik and Maesen (2002) and Tantaway *et al.*, 2004.

Corresponding Author:

Dr. Wael Taha Kasem

Botany and Microbiology Department, Faculty of Science, Al-Azhar University, Cairo, Egypt.

The present address: Associate Prof. in Jazan University, Faculty of Science, Kingdom of Saudi Arabia.

E-mail: ataawael@yahoo.com

References

1. Abdel Khalik, K. and Maesn, V. 2002. Seed morphology of some tribes of Brassicaceae (Implication for taxonomy and species identification for the flora of Egypt). *Blumea*, 47: 363–83
2. Abdel Khalik, K., Maesn Van Der, El Hadidi, M, El Maghraby, and El-Naggar, S. 2002. Biosystematic studies on Brassicaceae (Cruciferae) in Egypt. Ph.D. Thesis Wageningen University, Egypt
3. Al-Shehbaz, A. , Beilstein, M. A and Kellogg, E. A. 2006: Systematics and phylogeny of the Brassicaceae (Cruciferae): an overview. Volume 259, Numbers 2-4, 89-120, DOI: 10.1007/s00606-006-0415-z .
4. Aniszewski, T., Mervi, K. and Leinonen, A. 2001. Seed number, seed size and seed diversity in Washington Lupin (*Lupinus polyphyllus* Lindl). *Ann. Bot.*, 87: 77-82
5. Barthlott, W., 1981. Epidermal and seed surface characters of plants: Systematic applicability and some evolutionary aspects. *Nord. J.*
6. Barthlott, W., 1984. Microstructural features of seed surface. In: Heywood, V.H. and D.C. Moore (eds.). *Current Concepts in Plant Taxonomy*. pp: 95–105. Academic Press, London *Bot.*, 1: 345–55
7. Berggren, G. 1962. Reviews on the taxonomy of some species of the genus *Brassica*, based on their seeds. *Svensk Bot. Tidskr.* 56: 65-135.
8. Bernard, C., 2000. Comparative seed micromorphology of *Brassica* L. and *Sinapsis* L. species growing in France. *Seed Sci. Technol.*, 3: 699– 707.
9. Boulos, L., 1999. *Flora of Egypt*. Vol. 1, pp: 181–230. Al Hadara Pub., Cairo
10. Buth GM and Roshan, A. 1981. Seed coat anatomy of some cultivated *Brassica*. *Phytomorphology* 31: 69–78.
11. Corner, E.J., 1976. *The Seeds of Dicotyledons*. 2 Vol. Cambridge University Press, Dahlgren, C., Cambridge M. and Clifford, H.: 1982. *The Monocotyledons*. Academic Press, London
12. Dahlgren, R.M. and Clifford, H.T. 1982. *The monocotyledons*. Academic Press, London.
13. El -Hadidi, M.N. and Fayed, A.A. 1995. Materials for Excursion Flora of Egypt, *Taekholmia* 15: 40-53.
14. El-Naggar, S.M. and M.N. El-Hadidi, 1998. The tribe Alysseae Hayek (Brassicaceae) in Egypt. *J. Union Arab Biol.*, 6: 501–20
15. El-Naggar, S.M., 1987. Studies of the family Cruciferae in Egypt. Ph.D. Thesis, Assiut University, Egypt
16. Fayed A.A. and El Naggar, S.M. 1988. Taxonomic studies on Cruciferae in Egypt 2.
17. Fayed, A.A. and S.M. El-Naggar, 1996. Taxonomic studies on Cruciferae in Egypt. 4. Seed morphology and taxonomy of the Egyptian species of Lepidieae. *Bull. Fac Sci Assiut Univ*, 25:43–50
18. Heywood, V.H., 1993. *Scanning electron microscopy. Systematic and evolutionary applications*, London
19. Jonsell, B., 1986. A monograph of *Farsetia* (Cruciferae). *Syst. Bot. Ups.* 25: 1-106
20. Kapil, R.N., J. Bor and F. Bouman, 1980. Seed appendages in Angiosperms. I. Introduction. *Bot. Jahrb. Syst.*, 101: 555–73
21. Koul, K., Ranjna, N. and Raina, S.N. 2000: Seed coat microsculpturing in *Brassica* and allied genera subtribes Brassicinae, Raphaninae, Moricandiinae). *Ann. Bot.*, 86: 85-97
22. Mulligan GA, Bailey LG. 1976. Seed coat of some *Brassica* and *Sinapis* weeds and cultivated in Canada. *Economic Botany* 30: 143–148.
23. Murley MR. 1951. Seeds of the Cruciferae of North Eastern America. *American Middle Naturalichen* 46:1–81.
24. Musil, A.F. 1948. Distinguishing species of *Brassica* by their seeds. U.S. Dept. Agr. Washington, D.C. Misc. Pub. No. 643: 35 pp
25. Ren, C, and Bewley, J, 1998. Seed development, testa structure and precocious germination of Chinese cabbage (*Brassica rapa* sub. *pekinensis*). *Seed Science Research* 8: 385–397.
26. Rich, T., 1991. *Crucifers of Great Britain and Ireland*. Botanical Society of the British Isles, London. 336 pp.
27. Rohlf, F. J. 1993. *NTsys-pc, Numerical taxonomy and multivariate analysis system*. Exeter Software Pub. (Ltd.), New York.
28. Setia, R., and Richa, R. 1989. Anatomical studies on siliqua wall and seed coat development in *Brassica juncea* (L.) Czern. & Coss. *Phytomorphology* 39:371–377.
29. Täckholm, V., 1974. *Student's Flora of Egypt*. 2nd Ed., Cairo. *Taekholmia* 11: 87-95.
30. Tantaway, M, Sayed, F., Soad A. and Ghalia, T. 2004: Seed exomorphic characters of some Brassicaceae (LM and SEM Study). *International J. of Agriculture and Biology*. 1560, 821–830
31. Taxonomic significance of the seed coat sculpture in species of Tribe Brassiceae.
32. Vaughan, J.G. and J.M. Whitehouse, 1971. Seed structure and the taxonomy of the Cruciferae. *Bot. J. Linn. Soc.*, 64: 73.
33. Warwick, S.I., Francis, A. and Al-Shehbaz, I.A. 2006. Brassicaceae: species checklist and database on CD-Rom. *Pl. Syst. Evol.* 259: 249–258.

12/12/2010