Acta Bot. Croat. 64 (1), 57–73, 2005

CODEN: ABCRA 25
ISSN 0365–0588

Morphological studies on trichomes of Brassicaceae in Egypt and taxonomic significance

KADRY ABDEL KHALIK*

South Valley University, Faculty of Science, Botany Department, Sohag, Egypt

Trichomes morphology, structure, and taxonomic significance of 82 species belonging to 9 tribes of Brassicaceae from Egypt were studied using light microscopy (LM) and scanning electron microscopy (SEM). This work was largely based on herbarium material in addition, fresh material of most of the taxa was studied. A total of twelve trichome types could be distinguished and classified into unicellular or multicellular based on the structure of the hair. The unicellular trichomes could be distinguished as simple, hooked, vasculate, clavate simple glandular, appressed medifixed, trifixed, Y-shaped, branched (3–4 fids), dendroid and stellate. The multicellualr trichomes were glandular. We found trichomes as being valuable characteristics for identification of tribes, genera, species, subspecies, and varieties in Brassicaceae. A key for the identification of the investigated taxa based on trichome characters is provided in this paper.

Key words: Morphology, trichomes, Brassicaceae, identification key, SEM.

Introduction

The Brassicaceae (Cruciferae) are one of the largest Angiosperm families, comprising approximately 340 genera and more than 3350 species in some 10 poorly defined tribes, distributed throughout the world, chiefly in temperate regions of the Northern Hemisphere (AL-SHEHBAZ 1984). The major centers of distribution of the family are in the Irano-Turanian, Mediterranean, and Saharo-Sindian regions (HEDGE 1976).

In the flora of Egypt, Brassicaceae are one of the four largest families, represented by about 102 species belonging to 55 genera, assigned to 9 tribes (EL HADIDI et al. 1988). Species of the tribes Lepideae, Brassiceae and Alysseae (EL NAGGAR 1987, 1992, 1993; EL NAGGAR and EL HADIDI 1998), and species of Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae (O.E. SCHULZ's system 1936) have been studied taxonomically by (ABDEL KHALIK and MAESEN 2002; ABDEL KHALIK et al. 2002).

DENNERT (1884) was the first author to give attention to the different types of trichomes in Brassicaceae. He divided these hairs into simple, dichotomous and stellate. PRANTL (1891) used the hair shape as a basic character for the classification of Brassicaceae and recognized four tribes. SCHULZ (1936), did not investigate the indumentum from this point

* Corresponding author: e-mail: kadry3000@yahoo.com

of view, he only dealt with the morphology of hairs. JANCHEN (1942) used the indumentum as an important character. JONSELL (1971) revised the genus *Rorippa* in Eastern Siberia and the Soviet Far East and classified this genus into 5 species, based on morphological variations of fruits, indumentum and seed morphology. DVOŘÁK (1973) investigated three kinds of hairs with discriminate function: 1. Emergentiae stipitatae globosae (multicellular basal and ± globular terminal parts). 2. Pili eramosi simplices phragmigeri aequabiles (basal and terminal parts formed by a single row of cells); 3. Pili eramosi simplices capitati (single cell which is in the terminal part globular or slightly club-shaped). KERBER and STORK (1982) differentiated 4 groups from *Malcolmia, Maresia, Torularia* and *Eremobium* based on trichomes, fruits, flowers and chromosome numbers. INAMDAR and RAO (1983) studied the taxonomic significance of trichomes in 35 species of the family Brassicaceae. The trichomes are eglandular only which are classified into unicellular, bicellular and multicellular on the basis of number of cells. JONSELL (1986) monographed the genus *Farsetia* and classified it into 25 species dedpending on variation of stem anatomy, fruits, indumentum, and flowers. MULLIGAN (1995) treated 30 species from Arabis in Canada, Alaska and Greenland based on trichomes morphology and cytological studies and distinguished four types of hairs. The aim of the present work is to verify the hair morphological characters, to study the diversity and the range of variation present among species and use these data in the taxonomy of the Brassicaceae in Egypt.

Materials and Methods

Plant material

The present study is largely based on herbarium material and collections kept in the following herbaria B, BM, BR, CAI, K, L, W, WAG and Sohag University herbarium SHG. Herbarium acronyms are according to HOLMGREN and KEUKEN (1974). In addition, fresh material of most of the taxa was studied and field observations were made from several localities in Egypt. List of taxa used for the study, arranged alphabetically within tribes according to SCHULZ (1936):

Tribe Alysseae

Alyssum desertorum Stapf.: Egypt, El Alamin, V. Täckholm et al., s.n. (CAI).

A. homalocarpum (Fisch. and Mey.) Boiss.: Egypt, Sinai, 220 km from Tor Sinai, Abdel Khalik s.n. (SHG).

A. marginatum Steud. Ex Boiss.: Egypt, South Sinai, Gebel Serbal, Fayed et al., s.n. (SHG).

Farsetia aegyptia Turra: Egypt, Burg El Arab, Abdel Khalik s.n. (SHG).

F. longisiliqua Decne: Egypt, Gebel Elba, Wadi El Shalal, Abdel Khalik s.n. (SHG).

F. stylosa R. Br.: Egypt, N. Sinai, El Hasana, Abdel Khalik s.n. (SHG).

Lobularia arabica (Boiss.) Muschl.: Egypt, 7 km from Rafah-El Shekh Zewid, Abdel Khalik s.n. (SHG).

L. libyca (Viv.) Meissn.: Egypt, Mersa Matrouh, Abdel Khalik s.n. (SHG).

L. maritima (L.) Desv. : Egypt, Mersa Matrouh, V. Täckholm et al., s.n. (CAI).

Tribe Arabideae

Arabis alpina L. subsp. *caucasica* (Willd.) Briq: Israel, Mont Jow, Deyrolle 948 (BR).

A. nova Vill.: Egypt, S. Sinai, Gebel Musa, V. Täckholm et al., s.n. (CAI).
Nasturtium officinale R. Br.: Egypt, Abu-Atwa, S. Ismailia, A. El Bakry 764 (CAI).
Rorippa indica (L.) Hiern: Egypt, Qena, El-Mahrosa island, M. Fawzy (SHG).
R. integrifolia Boulos: Egypt, Middle of Sinai, about 5 km before Ras Sedr, Abdel Khalik 9 (SHG).
R. palustris (L.) Besser: Egypt, along the canal of Ismailiya, Abdel Khalik 20 (SHG).

Tribe Brassiceae

Brassica nigra (L.) W.D.J. Koch: Egypt, Mariut, V. Täckholm et al., s.n. (CAI).
B. rapa L.: Egypt, Sohag, Abdel Khalik s.n. (SHG).
B. tournefortii Gouan: Egypt, Burg el Arab, Abdel Khalik s.n. (SHG).
Cakile maritima Scop.: Egypt, Burg el Arab, Abdel Khalik s.n. (SHG).
Carrichtera annua (L.) DC.: Egypt, Wadi El Habs, Matrouh-El Qasr road, Abdel Khalik s.n. (SHG).
Diplotaxis acris (Forssk.) Boiss.: Egypt, El Hasana-El Naqb, Sinai, Abdel Khalik s.n. (SHG).
D. harra (Forssk.) Boiss.: Egypt, Wadi El Arbaien, S. Sinai, Abdel Khalik s.n. (SHG).
D. muralis (L.) DC.: Egypt, Burg el Arab-El Alamein, V. Täckholm et al., s.n. (CAI).
Enarthrocarpus lyratus (Forssk.) DC.: Egypt, 180 km from Cairo, Cairo-Alexandria desert road (SHG).
E. strangulates Boiss.: Egypt, Ras El Hekma, V. Täckholm et al., s.n. (CAI).
Eruca sativa Mill.: Egypt, Assuan, V. Täckholm et al., s.n. (CAI).
Erucaria hispanica (L.) Druce: Egypt, Burg El Arab, V. Täckholm et al., s.n. (CAI).
E. microcarpa Boiss.: Egypt, Mersa Matrouh, V. Täckholm et al., s.n. (CAI).
Erucastrum arabicum Fisch. et Mey.: Egypt, Sohag, Abdel Khalik s.n. (SHG).
Moricandia nitens (Viv.) Durand et Barratte: Egypt, Sinai, El Hasana, Abdel Khalik s.n. (SHG).
M. sinaica (Boiss.) Boiss.: Egypt, S. Sinai, Gebel Musa, Abdel Khaliks.n. (SHG).
Pseudorucaria clavata (Boiss. et Reut.) O. E. Schulz: Egypt, Wadi Hof, V. Täckholm et al., s.n. (CAI).
Raphanus raphanistrum L.: Egypt, Burg El Arab, Abdel Khalik s.n. (SHG).
Rapistrum rugosum (L.) All.: Egypt, Sidi Krer, Abdel Khalik s.n. (SHG).
Savigynya parviflora (Delile) Webb: Egypt, Suez road, V. Täckholm et al., s.n. (CAI).
Schouwia purpurea (Forssk.) Webb: Egypt, Qena-Safaga desert road, Abdel Khalik s.n. (SHG).
Sinapis alba L.: Egypt, Burg El Arab, Abdel Khalik s.n. (SHG).
S. arvensis L.: Egypt, Sohag University garden, abdel Khalik s.n. (SHG).
Zilla spinosa (L.) Prantl: Egypt, Qena-Safaga desert road, Abdel Khalik s.n. (SHG).

Tribe Euclidieae

Anastatica hierochuntica L.: Egypt, Cairo-Suez road, km 95 from Cairo, V. Täckholm et al., 327 (CAI).
Neslia paniculata (L.) Desv.: Egypt, Sinai mountains, W. Schimper 158 (BM).
Ochthodium aegyptiacum (L.) DC.: Egypt, without location, Schultes s.n., (L).
Schimpera arabica Hochst. et Steud.: Egypt, Sinai, Wadi Sidr, W. Barbey 34 (B).

Tribe Hesperideae

Eremobium aegyptiacum (Spreng.) subsp. *aegyptiacum* Abdel Khalik: Egypt, N. Sinai, El Arish area beside the Airport, Abdel Khalik 29 (SHG).

Erysimum repandum L.: Egypt, between Fuka and Matruh, V. Täckholm et al., s.n. (CAI).

Leptaleum filifolium (Willd.) DC.: Egypt, Wadi Chafura, north Galala, Schweinfurth s.n. (BR).

Malcolmia africana (L.) R.Br.: Egypt, S. Sinai, Deir el Rahba, Wadi el Arbain, Abdel Khalik 2 (SHG).

Maresia nana (DC.) Batt.: Egypt, El Arish-Rafah road, 23 km from El Arish, Abdel Khalik 28 (SHG).

M. pygmaea (Delile) O. E. Schulz: Egypt, 26 km, Sidi Krer, Alexandria-Matruh coastal road, Abdel Khalik 22 (SHG).

Tribe Lepidieae

Biscutella didyma L.: Egypt, wadi Um El Rakham, Matrouh-El-Qasr road, Abdel Khalik 139 (SHG).

Capsella bursa-pastoris (L.) Medic.: Egypt, Sohag city, Abdel Khlik s.n. (SHG).

Cronopus squamatus (Forssk.) Asch.: Egypt, Burg El Arab, Abdel Khalik s.n. (SHG).

Isatis microcarpa Boiss.: Egypt, Sinai, Gebel Serbal, Fayed et al., s.n. (SHG).

Lepidium aucheri Boiss.: Jordan, Azraq Oasis, near the hot Sprwy, 428 (CAI).

L. sativum L.: Egypt, Burg El Arab, V. Täckholm et al., s.n. (CAI).

Tribe Lunarieae

Ricotia lunaria (L.) DC.: Egypt, without location, 1235 (W).

Tribe Matthioleae

Diceratella eliptica (DC.) Jonsell: Egypt, Gebel Elba, Wadi el Shallal, Abdel Khalik 17 (SHG).

Matthiola arabica Boiss.: Egypt, S. Sinai, Wadi el Arbaien, Abdel Khalik 12 (SHG).

M. fruticulosa (L.) Maire: Egypt, Alexandria, N. B. Ward 34 (K).

M. longipetala subsp. *bicornis* (Sibth.) Ball: Egypt, Alexandria- Matruh coastal road, Abdel Khalik 24 (SHG).

M. longipetala subsp. *hirta* (Conti) Greuter et Burdet. : Egypt, Alex.-Matruh coastal road, near Burg El Arab Abdel Khalik 23 (SHG).

M. longipetala subsp. kralikii (Pomel) Maire : Egypt, Cairo-Alexandria desert road, 100 km from Alexandria, Abdel Khalik 7 (SHG).

M. longipetala subsp. *livida* (Delile) Maire : Egypt, Cairo-Ismailiya desert road, 23 km before Ismailiya, Abdel Khalik 27 (SHG).

M. longipetala subsp. *longipetala* (Vent.) Boulos: Egypt, 28 km before Matruh, Alexandria-Matruh road, Abdel Khalik 25 (SHG).

M. parviflora (Schousboe) R.Br.: Egypt, Wadi Natroun, El Hadidi s.n. (CAI).

Morettia canescens Boiss.: Egypt, S. Sinai, Wadi Feiran, Abdel Khalik 10 (SHG).

M. parviflora Boiss.: Egypt, S. Sinai, Bir Iqna, 2o km N. Feiran, El Hadidi s.n (CAI).

M. philaeana (Delile) DC.: Egypt, 35 km from Qena at the road Qena-Safaga, Abdel Khalik 3 SHG).

Notoceras bicorne (Ait.) Caruel: Egypt, Gebel Elba, Saddle between Gebel Asotriba and Makin, V. Täckholm 1052 (CAI).

Tribe Sisymbrieae

Crucihimalaya kneuckeri (Bornm.) Al-Shehbaz, O'Kane et Price: Egypt, Sinai, E slopes of Gebel Catherine, Podlech 49785 (CAI).

Descurainia sophia (L.) Webb et Berth.: Jordan, El-Jubeiha, university campus, D. El-Eisawi 1475 (B).

Nasturtiopsis coronopifolia (Desf.) Boiss.: Egypt, Burg El Arab, V. Täckholm et al., s.n. (CAI).

Neotorularia aculeolata (Boiss.) Hedge et Léonard: Egypt, S. Sinai, in shady area, Schimper 124(L).

N. torulosa (Desf.) Hedge et Léonard: Egypt, Burg El Arab, V. Täckholm et al., s.n. (CAI).

Olimarabidopsis pumila (Stephan) Al-Shehbaz, O'Kane et Price: Egypt, mountain of St. Catherine, W. Schimper 171 (B).

Robeschia schimperi (Boiss.) Schulz: Egypt, Sinai mountains, between granitic rocks, W. Schimper 170 (B).

Sisymbrium erysimoides Desf.: Egypt, Gebel Elba, Wadi Drawina, Abdel Khalik 19 (SHG).

S. irio L.: Egypt, S. Sinai, Deir el-Rahebat, Wadi Feiran, as weed in garden, Abdel Khalik 31 (SHG).

S. orientale L.: Egypt, S. Sinai, Deir Feiran, Wadi Feiran, Abdel Khalik 11 (SHG).

S. polyceratum L.: Italy, Palermo, Ross 705 (B).

S. runcinatum Lag. ex DC.: Libya, El Mekhali, El Naggar s.n. (SHG).

S. septulatum DC.: Egypt, mountains Sinai, Schimper 122 (L).

Microscopy

For Scanning electron microscopy, dried specimens were used. Small portions of leaves or stems were taken and mounted on a stub using double adhesive tape and coated with gold-paladium in Polaron Equipment limited SEM coating unit E 1100. After coating, the specimens were viewed with a Jeol JSM 5300 electron microscope at 25 KV. The drawings from light microscope observations were outlined using a camera Lucida adapted to Olympus microscope.

Data analysis

A total of 15 characters were measured on each specimen. The characters were scored as presence/absence. The characters were averaged of measurements of at least 20 specimens (where possible). A cluster analysis (UPGMA) was performed with NTSYS-pc 2.02k software (Applied Biostatistics Inc., Setauket, New York, USA) using average taxonomic distance.

Results

The form and distribution (density) of the trichomes are the basic for the identification and reclassification of Brassicaceae. Scanning electron microscopy, showing clear views for understanding trichome form and structure, essential for establishing a more precise terminology.

Plant surface

In the Brassicaceae the plant parts vary from glabrous; glabrous to hairy to densely hairy. In Euclidieae, Alysseae, Hesperideae, Matthioleae, Sisymbrieae are hairy; in Brassicaeae, Lepidieae, and Arabideae have glabrous to sparsely hairy; the glabrous surface only in *Nasturtium, Neotorularia aculeolata*, *Isatis* and some species from tribe Brassiceae. see table 1.

Tab. 1. Species with distribution of trichome types in Brassicaceae. Plant surface: 1. Glabrous. 2. Glabrous to sparsely hairy. 3. Hairy. A. Simple. B. Hooked. C. Vasculate. D. Medifixed. E. Trifixed. F. Y-shaped. G. Branched. H. Dendroid. I. Stellate. J. Glandular (Unicellular). K. Glandular (Multicellualr). L. Clavate.

Number	Taxon	Plant surface	Trichome type
	1. Tribe Alysseae		
1	*Alyssum desertorum* Stapf	3	I
2	*A. homalocarpum* (Fisch. & Mey.) Asch. & Schwein.	3	I
3	*A. marginatum* Steud. ex Boiss.	3	I
4	*Farsetia aegyptia* Turra	3	D
5	*F. longisiliqua* Decne	3	D
6	*F. stylosa* R. BR.	3	D
7	*Lobularia arabica* (Boiss.) Muschl.	3	D
8	*L. libyca* (Viv.) Meissn.	3	D
9	*L.maritima* (L.) Desv.	3	D
	2. Tribe Arabideae		
10	*Arabis alpina* L.	3	A, G
11	*Arabis nova* Vill.	3	A, G
12	*Nasturtium officinale* R.Br.	1	–
13	*Rorippa indica* (L.) Hiern	2	A
14	*R. integrifolia* Boulos	2	A
15	*R. palustris* (L.) Besser	2	A
	3. Tribe Brassiceae		
16	*Brassica nigra* (L.) W. O. J. Koch	2	A
17	*B. rapa* L.	2	A
18	*B. tournefortii* Gouan	2	A
19	*Cakile maritima* Scop.	1	–
20	*Carrichtera annua* (L.) DC.	2	A
21	*Diplotaxis acris* (Forssk.) Boiss.	2	A
22	*D. harra* (Forssk.) Boiss.	2	A
23	*D. muralis* (L.) DC.	2	A
24	*Enarthrocarpus lyratus* (Forrsk.) DC.	2	A

Tab. 1. – continued

Number	Taxon	Plant surface	Trichome type
25	*E. strangulatus* Boiss.	2	A
26	*Eruca sativa* Mill.	2	A
27	*Erucaria hispanica* (L.) Druce	2	A
28	*E. microcarpa* Boiss.	2	A
29	*Erucastrum arabicum* Fisch. & Mey.	2	A
30	*Moricandia nitens* (Viv.) Durand & Barratte	1	–
31	*M. sinaica* (Boiss.) Boiss.	1	–
32	*Pseudorucaria calvata* (Boiss. & Reut.) O.E. Schulz	1	–
33	*Raphanus raphanistrum* L.	2	A
34	*Rapistrum rugosum* (L.) All.	2	A
35	*Savignya parviflora* (Delile) Webb	2	A
36	*Schouwia purpurea* (Forssk.) Webb	1	–
37	*Sinapis alba* L.	2	A
38	*S. arvensis* L.	2	A
39	*Zilla spinosa* (Turra) Prantl	1	–
	4. Tribe Euclidieae		
40	*Anastatica hierochuntica* L.	3	H, I
41	*Neslia paniculata* (L.) Desv.	3	A, G
42	*Ochthodium aegyptiacum* (L.) DC.	3	A, J
43	*Schimpera arabica* Hochst. & Steud.	3	A
	5. Tribe Hesperideae		
44	*Eremobium aegyptiacum* (Spreng.) Boiss.	3	I
45	*Erysimum repandum* L.	3	D, E
46	*Leptaleum filifolium* (Willd.) DC.	3	A
47	*Malcolmia africana* (L.) R.Br.	3	A, G, H
48	*Maresia nana* (DC.) Batt.	3	I
49	*M. pygmaea* (Delile) O.E. Schulz	3	G
	6. Tribe lepidieae		
50	*Biscutella didyma* L.	3	A, L
51	*Capsella bursa-pastoris* (L.) Medic.	3	A, G
52	*Coronopus squamatus* (Forssk.) Asch.	2	A
53	*Isatis microcarpa* Boiss.	1	–
54	*Lepidium aucheri* Boiss.	2	A
55	*L. sativum* L.	2	A
	7.Tribe Lunarieae		
56	*Ricotia lunaria* (L.) DC.	2	A

Tab. 1. – continued

Number	Taxon	Plant surface	Trichome type
	8. Tribe Matthioleae		
57	*Diceratella eliptica* (DC.) Jonsell	3	A, G, I
58	*Matthiola arabica* Boiss.	3	K, H, I
59	*M. fruticulosa* (L.) Maire	3	A, G, I
60	*M. longipetala* subsp.*bicornis* (Sibth.) Ball	3	K, H, I
61	M. longipetala subsp. *hirta* (Conti) Greuter & Burdet	3	A, K, H
62	*M. longipetala* subsp. kralikii (Pomel) Maire	3	K, H, I
63	*M. longipetala* subsp. *livida* (Delile) Maire	3	K, H, I
64	*M. longipetala* subsp. *longipetala* (Vent.) Boulos	3	H, I
65	*M. parviflora* (Schousboe) R.Br.	3	K, H, I
66	*Morettia canescens* Boiss.	3	I
67	*M. parviflora* Boiss.	3	H, I
68	*M. philaeana* (Delile) DC.	3	H, I
69	*Notoceras bicorne* (Ait.) Caurel.	3	D
	9. Tribe Sisymbrieae		
70	*Crucihimalaya kneuckeri* (Bornm.) Al-Shehbaz, O'Kane & Price	3	H, I
71	*Descurainia sophia* (L.) Webb & Berth.	3	A, G
72	*Nasturtiopsis coronopifolia* (Desf.) Boiss.	3	A
73	*Neotorularia aculeolata* (Boiss.) Hedge & Léonard	1	–
74	*N. torulosa* (Desf.) Hedge & Léonard	3	A, G
75	*Olimarabidopsis pumila* (Stephan) Al-Shehbaz, O'Kane & Price	3	E, F
76	*Robeschia schimperi* (Boiss.) Schulz	3	G
77	*Sisymbrium erysimoides* Desf.	2	A
78	*S. irio* L.	2	A
79	*S. orientale* L.	2	A
80	*S. polyceratum* L.	2	A
81	*S. runcinatum* Lag. ex DC.	2	A, C
82	*S. septulatum* DC.	2	A

Basic Types of trichomes

In the present investigation eglandular and glandular trichomes are observed (see Figs. 1, 2, 3). The eglandular unicellular trichomes are: simple, hooked, vasculate, appressed medifixed and trifixed, Y-shaped, branched (3–4 fids), dendroid, stellate and clavate. Glandular trichomes consists of a multicellular stalk and a head of more cells and unicellular which is in the terminal part globular or slightly club-shaped.

Unicellular hairs

Simple hairs

The mature trichome consists of a single cell with a narrow or broad lumen. The outer wall is smooth or show linear warts (Fig.1. 1; Fig. 3. 2). The tip of the trichome is pointed or acute. This type is common in Arabideae, Brassiceae, Lepidieae, Lunarieae, and Sisymbrieae.

Hooked hairs

This type is similar to simple trichome. The trichome consists of a broad base that tapers towards the apex like a cone. The tip of the trichome is hooked (Fig. 1. 1; Fig. 3. 1). The basal part is broad and bulbous. The surface of trichome is smooth. This type is found in *Sinapis*.

Vasculate hairs

This type of trichome is similar to simple trichome but the tip of that one is vasculate (Fig.1. 2; Fig. 3. 3). The surface is smooth. This type is present mixed with simple hairs only in *Sisymbrium runcinatum*.

Medifixed hairs

The trichome is unicellular and not differentiated into foot, stalk and head. It has two arms which may be equal or unequal in length (Fig. 1. 3; Fig. 3. 10). The walls of the arms are thick and ornamented with tubercles. This type of hairs are distinguished *Farsetia* and *Lobularia* from the other genera of tribe Alysseae, and also it was recorded in *Erysimum* and *Notoceras.*

Trifixed hairs

This type of hair is similar to medifixed hair but one of the arms of the trichome bifurcates at the tip (Fig. 1. 4; Fig. 3. 10). The trichome surface is ornamented with tubercles. This type is found in rare and mixed with the appressed medifixed one in *Erysimum repandum* and *Olimarabidopsis pumila*

Y- shaped hairs

The trichome is unicellular. The trichome is bifurcates at the apex to give rise two arms which elongate to give rise to Y- shaped trichome (Fig. 1. 5; Fig. 3. 9). The outer surface is smooth. This type in *Olimarabidopsis pumila*.

Branched hairs (3–4 fids)

The trichome is unicellular. This type consists of a broad base that narrow towards the apex. The tip of trichome is branched into three or four arms (Fig. 1. 6; Fig. 3. 8). Outer surface is smooth. This type is present alone in *Maresia, Robeschia* or mixed with other types of trichomes like in *Neslia, Arabis*, *Descurainia, Capsella, Diceratella, Matthiola, Malcolmia and Neotorularia* with simple hairs, or with dendroid and stellate hairs.

Dendroid hairs

This type of hair is similar to branched hair but the tip is branched like tree into many arms (Fig.1. 3; Fig. 3. 7). The surface of trichome is smooth. This trichome present with other types (stellate, branched, simple, glandular) in *Crucihimalaya, Matthiola, Malcolmia, Morettia* and *Anastatica.*

Stellate hairs

The trichome initial proliferates at the apex to give rise arms in a stellate shape. The mature trichome consists of 3 or four or five arms (triradiate, tetraradiate, and pentaradiate) arising from a common point. Each arm is consists of 2 or 3 or 4 arms (Fig. 2. 7 and 8; Fig.

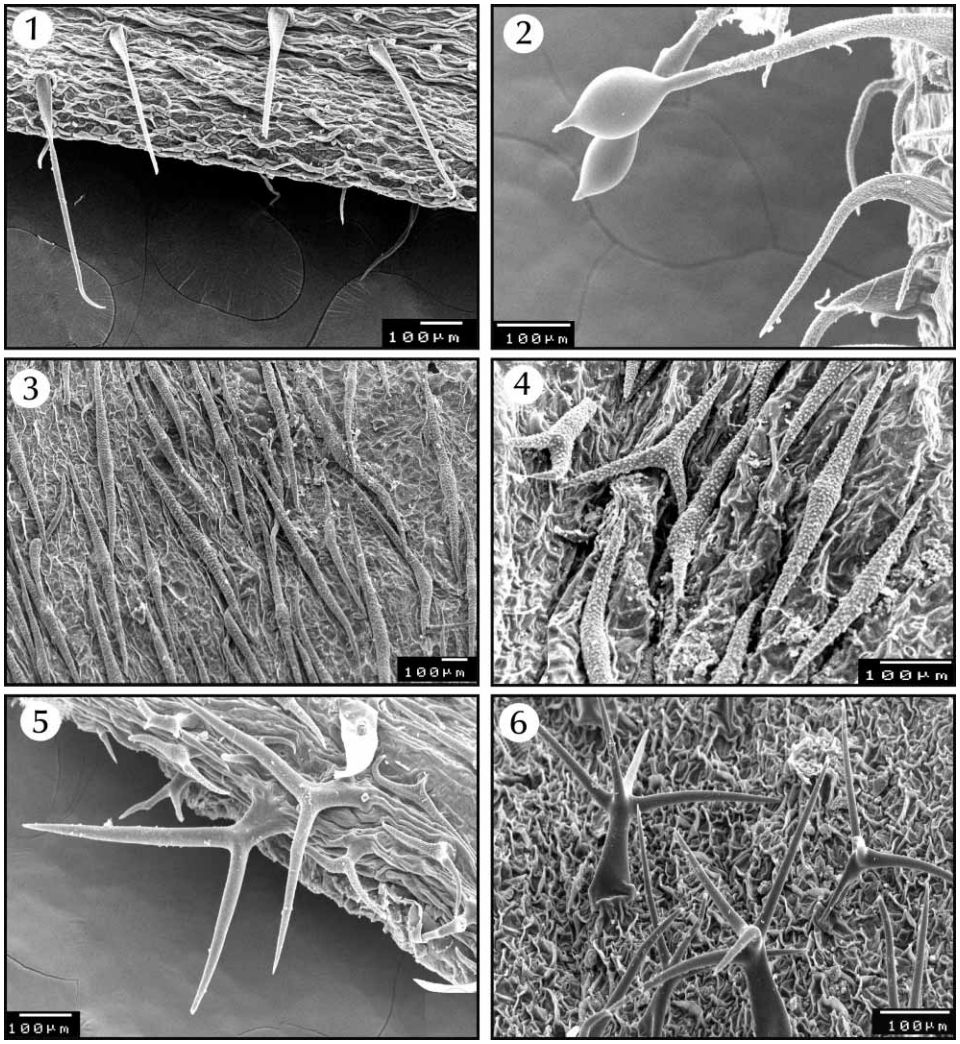

Fig. 1. SEM photographs of the indumentum. 1 simple and hooked hairs, 2 vasculate hairs, 3 medifixed hairs, 4 trifixed hairs, 5 y-shaped hairs, 6 branched hairs (3–4 fids).

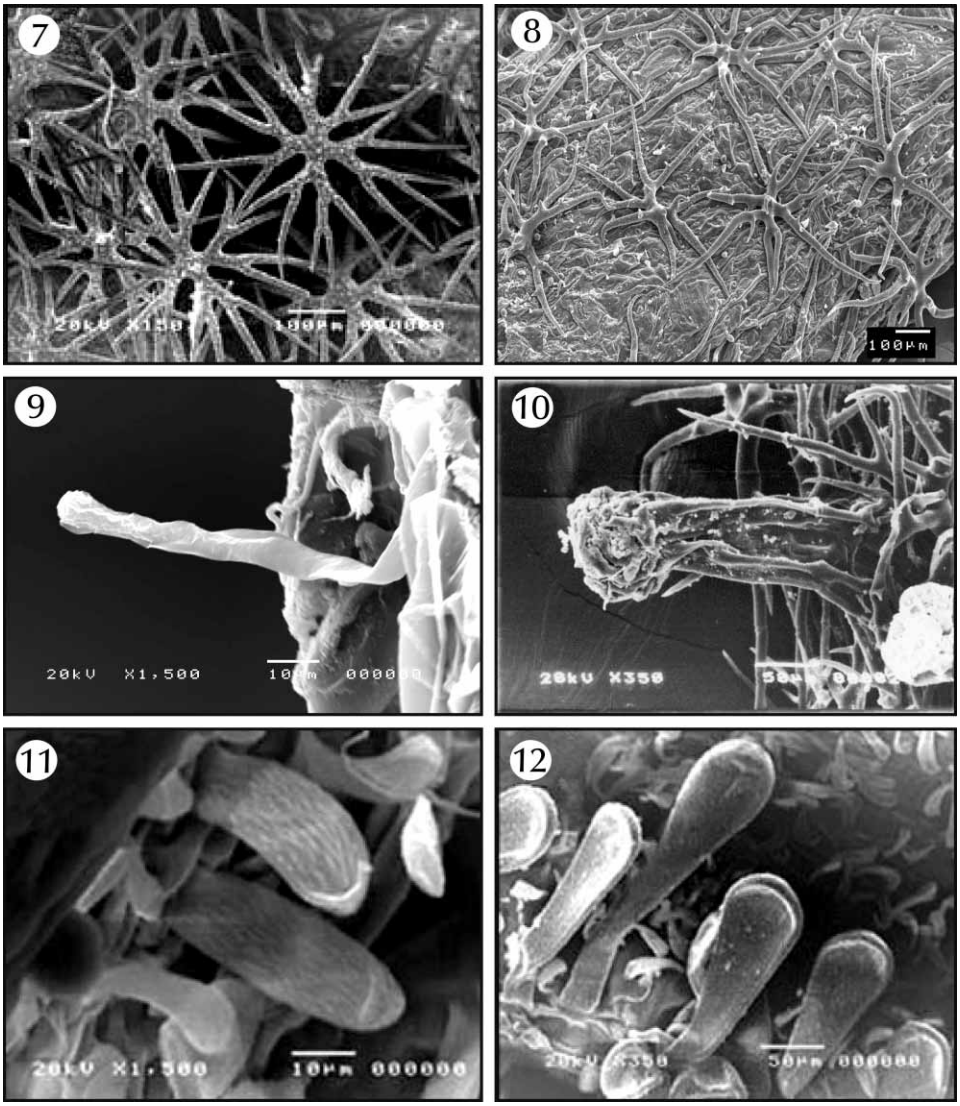

Fig. 2. SEM photographs of the indumentum. 7 and 8 stellate hairs, 9 glandular hairs (unicellular), 10 glandular hairs (multicellular), 11 and 12 clavate hairs.

3. 11 and 12). The outer wall is thin or thick. This type is occur either single in *Alyssum*, *Eremobium*, *Maresia nana*, and *Morettia canescens* or mixed with other types of trichomes (glandular, branched, dendroid and simple) like in *Matthiola*, *Diceratella* and *Anastatica*.

Glandular unicellular hairs

This type of hair formed by a single cell which is in the terminal part globularly or in a slightly club-shaped (Fig. 2. 9; Fig. 3. 6). The outer wall is smooth. This trichome is very rare and found mixed with simple hairs only in *Ochthodium aegyptiacum.*

Clavate hairs

The trichome is consists of one cell. This type is short and the tip enlarged into clavate. (Fig. 2. 11 and 12; Fig. 3. 4). The surface is thick. This type is present in the surface margin of fruit in *Biscutella didyma*.

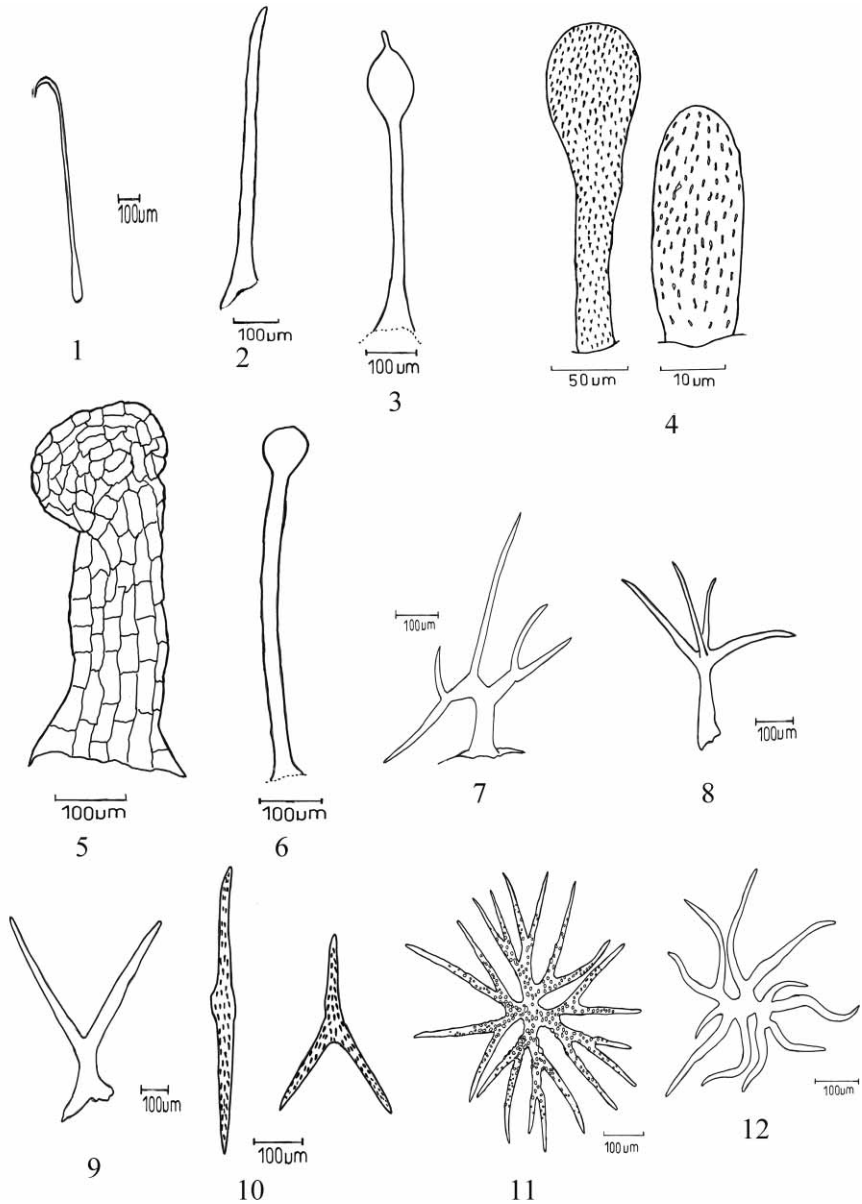

Fig. 3. Trichome types. 1 hooked hairs, 2 vasculate hairs, 3 simple hairs 4 clavate hairs, 5 glandular hairs (multicellular), 6 glandular hairs (unicellular), 7 dendroid hairs, 8 branched hairs, 9 y-shape hairs, 10 medifixed and trifixed hairs, 11 and 12 stellate hairs.

Multicellular hairs

Glandular multicellular hairs

The trichome is multicellular. It is composed of multicellular stalk and multicellular head (Fig. 2. 10; Fig. 3. 5). The outer wall is smooth. This type is relatively extremely rare in the Brassicaceae, only in three species of *Matthiola*.

Discussion

The family Brassicaceae is characterized by a great diversity of hair forms. This diversity provides by far the most important taxonomic characters of the epidermis, and in many cases are as valuable as any of the other features of the plants.

MATCALFE and CHALK (1950) pointed out that the trichomes in the Brassicaceae are variable in form, but always unicellular and very rarely glandular. Eglandular trichomes are simple unbranched T-, Y-shaped, 2-armed peltate or dendroid. They have recorded glandular trichomes consisting of multicellular stalk and a head of one or more cells in the species of *Anchonium, Bunias, Chorispora, Descurainia, Hesperis, Matthiola, Parrya* and *Sterigma*. THEOBOLD et al. (1979) also observed unicellular, 2–5 armed, stellate, scales and dendritic trichomes in the Brassicaceae. ROLLINS and BANERJEE (1975, 1976, 1979) pointed out the significant differences in trichome pattern and ornamentaion on trichomes in *Lesquerella* and *Physaria*, and they concluded that trichomes of Brassicaceae are single celled structures.

In the present investigation two main types of trichome are observed in the Brassicaceae based on the number of cells. 1. eglandular unicellular trichomes which may be simple, hooked, vasculate, appressed medifixed and trifixed, Y-shaped, branched (3–4 fids), dendroid, stellate and clavate and 2. glandular trichomes which is consists of a multicellular stalk and a head of more cells and unicellular which is in the terminal part globular or slightly club-shaped.

Our results indicate that it is possible to distinguish four tribes (Arabideae, Brassicaeae, Lunarieae and Alysseae) from the rest of nine tribes see Fig. 4. In the tribes Brassicaeae, Lunarieae and Arabideae trichomes are varying from glabrous to simple hairs. The members of tribe Brassiceae are combined to one clade, and this clade is combind with *Rorippa indica, Nasturtiopsis, Sisymbrium, Ricota,* and *Lepidium* with high similarity coefficient (Fig. 4). In the tribe Alysseae are distinct from other tribes being have appressed medifixed hairs as well as stellate hairs. The appressed medifixed hairs are distinguished *Farsetia* and *Lobularia* from the rest of the tribe Alysseae. The appressed medifixed hairs are also recorded in other genera of different tribes e.g. *Notoceras* and *Erysimum*. The appressed stellate hairs with few branched hairs present in *Alyssum*, *Anastatica, Eremobium, Maresia nana,* and some genera from tribe Matthioleae (*Morettia canescens*).

The morphology of trichomes are mostly congruent with the results of KOCH et al. (2001) based on morphological and molecular (Chs and matK) data to analyse the phylogeny of five tribes of Brassicaceae: Arabideae, Sisymbrieae, Hesperideae, Lepidieae and Brassiceae. The five tribes (Arabideae, Sisymbrieae, Euclidieae, Lepidieae and Hesperideae (includes Matthioleae) that are the same tribes studied by us prove to be heterogeneous because around seven types of trichomes are presented within tribes. Their results

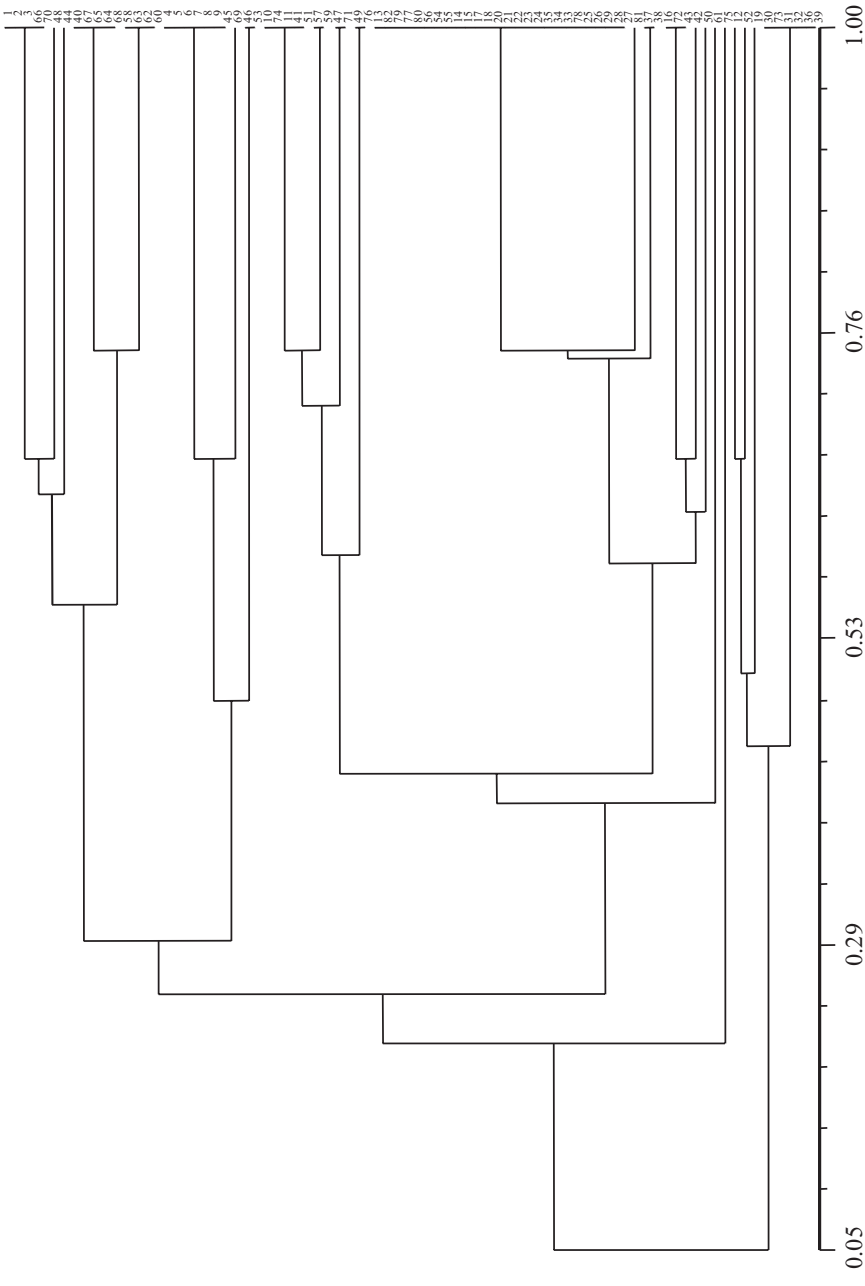

Fig. 4. Phenogram of the 82 studied taxa, clustering with UPGMA method, 1–9 Alysseae; 10–15 Arabideae; 16–39 Brassiceae; 40–43 Euclidieae; 44–49 Hesperideae; 50–55 Lepidieae; 56 Lunarieae; 57–69 Matthioleae; 70–82 Sisymbrieae

also show Brassiceae to be monophyletic. Based on our results their are congruence with that results in tribes Lunarieae and Brassicaeae are homogeneous because we found only one type of hairs (simple hairs) among genera of these tribes. JANCHEN (1942) treated tribes Hesperideae and Matthioleae under one tribe Hesperideae. SCHULZ (1936) considered tribe Matthioleae as a separate tribe. In our results, cluster analysis shows that the group of *Anastatica hierochuntica, Matthiola arabica, M. parviflora, M. longipetala* and its subspecies (subsp. *longipetala*, subsp. *kralikii*, subsp. *hirta*, subsp. *bicornis* and subsp. *livida* (tribe Matthioleae), *Morettia parviflora* and *Morettia philaeana* can be almost separated from the rest of the groups. The taxa of this group are rather homogeneous. In comparison with other tribes these taxa have simple, glandular, dendroid and stellate hairs. *Diceratella elliptica* clusters with *Matthiola fruticulosa* have simple, branched and stellate hairs. However, other representatives of the tribe Matthioleae, like *Morettia canescens* and *Notoceras* cluster in the other group (Fig. 4). Our results contradict these traditional treatments (SCHULZ 1936) and are congruent with treatments suggested by JANCHEN (1942), and suggest that tribe Hesperideae (includes Matthioleae) is heterogeneous tribe.

Vasculate and hooked trichomes are very rare and can use to distinguished *Sisymbrium runcinatum* from the rest of *Sisymbrium*. Glandular hairs vary from a multicellular stalk with a head in *Matthiola arabica, M. parviflora* and *M. longipetala* to unicellular in *Descurainia* and *Ochthodium*.

Glandular hairs (multicellular) is used to distinguish *Matthiola fruticulosa* from the rest of *Matthiola,* also the lacking of trichomes on the fruits of *Maresia pygmaea* is distinguished this species from *M. nana*, and *Alyssum homalocarpum* from the other two species *A. marginatum* and *A. simplex* which they have fruits covered with stellate hairs.

The presence/ absence of trichomes was found useful to distinguish between the varieties of *Sinapis arvensis*. In *S. arvensis* var. *arvensis* the plant and fruits are glabrous but in *S. arvensis* var. *orientales* the plant and fruits are covered with hispid hairs.

Key to the studied taxa based on trichomes morphology

1a. Plant glabrous . . . . . *Nasturtium, Neotorularia aculeolata*, *Isatis, Zilla, Schouwia, Moricandia, Cakile, Pseudorucaria.*

1b. Plant hairy. 2

2a. Plant covered with one type of hairs

1. Plant covered with simple hairs. . . . . Brassicaeae, *Rorippa, Schimpera, Leptaleum, Coronopus, Lepidium, Ricotia, Nasturtiopsis, Sisymbrium*
2. Plant covered with stellate hairs . . . . . *Alyssum, Eremobium, Morettia canescens, Maresia nana*
3. Plant covered with medifixed hairs. . . . . *Farsetia*, *Lobularia, Notoceras*
4. Plant covered with branched hairs. . . . . *Robeschia, Maresia pygmaea*

2b. Plant covered with more than one type of hairs 3

3a. Plant covered with two types of hairs
1. Plant covered with simple and branched hairs . . . . . *Arabis, Capsella, Descurainia, Neotorularia torulosa, Neslia*
2. Plant covered with simple and clavate hairs . . . . . *Biscutella*
3. Plant covered with simple and vasculate hairs . . . . . *Sisymbrium runcinatum*
4. Plant covered with simple and glandular hairs . . . . . *Ochthodium*
5. Plant covered with dendroid and stellate hairs . . . . . *Anastatica, Morettia, Crucihimalaya, Matthiola longipetala* subsp. *longipetala*
6. Plant covered with medifixed and trifixed hairs . . . . . *Erysimum*
7. Plant covered with trifixed and Y-shaped hairs . . . . . *Olimarabidopsis*

3b. Plant covered with three types of hairs
1. Plant covered with simple, branched and dendroid hairs. . . . . *Malcolmia*
2. Plant covered with simple, branched and stellate hairs . . . . . *Diceratella, Matthiola fruticulosa*
3. Plant covered with simple, glandular and dendroid hairs . . . . . *Matthiola longipetala* subsp. *hirta*
4. Plant covered with stellate, glandular and dendroid hairs. . . . . *Matthiola arabica, M. fruticulosa, M. longipetala* subsp. *bicornis,* subsp. *livida,* subsp. *kralikii*

References

ABDEL KHALIK, K., MAESEN, L. J. G. VAN DER, 2002: Seed morphology of some tribes of Brassicaceae (implications for taxonomy and species identification for the flora of Egypt). Blumea 47, 363–383.

ABDEL KHALIK, K., MAESEN, L. J. G. VAN DER, KOOPMAN, W. J. M., VAN DEN BERG, R. G., 2002: Numerical taxonomic study of some tribes of Brassicaceae from Egypt. Plant Syst. Evol. 233, 207–221.

ABDEL KHALIK, K., VAN DEN BERG, R. G., MAESEN, L. J. G. VAN DER, EL HADIDI, M.N., 2002. Pollen morphology of some tribes of Brassicaceae from Egypt and its systematic implications. Feddes Rep.113, 211–223.

AL-SHEHBAZ, I. A., 1984. The tribes of Cruciferae (Brassicaceae) in the southeastern United States. J. Arnold Arb. 65, 343–373.

DENNERT, E., 1884. Beiträge zur vergleichenden Anatomie des Laubstengels der Cruciferen, Marburg.

DVOŘÁK, F., 1973: The importance of the indumentum for the investigation of evolutional relationship in the family Brassicaceae. Österr. Bot. Zeitschr. 121, 155–164.

EL HADIDI, M. N., EL NAGGAR, S. M., HEDGE, I. C., 1988: Taxonomic studies on Cruciferae in Egypt. 1. Check list and key to the genera. Taeckholmia 11, 73–86.

EL NAGGAR, S. M., 1987: Studies of the family Cruciferae in Egypt. PhD. Thesis, Assiut University.

EL NAGGAR, S. M., 1992: Systematic studies on the tribe Brassiceae. (Cruciferae) in Egypt. Feddes Rep. 103, 515–522.

EL NAGGAR, S. M., 1993: Numerical taxonomy of the tribe Lepideae and some other genera. Feddes Rep. 104, 201–208.

EL NAGGAR, S. M., EL HADIDI, M. N., 1998: The tribe Alysseae Hayek (Brassicaceae) in Egypt. J. Union Arab Biol. Cairo 6, 501–520.

HEDGE, I. C., 1976. A systematic and geographical survey of old World Cruciferae. In: VAUGHAN, J. G., MACLEOD, A. J., JONES, B. M. G. (ed.), The biology and chemistry of the Cruciferae,1–46. Academic Press, London.

HOLMGREN, P. K., KEUKEN, W., 1974: Index Herbariorum Part 1. The Herbaria of the World. Utrecht: Oosthoek Scheltema and Holkema for the International Bureau for Plant Taxonomy and Nomenclature.

INAMDAR, J. A., RAO, N. V., 1983: Light and scanning electron microscopic studies on trichomes of some Brassicaceae. Feddes Rep. 94, 183–190.

JANCHEN, E., 1942: Das System der Cruciferen. Österr. Bot. Zeitschr. 91, 1–28.

JONSELL, B., 1971: The genus *Rorippa* in Eastern Siberia and the Soviet Far East. Sven. Bot. Tidsk. Bad 65, 293–307.

JONSELL, B., 1986: A monograph of *Farsetia* (Cruciferae). Symb. Bot. Ups. 25, 1–106.

KERBER, E., STORK, A. L., 1982: Fettsauremuster, P. Hydroxy benzylglucosinolat and Sinapin im samen von *Malcolmia* S.L. (Cruciferae). Beitr. Biol. Pflanzen 58, 157–176.

KOCH, M., HAUBOLD, B., MITCHELL-OLDS, T., 2001: Molecular systematics of the Brassicaceae: evidence from coding plastidic matK and nuclear Chs sequences. Amer. J. Bot. 88, 534–544.

METCALFE, C. R., CHALK, L., 1950: Anatomy of dicotyledons.vol. 1. Oxford.

MULLIGAN, G. A., 1995: Synopsis of the genus *Arabis* (Brassicaceae) in Canada, Alaska and Greenland. Rhodora 97, 109–163.

PRANTL, K., 1891: Cruciferae. In: ENGLER, A., PRANTL, K. (ed.), Die Natürlichen Pflanzenfamilien, vol. 3, 145–206. Wilhelm Engelmann, Leipzig.

ROLLINS, R. C., BANERJEE, U. C., 1975: Atlas of the trichomes of *Lesquerella* (Cruciferae). Bussey Institution of Harvard Univ. 49 pp.

ROLLINS, R. C., BANERJEE, U. C., 1976: Trichomes in studies of the Cruciferae. In: VAUGHAN, J. G., MACLEOD, A. J., JONES, B. M. G. (ed.), The biology and chemistry of the cruciferae,145–166. Academic Press, London.

ROLLINS, R. C., BANERJEE, U. C., 1979: Trichome pattern in *Physaria*. Bussey Institution of Harvard University.

SCHULZ, O. E., 1936: Cruciferae. In: ENGLER, A., PRANTL, K. (ed.), Die Natürlichen Pflanzenfamilien, vol. 17B, 227–658. Wilhelm Engelmann, Leipzig.

THEOBOLD, W. L., KRAHULIK, J. L., ROLLINS, R. C., 1979: Trichome description and classification. In: METCALFE, C. R., CHALK, L. (eds.), Anatomy of the dicotyledons, vol. 1. Cambridge.