

Seed Exomorphic Characters of Some Brassicaceae (LM and SEM Study)

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ABSTRACT

The seed exomorphic characters of 34 taxa of Brassicaceae representing 22 genera, 30 species, three sub-species and four varieties were investigated by the aid of LM and SEM. The seed exomorphic characters that is diagnostic at the generic and specific level are, seed shape, dimensions, colour, epidermal cells, and seed surface sculpture, aspect of anticlinal and periclinal walls. The SEM investigation at higher magnifications revealed eight types of seed surface sculpture pattern, viz. reticulate which is the basic type, ocellate, rugose, alveolate-papillate, pusticulate, glebulate, domate, and undulate-domate. The seed exomorphic criteria extracted from LM and SEM investigation facilitate the construction of an artificial key for the studied taxa.

Key Words: Brassicaceae (Cruciferae); Seed coat sculpture; LM; SEM

INTRODUCTION

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; Vaughan *et al.*, 1971). Discrimination between Brassicaceae seeds is very difficult with the naked eye or lens. 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. Heywood (1971) drew attention to the importance and impact of Scanning Electron Microscope in the study of systematic problems by using this technique. Recently, the application of SEM in the study of the seed coat has become wide spread (Brisson & Peterson, 1976, 1977; Mulligan & Bailey, 1976; Stork *et al.*, 1980). Concerning the Brassicaceae, the exo- and endomorphic characters of seeds have been studied by Kondo (1917), McGugan (1948), Musil (1948), Murley (1951), Berggren (1962), Corner (1976), El-Naggar (1987, 1996), Fayed and El-Naggar (1988, 1996), El-Naggar and El-Hadidi (1998) and Abdel Khalik *et al.* (2002).

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. Jonsell (1986) and Koul *et al.* (2000) investigated the seed coat morphology and microsculpturing seed coat in certain genera of Brassicaceae and provided evidence for the close relationships among various genera.

The present investigation concern with the

exomorphic characters of seeds of certain Brassicaceae by using LM and SEM to emphasize the taxonomic significance of seed characters as a criterion for the separation of genera and species studied.

MATERIALS AND METHODS

In the present study 34 taxa of Brassicaceae have been collected representing 22 genera, 30 species, three sub-species and four varieties. The specimens represent wild as well as horticultural taxa collected from different localities as shown in Table I. The studied taxa were matched against the taxa kept in both Herbaria of Ain Shams University (CAIA) and Cairo University (CAI), and identified according to Bailey (1949), Montasir and Hassieb (1956), Täckholm (1974) and Boulos (1999). The voucher specimens of the studied taxa are kept in CAIA.

Only mature seeds were taken for investigation. The dry 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). Where each seed was uniformly coated with 20-30 nm thick gold. These 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 (seed in whole mount with X= 50 and Seed scan with X=2000).

Table I. Collection data and sources of collection

No	Taxa	*	No	Taxa	*
1	<i>Biscutella didyma</i> L.	6	18	<i>E. sativa</i> Mill. v. <i>oblongifolia</i> Passq.	1
2	<i>Brassica kaber</i> Wheeler	1	19	<i>Erucaria hispanica</i> (L.) Druce.	3
3	<i>B. napus</i> L.	1	20	<i>Erysimum asperum</i> DC	4
4	<i>B. oleracea</i> L.	1	21	<i>Farsetia aegyptia</i> Turra.	5
5	<i>B. rapa</i> L.	1	22	<i>Ibris gibraltatica</i> L.	1
6	<i>B. tournefortii</i> Gouan	6	23	<i>Lepidium sativum</i> L.	1
7	<i>Cakile maritima</i> Scop.	3	24	<i>Lobularia libyca</i> (Viv) Tackh. C.F.W. Meissn.	3
8	<i>Capsella bursa-pastoris</i> (L.) Medik.	4	25	<i>L. maritima</i> (L.) Desv.	2
9	<i>Carrichtera annua</i> (L.) DC.	6	26	<i>Matthiola longipetala</i> (Vent) DC. spp. <i>bicornis</i> (Sibth) Ball.	4
10	<i>Coronopus didymus</i> (L.) Sm.	1	27	<i>M. longipetala</i> (Vent) DC. spp. <i>hitra</i> (Conti)	6
11	<i>Didesmus aegyptius</i> (L.) Desv.	6	28	<i>M. longipetala</i> (Vent) DC. spp. <i>incana</i> R.Br.	1
12	<i>D. bipinnatus</i> (Desf.) DC.	6	29	<i>Morettia philaeana</i> (Delile) DC	5
13	<i>Diplotaxis harra</i> (Forssk) Boiss.	5	30	<i>Raphanus raphanistrum</i> L.	5
14	<i>Enarthrocarpus pterocarpus</i> (Pres.) v. <i>hispidus</i> Pamp.	7	31	<i>R. sativus</i> L.	4
15	<i>E. pterocarpus</i> (Pres.) v. <i>pterocarpus</i> (Pres.) DC.	7	32	<i>Schouwia purpura</i> (Forsk) Schweinf.	1
16	<i>E. strangulatus</i> Boiss.	4	33	<i>Sinapis alba</i> L.	9
17	<i>Eruca sativa</i> Mill. v. <i>longirostris</i> (Uechtr) Ray	8	34	<i>Sisymbrium irio</i> L.	6

* Source of collection. 1- Botanical Garden, Botany Department, Faculty of Science, Ain Shams University Abassia, Cairo, Egypt; 2- Ramses Botanical Garden, Ramses Square, Cairo, Egypt; 3- Cairo- Alexandria Desert Road, Egypt; 4- Mediterranean Coast; 5- Cairo-Suez Desert Road Area, Egypt; 6- Botanical Garden, Garyounis University Area, Benghazi, Libya; 7- 23 July Garden, Benghazi, Libya; 8- Gwarsha Fields Area, Benghazi, Libya; 9- El-Aoally, Makka, Saudia Arabia.

The terms used for describing the seed coat patterns have been adopted according to Stearn (1992) and Koul *et al.* (2000). All photographs were taken at Central Lab. of Ain Shams University, Cairo, Egypt.

RESULTS AND DISCUSSION

The seed morphological characters of the studied Brassicaceae as shown by LM and SEM are reviewed in the following (Table II; Fig. 1–74). Fig. 39, 40, 59, 60 and 67, 68 are not representative because the seeds of these taxa were not available.

***Biscutella didyma* (Fig. 1 & 2).** Seeds muchly compressed, sub-orbicular with smooth surfaces. Seeds relatively large 1.5x2 mm in dimensions (L X W) with orange colour. SEM investigation indicated that the seed surface sculpture is reticulate. The anticlinal walls are broad, raised with smooth-lineolate surfaces. The periclinal walls are shallow depressed with lobed- lineolate surfaces.

***Brassica kaber* (Fig. 3 & 4).** Seeds are small 1x1.5 mm in dimensions, globose with smooth surfaces and dark brown colour. SEM indicated that there is deposition of epicuticular wax layer over the seed surface showing the clear reticulate appearance with wide lumens at higher magnifications. The seed surface pattern at higher magnifications is reticulate with smooth raised anticlinal walls and shallow depressed periclinal walls.

***B. napus* (Fig. 5 & 6).** Seeds are relatively large 1.1x2.6 mm in dimensions. Seeds ovate-elliptic with smooth surfaces and dark brown colour. SEM shows rugose-striate seed surface sculpture. The anticlinal walls broad and highly raised with striate surfaces. The periclinal walls are deeply depressed.

***B. oleracea* (Fig. 7 & 8).** Seeds relatively large, 1.5x2 mm, globose, glabrous with brownish colour. SEM revealed reticulate-alveolate surface pattern. The anticlinal walls broad, raised with smooth-striate surface. The periclinal walls are deeply depressed and hardly to describe (ill-

defined).

***B. rapa* (Fig. 9 & 10).** Seeds are relatively small, 1x1.5 mm. Seeds are globose with smooth surfaces and reddish-brown colour. SEM investigation showed that the seed surface sculpture is pusticulate with epicuticular flags or rods showing the rugose manner over the seed surface. The anticlinal wall is more or less narrow with smooth-striate surfaces. The periclinal walls are deeply depressed and appear as narrow slits.

***B. tournefortii* (Fig. 11 & 12).** Seeds are globose, small in sizes, 1x1.2 mm, with smooth surfaces and dark brown colour. SEM indicated that the seed surface pattern is reticulate. The anticlinal walls are broad and highly raised, with smooth surfaces and fine folds. The periclinal walls are depressed more or less distinct with smooth surfaces.

***Cakile maritima* (Fig. 13 & 14).** Seeds are oblong-ellipsoid, relatively large, 3-4x1-2 mm. Seed surface is smooth and with yellowish brown colour. SEM showed undulate-domate seed surface pattern. The anticlinal walls are shallow raised, broad, with smooth with irregularly arranged striae or folds running in different directions. The periclinal walls are very narrow and deeply depressed.

***Capsella bursa-pastoris* (Fig. 15 & 16).** Seeds are small with 1x0.5 mm dimensions. The seed shape is oblong ellipsoid with smooth surface and reddish-brown colour. SEM investigation showed reticulate-papillate seed surface pattern. The anticlinal walls are more or less broad, raised with smooth tops and slightly striated lateral sides. The periclinal walls are shallow depressed with central papillae or tubercles. The tops of the latter are smooth whereas the lateral sides are striated.

***Carrichtera annua* (Fig. 17 & 18).** Seeds are relatively small, 1.2x1 mm. Shape sub-globose with smooth surface and brownish colour. SEM indicated ocellate seed surface pattern with broad raised circular borders. The anticlinal walls are smooth-striated at their lateral sides and tops. The periclinal walls are slightly distinct with slightly convex centers as tubercles with smooth surfaces.

Table II. Morphological seed characters of the studied Brassicaceae as revealed by LM & SEM

No	Characters Taxa	Seed Morphology LM				
		Size	Dimension	Shape	Texture	Color
1	<i>Biscutella didyma</i>	Medium	1.5 X 2	Sub-orbicular	Glabrous	Orange
2	<i>Brassica kaber</i>	Small	1 X 0.5	Globose	Glabrous	Dark brown
3	<i>B. napus</i>	Relatively large	1.1 X 2.6	Ovate-elliptic	Glabrous	Dark brown
4	<i>B. oleracea</i>	Relatively large	1.5 X 2	Globose	Glabrous	Brownish-black
5	<i>B. rapa</i>	Relatively small	1 X 1.5	Globose	Glabrous	Reddish-brown
6	<i>B. tourneforti</i>	Small	1 X 1.2	Globose	Glabrous	Dark-brown
7	<i>Cakile maritima</i>	Relatively large	3-4 X 1-2	Oblong ellipsoid	Glabrous	Yellowish-brown
8	<i>Capsella bursa-pastoris</i>	Small	1 X 0.5	Oblong ellipsoid	Glabrous	Reddish-brown
9	<i>Carrichtera annua</i>	Relatively small	1.2 X 1	Sub-globose	Glabrous	Brownish
10	<i>Coronopus didymus</i>	Small	0.8 X 1	Kidney shape	Glabrous	Orange-shiny brown
11	<i>Didesmus aegyptius</i>	Relatively small	1 X 1.5	Ovoid	Glabrous	Brownish
12	<i>D. bipinnatus (Desf.) DC.</i>	Relatively small	1.5 X 1	Ovoid	Glabrous	Brownish
13	<i>Diplotaxis harra</i>	Small	0.8 X 1.2	Oblong ellipsoid	Glabrous	Yellowish-brown
14	<i>Enarthrocarpus pterocarpus v. hispidus</i>	Small	1.5 X 1	Oblong ellipsoid	Glabrous	Brownish
15	<i>E. pterocarpus v. pterocarpus</i>	Small	1.5 X 1	Oblong ellipsoid	Glabrous	Brownish
16	<i>E. strangulata</i>	Small	1.2 X 1	Ellipsoid	Glabrous	Brownish
17	<i>Eruca sativa v. longirostris</i>	Relatively large	1.8 X 1.5	Sub-globose	Glabrous	Dark brown
18	<i>E. sativa v. oblongifolia</i>	Relatively large	1.8 X 1.5	Sub-globose	Glabrous	Dark brownish
19	<i>Erucaria hispanica</i>	Small	1.5 X 1	Sub-globose	Glabrous	Brownish
20	<i>Erysimum asperum</i>	Relatively large	3 X 1.5	Oblong ovate, winged	Glabrous	Brown-orange
21	<i>Farsetia aegyptia</i>	Large	4-6 X 5	Ovoid, winged	Glabrous	Brown-orange
22	<i>Ibris gibraltaria</i>	Large	4-6 X 5.5	Orbicular	Glabrous	Brown-orange
23	<i>Lepidium sativum</i>	Relatively large	3 X 1	Obliquely ovate	Glabrous	Brown
24	<i>Lobularia libyca</i>	Medium	1.5 X 2	Ovate-sub-orbicular	Glabrous	Brownish
25	<i>L. maritima</i>	Relatively small	1.5 X 1	Ovate-sub-orbicular	Glabrous	Brownish
26	<i>Matthiola longipetala spp. bicornis</i>	Medium	1.5 X 2	Sub-orbicular, winged	Glabrous	Light-brown
27	<i>M. longipetala spp. hirta</i>	Relatively small	1.5 X 1	Sub-orbicular	Glabrous	Brownish
28	<i>M. longipetala spp. incana</i>	Relatively large	2 X 0.5	Oblong-elliptic, winged	Glabrous	Brownish
29	<i>Morettia philaena</i>	Relatively small	1.5 X 1-1.3	Ellipsoid-ovoid	Glabrous	Brownish
30	<i>Raphanus raphanistrum</i>	Relatively large	1.5 X 2.5	Sub-globose-ovate	Glabrous	Brown
31	<i>R. sativus</i>	Relatively large	2 X 3	Globose	Glabrous	Brown
32	<i>Schouwia purpura</i>	Medium	1.3 X 1	Circular-sub-orbicular	Glabrous	Brownish
33	<i>Sinapsis alba</i>	Relatively large	2 X 3	Globose	Glabrous	Whitish-brown
34	<i>Sisymbrium irio</i>	Small	1 X 0.5	Oblong-ellipsoid	Glabrous	yellowish

No	Seed Morphology SEM						
	Epidermis	Pattern	Anticlinal Wall	Elevation	Surface	Periclinal Wall Elevation	Surface
1	Developed	Reticulate	Broad	Raised	Smooth-lineolate	Shallow depressed	Folded-lineolate
2	Developed	Reticulate	Narrow	Raised	Smooth	Shallow depressed	Smooth
3	Developed	Rugose-striate	Broad	Raised	Striate	Deeply depressed	Ill-defined
4	Developed	Reticulate-alveolate	Broad	Raised	Smooth-striate	Deeply depressed	Ill-defined
5	Developed	Pusticulate	± Narrow	Raised	Smooth-striate	Deeply depressed	Ill-defined
6	Developed	Reticulate	± Broad	Raised	Smooth-folded	Depressed	Smooth-folded
7	Ill developed	Undulate-domate	± Broad	± Raised	Striate	Shallow depressed	Folded
8	Developed	Reticulate-papillate	Broad	Raised	Smooth-striate	Shallow depressed	Folded-papillate
9	Developed	Ocellate	Broad	Raised	Smooth-striate	Depressed	Coarsely folded or tuberculate
10	Developed	Reticulate	Broad	Raised	Coarsely-striate	Shallow depressed	Striate
11	Developed	Reticulate-striate	Broad	Raised	Smooth-striate	Shallow depressed	Smooth-striate
12	Developed	Reticulate	Broad	Raised	Smooth-striate	Deeply depressed	Smooth
13	Developed	Reticulate	± Broad	Raised	Smooth	Shallow depressed	Smooth
14	Developed	Reticulate	± Broad	Raised	Smooth-fine folds	Shallow depressed	Smooth-septate
15	Developed	Reticulate	± Broad	Raised	Smooth	Deeply depressed	Ill-defined
16	Developed	Reticulate	± Broad	Raised	Smooth	Deeply depressed	Ill-defined
17	Developed	Reticulate-ocellate	Broad	Raised	Smooth-segmented striate	Shallow depressed	Clumped
18	Developed	Glebulate	Broad	Raised	Smooth-segmented striate	Shallow depressed	Clumped
19	Developed	Reticulate	Broad	Raised	Smooth-segmented striate	Shallow depressed	Striate-lineolate
20	Developed	Reticulate	± Broad	± raised	Smooth	Shallow depressed	Smooth-foldedor tuberculate
21	Developed	Reticulate	± Broad	± raised	Smooth-ciliate	Shallow depressed	Smooth-folded
22	Ill developed	Rugose	± Broad	Raised	Smooth	Shallow depressed	Folded
23	Developed	Reticulate-rugose	± Broad	Raised	Smooth	Shallow convex	Striate-folded
24	Developed	Reticulate-glebulate	± Broad	Raised	Smooth-striate	Shallow depressed	Folded-striate
25	Developed	Reticulate	± Broad	Raised	Smooth	Shallow depressed	Smooth-folded
26	Developed	Reticulate	± Broad	Raised	Smooth	Shallow convex	Folded-striate
27	Developed	Domate	± Broad	Raised	Smooth-cracked	Shallow convex	Folded-striate
28	Developed	Reticulate	± Broad	Raised	Smooth	Shallow convex	Folded-striate
29	Developed	Ocellate	± Broad	Raised	Smooth	Shallow depressed	Smooth-folded
30	Developed	Reticulate-glebulate	± Broad	Raised	Smooth	Shallow depressed	Smooth-folded
31	Developed	Reticulate-glebulate	± Broad	Raised	Smooth	Shallow depressed	Smooth-folded
32	Developed	Ocellate	± Broad	Raised	Smooth-segmented striate	Shallow elevated	Cracked with central papillae
33	Ill developed	Reticulate-sulcate	± Broad	Raised	Smooth-segmented striate	Shallow elevated	Segmented-smooth
34	Developed	Alveolate-papillate	Narrow	Raised	Smooth	Shallow depressed	Smooth-papillate

The seed morphological characters as seen by LM and SEM facilitate the construction of an artificial key for distinguishing the studied taxa

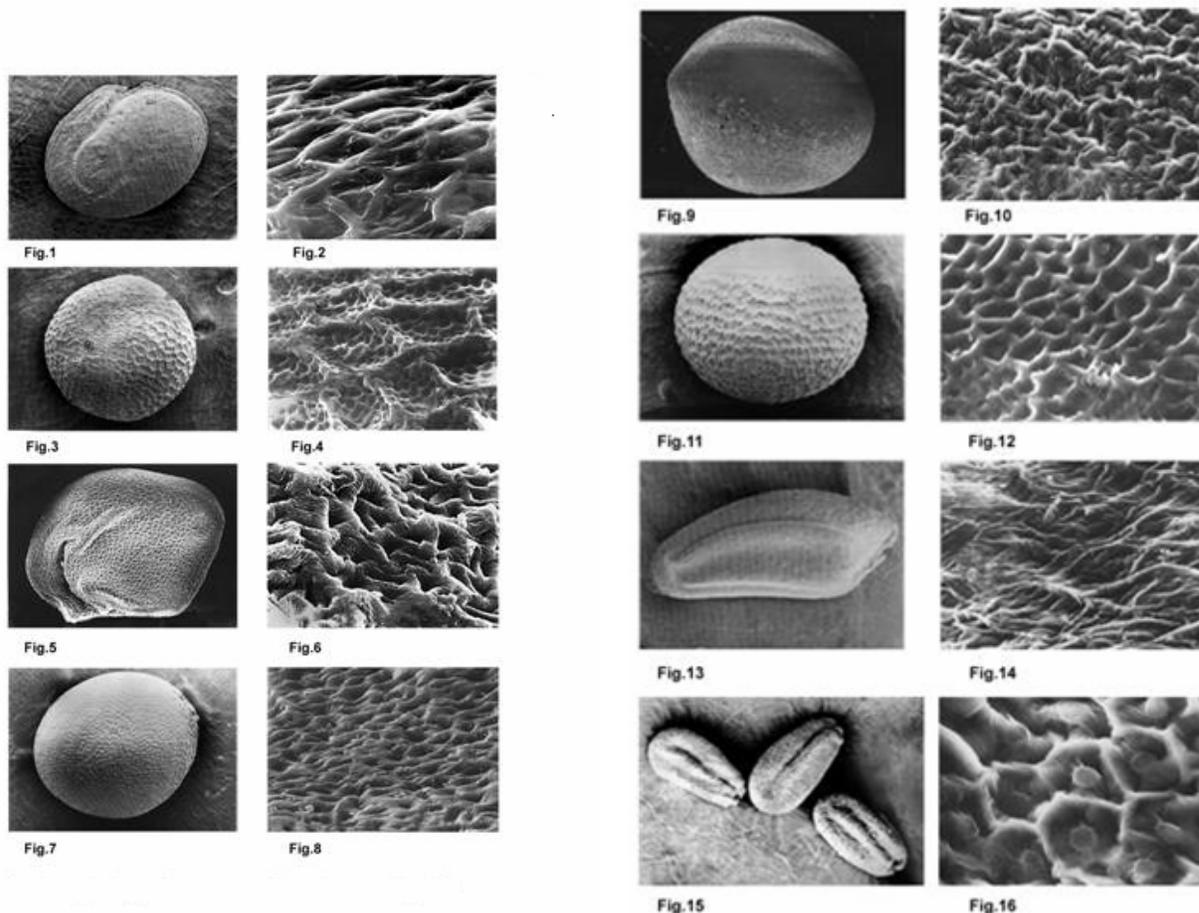
Seed morphological characters	Taxa
A ₁ - Seed surface is alveolate-papillate	<i>Sisymbrium irio</i>
A ₂ - Seed surface sculpture is domate	<i>Matthiola longipetala</i> spp. <i>hitra</i>
A ₃ - Seed surface sculpture is pusticulate	<i>Brassica rapa</i>
A ₄ - Seed surface sculpture is undulate-domate	<i>Cakile maritima</i>
A ₅ - Seed surface sculpture is glebulate	<i>Eruca sativa</i> v. <i>oblongifolia</i>
A ₆ - Seed surface sculpture is rugose	
B ₁ -Anticlinal walls are striated, periclinal walls are deeply depressed and ill- defined	<i>Brassica napus</i>
B ₂ -Anticlinal walls are smooth, periclinal walls are shallow depressed and folded	<i>Ibris gibraltaria</i>
A ₇ -Seed surface sculpture is ocellate	
C ₁ -Seeds sub-globose, 1.2 x 1 mm, anticlinal walls smooth-striated, periclinal walls are depressed, and folded or tuberculate	<i>Carrichtera annua</i>
C ₂ -Seeds ellipsoid-ovoid, 1-1.5 x 1-1.3 mm, anticlinal walls are smooth, periclinal walls are folded.	<i>Morettia philaeana</i>
C ₃ -Seeds circular,sub-orbicular, 1.3 x 1 mm, anticlinal walls are smooth-segmented, periclinal walls elevated with central opened papillae.	<i>Schouwia purpurea</i>
A ₈ - Seed surface sculpture is reticulate as general	
D ₁ - Reticulate-sulcate	<i>Sinapsis alba</i>
D ₂ - Reticulate-rugose	<i>Lepidium sativum</i>
D ₃ - Reticulate-ocellate	<i>Eruca sativa</i> v. <i>longirostris</i>
D ₄ - Reticulate-striate	<i>Didesmus aegyptius</i>
D ₅ - Reticualte-papillate	<i>Capsella bursa-pastoris</i>
D ₆ - Reticulate- alveolate	<i>Brassica oleracea</i>
D ₇ - Reticulate-glebulate	
E ₁ -Seed ovate-sub-orbicular, 1.5 x 2, anticlinal walls are smooth and periclinal walls are shallow depressed, folded-smooth.	<i>Lobularia libyca</i>
E ₂ -Seeds sub-globose, 1.5 x 2 mm, anticlinal walls smooth and periclinal walls are shallow depressed folded	<i>Raphanus raphanistrum</i>
E ₃ -Seeds globose, 2 x 3 mm, anticlinal walls are smooth and periclinal walls are shallow depressed, folded-smooth	<i>Raphanus sativus</i>
D ₈ - Reticulate-winged seeds	
F ₁ -Seeds oblong-ovate, wing apical, 3 x 1.5 mm, anticlinal walls are smooth and periclinal walls are shallow depressed, folded or tuberculate	<i>Erysmium asperum</i>
F ₂ -Seeds ovoid, wings marginal, 4-6 x 5 mm, anticlinal walls are ciliate and periclinal walls are shallow depressed, smooth-folded	<i>Farsetia aegyptia</i>
F ₃ -Seed sub-orbicular, wing marginal, 1.5 x 2 mm, anticlinal walls smooth and periclinal walls shallow convex, folded-striate	<i>Matthiola longipetala</i> spp. <i>bicornis</i>
F ₄ -Seed elliptic-oblong, or sub-orbicular, 2 x 1.5 mm, anticlinal walls cracked and periclinal walls are folded-striate	<i>Matthiola longipetala</i> spp. <i>incana</i>
D ₉ - Reticulate with wingless seeds	
G ₁ - Ellipsoidal seed shape or oblong ellipsoidal	
H ₁ - Periclinal walls are deeply depressed and ill-defined	
I ₁ -Seeds are oblong ellipsoidal, 1.5 x 1	<i>Enarthrocarpus pterocarpus</i> v. <i>pterocarpus</i>
I ₂ - Seeds ellipsoid, 1.2 x 1	<i>Enarthrocarpus strangulatus</i>
H ₂ -Periclinal walls are shallow depressed and with irregularly folded or smooth- septate	
J ₁ -Seeds are yellowish-brown, 0.8 x 1.2 mm and periclinal walls irregularly folded	<i>Diplotaxis harra</i>
J ₂ -Seeds brownish, 1.5 x 1 and periclinal shallow depressed and smooth-septate .	<i>Enarthrocarpus pterocarpus</i> v. <i>hispidus</i>
G ₂ - Seed shapes otherwise	
K ₁ - Seeds brownish, 1.5 x 1 mm in dimensions	
L ₁ -Seeds ovoid, anticlinal walls are smooth-striated and periclinal walls are deeply depressed smooth	<i>Diplotaxis bipinnatus</i>
L ₂ -Sub-globose, anticlinal walls are segmented-smooth, striate and periclinal walls are shallow depressed clumped....	<i>Erucaria hispanica</i>
L ₃ -Ovate-sub-orbicular, anticlinal walls are smooth and periclinal walls are shallow depressed, smooth-folded	<i>Lobularia maritima</i>
K ₂ - Seeds are orange or dark brown in color	
M ₁ - Seeds globose and dark brown	
N ₁ -Seeds 1 x 0.5 mm, anticlinal walls are narrow, smooth and periclinal walls are shallow depressed, smooth	<i>Brassica kaber</i>
N ₂ -Seeds 1 x 1.2 mm, anticlinal walls are more or less broad and smooth and the periclinal walls are deeply depressed smooth	<i>Brassica tournefortii</i>
M ₂ - Seeds sub-orbicular, or kidney shape	
O ₁ -Sub-orbicular, 1.5 x 2 mm in dimensions, anticlinal walls broad, smooth- lineolate and periclinal walls are shallow depressed lineolate	<i>Biscutella didyma</i>
O ₂ -Kidney shape, 0.8 x 1 mm, anticlinal walls are broad and periclinal walls are shallow depressed. The surface of both walls are with coarse striate	<i>Coronopus didymus</i>

Coronopus didymus (Fig. 19 & 20). Seeds small, 0.8 x 1 mm, kidney shape with smooth surfaces and orange-shiny brown colour. SEM showed that the seed surface sculpture is reticulate. The anticlinal walls are broad, raised with fine and coarse striated folds on their surfaces. The periclinal walls are shallow depressed with fine and coarsely striated surfaces.

Didesmus aegyptius (Fig. 21 & 22). Seeds ovoid relatively small in dimension, 1 x 1.5 mm. Seed colour is brownish

and the seed surface is smooth. SEM investigation showed that the seed surface pattern is reticulate-striate with broad raised anticlinal walls and shallow depressed periclinal walls. The surface of both walls is smooth-striated.

D. bipinnatus (Fig. 23 & 24). Seeds relatively small, 1.5 x 1 mm, ovoid shape and brownish colour and smooth surfaces. SEM showed reticulate seed surface sculpture with thin film of epicuticular waxes overall the surface. The anticlinal walls are broad and highly raised. The tops and lateral sides

Fig. 1. Microphotographs of seed surface sculpture of the studied Brassicaceae (SEM) whole mount and surface scan

are smooth-striated. The periclinal walls are deeply depressed in certain places and shallow depressed in others with smooth surfaces.

***Diploaxis harra* (Fig. 25 & 26).** Seeds are small, 0.8 x 1.2 mm. Shape oblong ellipsoidal with smooth surfaces and yellowish colour. SEM indicated that the surface sculpture is reticulate. The anticlinal walls are more or less broad and raised with smooth tops and lateral sides. The periclinal walls are with irregular elevations and depression, smooth to slightly striate.

***Enarthrocarpus pterocarpus* v. *hispidus* (Fig. 27 & 28).** Seeds are small, 1.5x1 mm with smooth surface and oblong ellipsoidal shape and brownish colour. SEM seed surface sculpture is reticulate. The epicuticular wax deposition over the seed surface show reticulate manner. The anticlinal walls are raised more or less broad with smooth or little fine striate surface. The periclinal wall, are shallow depressed, slightly septated with smooth surfaces.

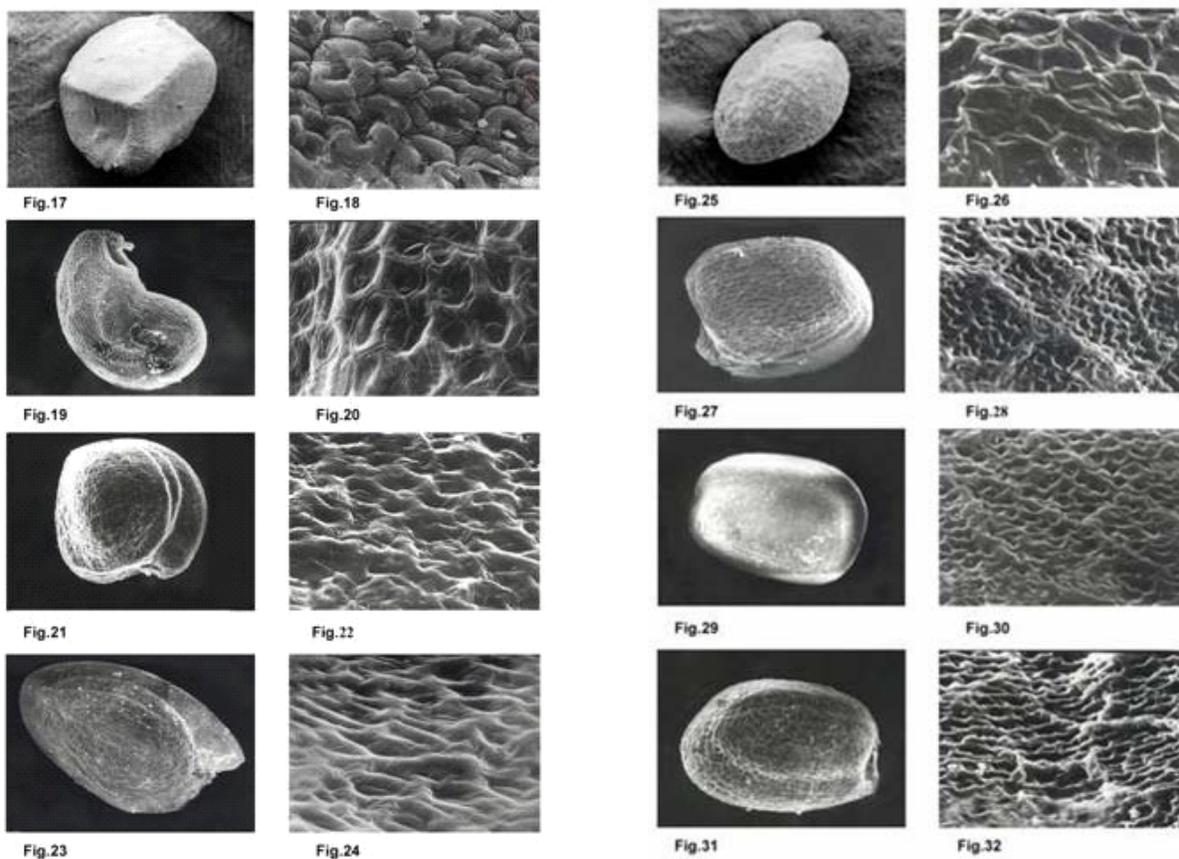
***Pterocarpus* v. *pterocarpus* (Fig. 29 & 30).** Seeds are small, 1.5 x 1 mm in dimensions. Oblong ellipsoidal shape, smooth surface and brownish colour. SEM investigation indicates that the seed surface pattern is reticulate with more

or less broad raised anticlinal walls. The latter is smooth. The periclinal walls are deeply depressed and hardly to distinct.

***Strangulates* (Fig. 31 & 32).** Seeds are small, 1.2 x 1 mm. Seed shape is ellipsoid, with smooth surface and brownish colour. SEM showed reticulate surface pattern with smooth elevated anticlinal walls and deeply depressed periclinal walls.

***Eruca sativa* v. *longirostris* (Fig. 33 & 34).** Seeds are relatively large, 1.8 x 1.5 mm. Seeds sub-globose with smooth surface and dark brown colour. SEM indicated that the seed surface sculpture is reticulate-ocellate with reticulate pattern of epicuticular wax deposition which hidden the boundaries of some cells. The anticlinal walls are more or less broad, raised with segmented smooth-striated tops and lateral sides. The periclinal walls are shallow depressed with small clumps or tubercles with irregular sizes.

***E. sativa* v. *oblongifolia* (Fig. 35 & 36).** Seeds relatively large, 1.8 x 1.5 mm, sub-globose with smooth surfaces and dark brownish colour. SEM show glebulate seed surface



pattern. The deposition of epicuticular wax deposition was as those of proceeding variety. The anticlinal walls are shallow raised and broad, smooth striated. The periclinal walls are clumped with irregularly placed granules with smooth surfaces.

***Erucaria hispanica* (Fig. 37 & 38).** Seeds relatively small, 1.5 x 1 mm in dimensions. Seeds compressed, sub-globose-ovate with smooth surfaces and brownish colour. SEM indicated that the seed surface pattern is reticulate with more or less broad anticlinal walls and shallow depressed periclinal walls. The surface of both walls is striate-lineate.

***Erysmium asperum* (Fig. 41 & 42).** Seeds are relatively large, 3 x 1.5 mm. Ovate-oblong with smooth surfaces and apical wing. The seed is light brown-orange in colour. SEM revealed that the seed surface pattern is reticulate. The anticlinal walls are relatively raised, broad with striate-rugose tops and lateral sides. The periclinal walls are slightly depressed with smooth surfaces and small knobs at the centers.

***Farsetia aegyptia* (Fig. 43 & 44).** Seeds are large, 4-6 x 5 mm, compressed with wide marginal wings. Seeds ovoid or flat with smooth surfaces and brown-orange colour. SEM revealed that the seed surface pattern is reticulate. The anticlinal walls are more or less narrow with smooth tops and striated lateral sides. The periclinal walls are shallow

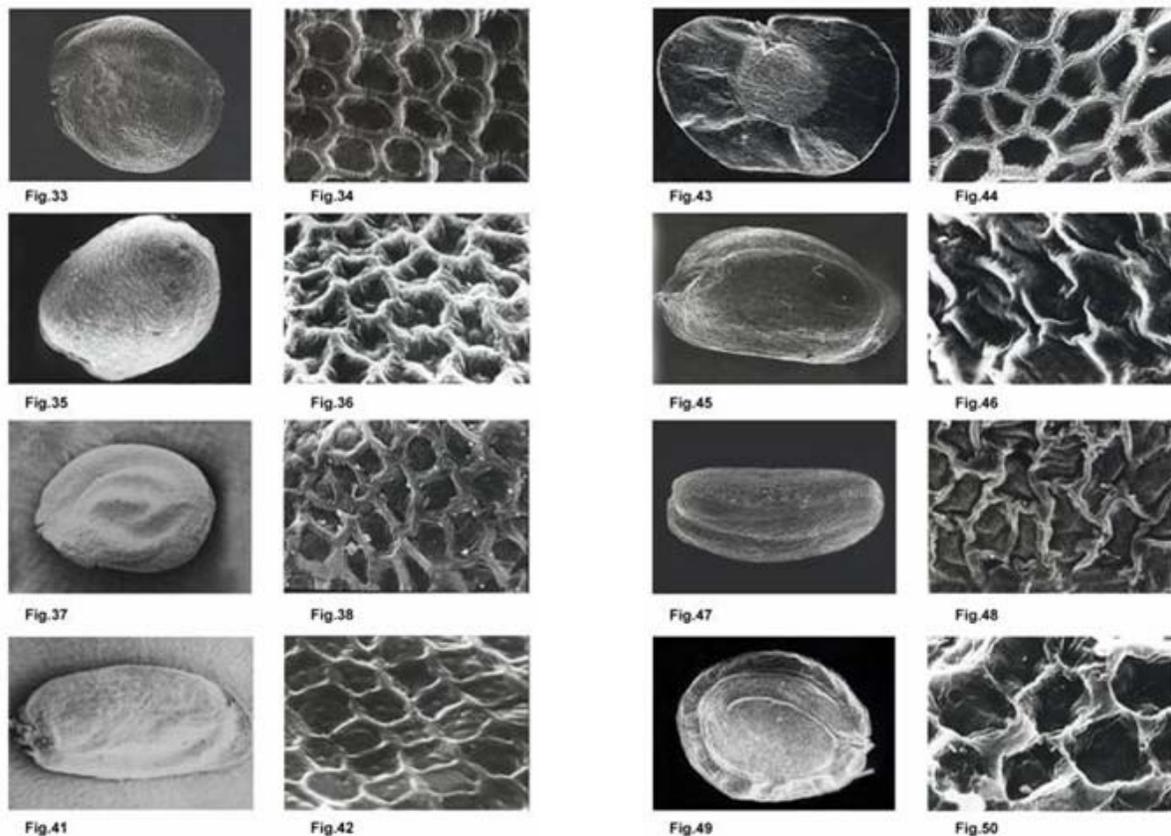
depressed, folded, smooth.

***Ibris gibraltaria* (Fig. 45 & 46).** Seeds are large, 4-6 x 5.5 mm. Seeds compressed, orbicular with wide marginal wings. Seeds are smooth with light brown-orange colour and white wings. SEM showed rugose seed surface. The anticlinal walls are more or less narrow with smooth surfaces of tops and lateral sides. The periclinal walls are shallow depressed and folded.

***Lepidium sativum* (Fig. 47 & 48).** Seeds relatively large, 3 x 1. obliquely ovate with smooth surfaces and brown colour. SEM showed at lower magnifications reticulate manner of epicuticular wax deposition. At higher magnification the seed surfaces is reticulate with narrow cross bands forming reticulum. The anticlinal walls are narrow, slightly raised with smooth surfaces. The periclinal walls are shallow depressed with cross banded surface.

***Lobularia libyca* (Fig. 49 & 50).** Seeds are relatively large, 1.5 x 2 mm in dimensions. Seeds are ovate-sub-orbicular with smooth surfaces and brownish colour. SEM revealed reticulate-gebulate with reticulate epicuticular wax deposition over all the boundaries. The anticlinal walls are broad, raised with striate-gebulate lateral sides. The periclinal walls are segmented into irregular clumps with varying sizes. The latter surface is smooth.

***L. maritima* (Fig. 51 & 52).** Seeds are relatively small, 1.5 x



1 mm. Ovate-sub-orbicular with smooth surface and brownish colour. SEM revealed reticulate surface pattern. The anticlinal walls are more or less broad, raised with smooth surfaces. The periclinal walls are shallow depressed with finely granular surface.

Matthiola longipetala spp. *bicornis* (Fig. 53 & 54). Seeds are relatively large, 1.5 x 2 mm. Compressed, sub-orbicular with wide crescenti-form wing. Surface is smooth and colour is light brown. The seed surface sculpture is reticulate with more or less broad and raised anticlinal walls. The tops and lateral sides of the latter walls are smooth gradually septated into micro-folds toward the lateral sides. The periclinal walls are more or less raised with smooth striated lateral sides and central knobs.

M. longipetala spp. *hitra* (Fig. 55 & 56). Seeds are relatively small, 1.5 x 1 mm, compressed, sub-orbicular. Surface smooth and seed colour is yellow-brownish. The seed surface pattern is domate with cracks and flaks of epicuticular wax. The anticlinal walls are shallow raised with smooth irregularly arranged folds running in different directions. The periclinal walls very narrow and deeply depressed.

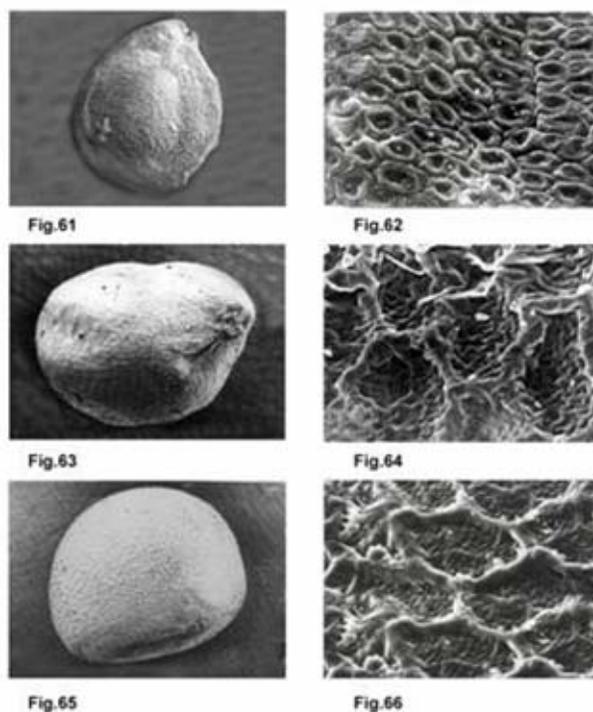
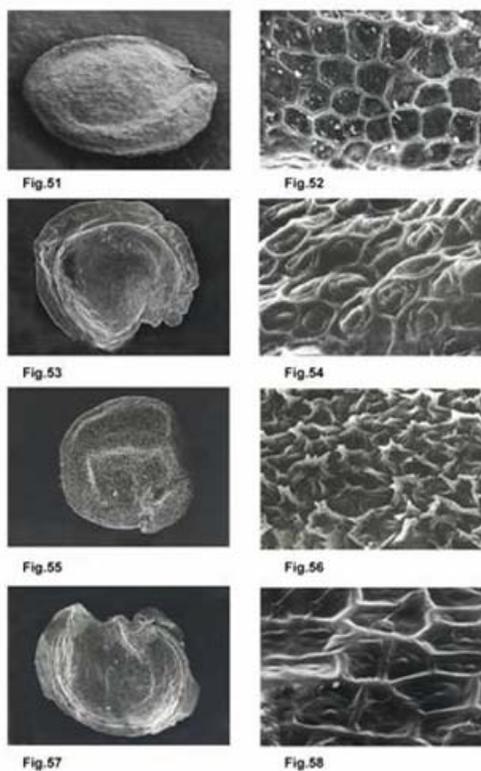
M. longipetala spp. *incana* (Fig. 57 & 58). Sees relatively large, 2 x 1.5 mm, much compressed with elliptic-oblong shape. The seeds are brownish in colour and sometimes sub-

orbicular with marginal wing. The seed surface pattern is reticulate. The anticlinal walls are more or less broad, raised with smooth surfaces. The periclinal walls are shallow depressed with smooth- papillate surface in certain areas and smooth-striated in others.

Morettia philaeana (Fig. 61 & 62). Seeds are relatively small, 1-1.5 x 1-1.3 mm. Seeds are ellipsoid-ovoid with smooth surface and brownish colour. The seed surface sculpture is ocellate. The anticlinal walls are more or less raised and broad. The tops and lateral sides are striated. The periclinal walls are shallow depressed and smooth-striated.

Raphanus raphanistrum (Fig. 63 & 64). Seed large, 1.5 x 2.5 mm in dimensions. Seeds are sub-globose to ovate with smooth surfaces and brown colour. SEM revealed reticulate-glebulate surface pattern. Deposition of epicuticular wax takes place over the entire surface. The anticlinal walls are raised, broad, smooth to rugose surface. The periclinal walls are shallow depresses with ruminant surface.

Raphanus sativus (Fig. 65 & 66). Seeds are relatively large, 2 x 3 mm. Seeds globose with smooth surface and brown colour. SEM showed reticulate surface pattern with reticulate frame network of epicuticular wax. The anticlinal walls are raised with smooth surfaces. The periclinal walls are ruminating and smooth.

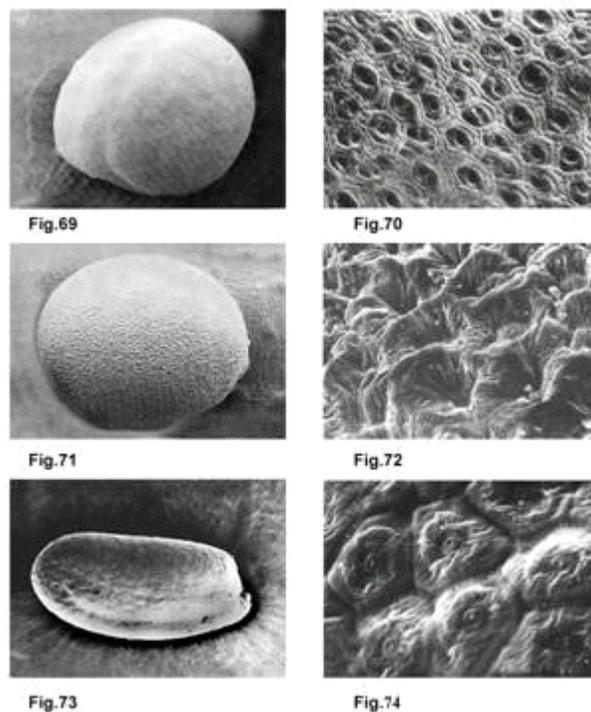


Schouwia purpurea (Fig. 69 & 70). Seeds are relatively large, 1.3 x 1 mm, circular to sub-orbicular shape. Colour brownish and surface smooth. SEM revealed that the seed surface is ocellate with more or less rounded lumens. The anticlinal walls are more or less narrow, raised with smooth surfaces. The periclinal walls are shallow raised at the periphery and deeply depressed at the centers.

Sinapsis alba (Fig. 71 & 72). Seeds are relatively large, 2 x 3 mm in dimensions. The seed shape is globose with smooth surfaces. The surface is whitish-brown. The seed surface at lower magnifications appears with whitish granulated epicuticular pattern film. At higher magnifications the seed surface pattern is reticulate-sulcate. The cuticular wax hidden the tops of the anticlinal walls and directed toward the lateral sides showing cone-like depressions.

Sisymbrium irio (Fig. 73 & 74). Seeds are small, 1 x 0.5 mm. Oblong ellipsoidal with smooth surfaces and yellowish color. The seed surface sculpture is alveolate-papillate. The elevations not rounded. The anticlinal walls are very narrow, deeply depressed. The periclinal walls are raised with raised opened papillae.

The seed shape among the investigated taxa showed wide range of variations. Most of the seeds vary from globose to oblong ellipsoidal or orbicular. However, they are ovoid in *Didesmus aegyptius* and *D. bipinnatus*, kidney shape in *Coronopus didymus*, sub-orbicular in *Biscutella didyma*, *Lepidium sativum*, three sub-species of *Matthiola*. and *Schouwia purpurea*.



The seed shape as observed in the present study seems to be diagnostic at the generic level. For example in genus *Brassica* (five species), the seed shape is globose, in

Didesmus, (two species), the shape is ovoid, in *Eruca* (one species & two varieties), the shape is sub-globose, in *Enarthrocarpus* (two species & two varieties), the seed shape is oblong ellipsoidal and in *Matthiola* (three spp.), the seed shape is sub-orbicular. In some genera it was diagnostic at the specific level.

Most of the investigated seeds have no wings, but in *Erysimium asperum*, *Farsetia aegyptia*, *Ibris gibraltaria* and *Matthiola longipetala* spp. *bicornis* and spp. *incana*, the wing is present and may be apical (small) or marginal (largely expanded). The presence or absence of wing to be of diagnostic value in distinguishing between the studied taxa. This is in agreement with the work of Kapil *et al.* (1980) and Abdel Khalik *et al.* (2002).

Seed dimensions. In the studied taxa of Brassicaceae the seed size vary greatly. The largest seed size is 4-6 x 5-5.5 in orbicular and ovoid seeds of *Farsetia aegyptia* and *Ibris gibraltaria*, relatively large in 10 taxa, medium (*Biscutella didyma* & *Matthiola longipetala* spp. *bicornis*) or small sizes in the rest studied taxa (Table II). 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).

Seed surface: In all the studied taxa, the seed surface is glabrous and to be unreliable criterion to use at the generic and specific level.

The seed colour varies from brown, brownish, dark brown, black, reddish-brown, orange, orange-shiny brown to whitish brown (Table II). The 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).

The epidermal cells are well-developed in the majority of the investigated taxa. In some taxa as *Cakile maritima*, *Ibris gibraltaria* and *Sinapsis alba*, the epidermal cells ill-developed.

The deposition of epicuticular wax takes place in the form of flaks, rods giving reticulum manner overall the seed surface in some of the studied taxa. The epidermal cells and the deposition of epicuticular wax is considered as fundamental characters to use in separation between taxa.

SEM investigation showed eight types of seed surface sculpture, *viz.* reticulate, ocellate, domate, undulate-domate, alveolate-papillate, rugose, pusticulate and glebulate. The reticulate seed surface pattern is the basic type in the majority of the studied taxa (24 taxa). The separation between them based on the aspects of anticlinal and periclinal walls. Ocellate type was recorded in *Carrichtera annua*, *Morettia philaeana* and *Shouwia purpurea*. Rugose type in *Brassica napus* and *Farsetia aegyptia*. Undulate-domate in *Cakile maritima*. Domate in *Matthiola longipetala* spp. *hitra*. Pusticulate in *Brassica rapa*. Alveolate-papillate in *Sisymbrium irio*. Glebulate in *Eruca sativa* v. *longirostris*.

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).

CONCLUSION

The exomorphic characters of seeds in the present study are considered diagnostic at the generic and specific level of Brassicaceae for some extent. We recommend collecting enormous morphological, anatomical and molecular criteria to find the relationships between the studied taxa more precisely.

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