BIOSYSTEMATIC STUDIES ON BRASSICACEAE (CRUCIFERAE) IN EGYPT

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KADRY N. E. ABDEL KHALIK

Proefschrift

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To

My parents

My wife Eman and my lovely daughter Yara

To whose encouraged and helped me to finish this work

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1.

GENERAL INTRODUCTION

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1.1. LITERATURE REVIEW

1.1.1. Suprafamilial classification

Bentham & Hooker (1862: 57) classified the order Cruciferae into 5 series (10 tribes) depending on the shape of fruit and dehiscence, the number of rows of seeds in each locule, and the position of the radicle relative to the cotyledons.

Bessey (1897) classified the order Thalamiflorae into 7 sub-orders and put the family Cruciferae with 11 families in suborder Parietales based on the leaves, stems, roots morphology, the flower strobilus, the perianth and pollen, and ovule leaves.

Alston & Turner (1963) investigated mustard oils which are common in Cruciferae, Capparidaceae, Moringaceae, Tropaeolaceae and Resedaceae; the isothiocyanates represent a major source of taxonomic information in the Cruciferae and all members of this family so investigated have proven to contain isothiocyanates. Hutchinson (1973) and Judd et al. (1999) treated Brassicaceae in the order Brassicales.

Benson (1979: 152-160) classified the order Papaverales into two suborders: Papaverineae and Capparidineae, depending on the number of petals and sepals, opening of the fruit and the number of carpels and stamens; and put Brassicaceae under the suborder Capparidineae.

Rodman (1981); Gershenzon & Mabry (1983); and Rodman et al. (1998) agree that the Rhoeadales represent two unrelated orders: the Capparales (which contain glucosinolates, myrosin cells, centrifugal stamens, and lack laticifers and benzylisoquinoline alkaloids) and the Papaverales (with benzylisoquinoline alkaloids, laticifers and centripetal stamens, and lacking glucosinolates and myrosin cells). Cronquist (1988: 346) treated Brassicaceae, Capparaceae, Tovariaceae, Moringaceae and Resedaceae in the order Capparales based on the presence of glucosinolates and myrosin cells. Rodman (1991b); Rodman et al. (1993 & 1996); Judd et al. (1994) and Soltis et al. (1997) used cladistic analysis of morphological cpDNA and rDNA characters, to study the phylogenetic relationships within the order Brassicales.

Recently Brassicaceae have been placed as subclade of Brassicales which is diagnosed by the presence of glucosinolates, myrosin cells, 4-merous flowers, seeds with curved or folded embryos and lacking or nearly lacking endosperm, vessels with vestured pits, protein-rich, vacuolar and utricular cysternae of endoplasmic reticulum (Judd et al., 1999).

1.1.2. Infrafamilial classification

One of the earliest attempts at a natural classification of family Cruciferae was given by Morison (1680). He divided the Cruciferae into two main groups based on the fruit length: the first group has a long fruit (siliqua) and the second one a short fruit (silicula). Linnaeus in the

Species Plantarum (1753) also used the same two main divisions based on the length of fruit as had Morison.

Bentham & Hooker (1862: 58) recognized 10 tribes based on fruit length and cotyledon / radicle characters. Prantl (1891) in the Pflanzenfamilien used indumentum characters and recognized four tribes. Hayek (1911) used nectary glands and myrosin cells and recognized 10 tribes.

Schulz (1919-1936) contributed enormously to our knowledge of the Brassicaceae on a world basis. He recognized 360 genera throughout the world and assigned these genera to 19 tribes depending on number of characters, such as nectaries glands, septum, cotyledons relative to radicle, fruit-length, and indumentum.

Janchen (1942) reduced the total number of Schulz's tribes from 19 to 15. He united Schulz's tribes Hesperideae and Matthioleae under Hesperideae, because, he did not consider the differences of incumbent (Hesperideae) versus accumbent (Matthioleae) radicles of sufficient importance to separate tribes. He also united Schulz's tribes Alysseae, Lunarieae and Drabeae under Alysseae, because he did not believe that the details of cell structure in the septum were adequate for recognition of 3 independent tribes, and also transferred some genera from tribes into new tribes.

Avetisian (1976, 1983) reduced Schulz's tribes to three tribes; Thelypodieae, Brassiceae and Sisymbrieae. Al-Shehbaz (1984) classified the family Brassicaceae of the southeastern United States into 7 tribes based on the morphological characters of fruit, sepals, stamens and the position of cotyledons relative to the radicle. Al-Shehbaz (1985, 1987, 1988) also revised those tribes based on morphological characters.

Koch et al. (2001) used the chloroplast gene matK and nuclear Chs sequences to analyze tribal and subtribal structures in Brassicaceae. The analysis indicates that tribes Lepidieae, Arabideae and Sisymbrieae are not monophyletic and the tribe Brassiceae might be the only monophyletic group of the traditional tribes. Clemente & Hernandez-Bermejo (1980a, 1980b and 1980c) studied 145 taxa, belonging to 41 genera of the tribe Brassiceae growing in the Mediteranean region, based on different characters of calyx, corolla and nectaries and divided this tribe into 7 groups.

El Naggar (1992) investigated the tribe Brassiceae in Egypt and divided this tribe into 7 subtribes (Brassicinae, Cakilinae, Zillinae, Savigninae, Raphaninae, Vellinae and Moricandinae) based on the morphological characters of habit, leaf, stem, flower, fruit, seed and embryo. El Naggar (1993) also studied the tribe Lepideae in Egypt based on the morphological characters of habit, leaves, hairs, flowers, fruits and seeds. He classified this tribe into four subtribes (Isatidiinae, Ibredinae and Capsellinae) as monophyletic and (Lepidiniae) as polyphyletic and separated the Lepidiniae into two groups: Lepidium group and Cardaria group.

El Naggar & El Hadidi (1998) investigated the nomenclature, macro-and microcharacters of taxa of the tribe Alysseae in Egypt and verified that the tribe Alysseae is represented by 4 genera and 10 species. They stated that *Ricotia lunaria* does not belong in the tribe Alysseae (Janchen, 1942).

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, pedicels, indumentum and seed structure. On the other hand Stuckey (1972) investigated the genus *Rorippa* in North America and classified the genus into two sections depending on the shape of basal and cauline leaves, and he investigated 29 species based on the shape of leaves, stems, petals and fruits. Jonsell (1974) also revised the genus *Rorippa* in Tropical Africa and Madagascar and he recognized about 10 species based on the shape of stems, leaves, inflorescence, petals, fruits and seeds. Jonsell (1975) revised the genus *Lepidium* in Tropical Africa and he recognized about 9 species based on morphological variations of leaves, indumentum, flowers, fruits, pedicels and seed structure. Jonsell (1986) monographed the genus *Farsetia* and classified it into 25 species, two of which are subdivided into subspecies depending on variation in life form, nectarial arrangements, stem anatomy, indumentum, leaves, inflorescense, sepals, petals, stamens, siliqua septum patterns, style and stigma structure, pollen grains, seeds and chromosome numbers. Nine new species are described and two new combinations on subspecies level are published.

Prantl (1891: 200) divided the genus *Malcolmia* R. Br into two sections; sect. 1. Maresia (Pomel) Prantl, and sect. 2. Eumalcolmia Prantl based on the characters of style and stigma. Vasilcenko (1939) divided the genus *Malcolmia* R. Br. into three sections: sect. 1. Turkestanicae Vasilcenko; sect. 2. Africanae Vasilcenko, and sect. 3. Laeves Vasilcenko.

Ball (1963: 179) " *Malcolmia* is a relatively heterogeneous genus which can be divided into a number of distinct groups of species on morphological grounds". He separated four groups: *M. littorea* group, *M. maritima* group, *M. ramosissima* group and *M. africana* group, the Egyptian species belong to the latter group.

Stork (1972) studied the genus *Malcolmia* in Greece and adjacent areas and she recognized 5 species based on the geographical distribution, ecological vicarious, chromosome numbers, pollen grains fertility and seed set. Dvořāk & Konarikova (1970); Dvořāk (1972,1973) studied the characters of genus *Malcolmia* R.Br.

Stork & Wüest (1980) investigated the genus *Morettia* and they recognized *M. philaeana, M. parviflora* and *M. canescens* as closely related taxa of mainly Saharo-Sindian distribution, and *M. reroilii* as Somalian endemic based on the chromosome numbers, characters of indumentum, leaves, fruits, pollen grains and seeds.

Jonsell (1979) distinguished *Matthiola, Morettia* and *Diceratella* based on the characters of trichomes, sepals, petals, lateral nectaries, fruits, stigma, pollen grains and seed characters.

Kerber & Stork (1982) differentiated 4 groups from *Malcolmia* (Maritimia, Africana I and Π, Crenulata, Littorea and Ramosissima groups), *Maresia*, *Torularia* and *Eremobium aegyptiacum* based on the characters of p-hydroxybenzylglucosinolate and sinapin, trichomes, sepals, petals, lateral nectaries, fruits, seeds and chromosome numbers.

The genus *Arabis* contains about 100 species mainly in temperate Europe and Asia extending to North America and the southern hemisphere (Lan, 1987). Subsequently Al-Shehbaz (1988a) considered that the genus *Arabis* is represented by more than 180 species distributed in the temperate areas of the Northern Hemisphere, while *Arabis alpina* and *Arabis glabra* appear in the high mountains of tropical East Africa.

Rollins (1936a); Hopkins (1937) and Rollins (1941) monographed the genus *Arabis* in Northwest America. Rollins (1993b) published the first comprehensive taxonomic study of the genus *Arabis* in North America based on descriptions, habitats, distributions and cytological data. Mulligan (1995) investigated the genus *Arabis* in Canada, Alaska and Greenland and he recognized 30 species based on morphological characters and chromosome numbers. Huang et al. (1995) revised the Taiwan species of *Arabis* and recognized 4 species depending on the morphological characters.

According to Price et al. (1994), the genus *Arabidopsis* is represented by 27 species, mostly distributed in the high mountain ranges from Southwest Asia to China.

O'Kane & Al-Shehbaz (1997), transfered nine species and five subspecies from *Cardaminopsis* and *Arabis* to *Arabidopsis* based on analysis of rDNA sequences and morphological characters. Al-Shehbaz et al. (1999) excluded nine species from *Arabidopsis* and founded the newly named genera of *Crucihimalaya*, *Olimarabidopsis* and *Pseudoarabidopsis* based on molecular comparisons of both chloroplast DNA (Price et al. 1994), and nuclear Internal Transcribed Spacer (ITS) regions (O'Kane et al., 1995, 1997). They used morphological characters of basal and cauline leaves, trichomes, flowers, fruits and position of the radicle relative to the cotyledons.

Koch et al. (1999) investigated the phylogenetics of the genera *Arabidopsis* and *Arabis* based on nuclear ribosomal DNA sequences and they showed that traditional taxonomical concepts within tribe Arabideae are highly artificial. *Arabis* and *Arabidopsis* are paraphyletic and consist of several different independent lineages. He showed that the chromosome number reduction from n = 8 to n = 5 to 7 occurred several times in the tribe Arabideae.

Hickey (1973) and Melville (1976) classified the architecture of dicotyledonous and angiospermous leaves. Rao & Inamdar (1983) studied the leaf architecture in 19 genera and 35 species of the Brassicaceae. The areole size and shape is variable within the species and investigated that the major venation pattern is pinnate craspedodromous and the number of secondary veins and their angle of divergence vary from species to species and even within the same species.

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 ones. Prantl (1891) used the hair shape as a basic character for the classification of Brassicaceae. Schulz (1936), did not investigate the indumentum from this point of view, he only dealt with the morphology of hairs. Janchen (1942) used the indumentum as an important character. Dvořāk (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). Inamdar & 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. They recognized 11 types of eglandular trichomes (9 types of unicellular; 1 type of bicellular and 1 type of multicellular shape).

Deng & Hu (1995) studied the morphology and micromorphology as well as the structure of nectaries of 74 species and 1 variety, belonging to 9 tribes and 36 genera of Brassicaceae. The outer morphology of floral nectaries showed greater diversity in number, shape, cuticle sculpture, composition, position and existence of vascular bundles. These characters were different among genera of the same tribe and sometimes were also different in different species of the same genus. They divided the floral nectaries of Brassicaceae into three types according to their distribution, morphology and structure: 1. Lateral-nectary type; 2. Lateral and median nectaries type; 3. Annular-nectary type (Lateral and median nectaries united into an annular one). The lateral and median nectary types were considered as primitive whereas the lateral-type and annular-nectary type as advanced.

Zohary (1948) and Rollins (1993) used the fruit characters as the main base for classification of Brassicaceae. Appel (1999) used the beak of the fruit as character in the systematics of Brassicaceae particulary in the tribe Brassiceae and concluded that the term beak should be avoided and the complicated term heteroarthrocarpous used instead. The character is restricted to the Brassiceae and serves well in the delimitation of this tribe.

Gómez-Campo & Tortosa (1974) studied the shape of the cotyledon lamina and a few other juvenile characters for 140 taxa of the Brassicaceae in tribe Brassiceae and furthed discussed the relationship among genera. They cast a number of doubts on the present status of certain taxa, such as *Diplotaxis siifolia*, *Erucastrum cardaminoides* and *Brassica balearica*. The whole tribe Raphaninae appears rather unnatural when viewed from cotyledon evidence. The most primitive state of the cotyledons seems to be that present in the genus *Sinapidendron*.

1.2. PHYTOGEOGRAPHY

Phytogeography is concerned with describing and interpreting the distribution of the earth's plant life (Daubenmire, 1978). Brassicaceae are well represented in floras of many regions of the world.

According to Zohary (1973) and Zohary et al. (1980), the family Brassicaceae is well represented in the Mediterranean region, N Africa and SW Asia. They divided this area into three phytogeographical regions: The Mediterranean, Irano-Turanian and Saharo-Sindian region (Map 1). In the Middle East, NE Africa and SW and C Asia five phytogeographical regions meet. These regions are: The Euro-Siberian, Mediterranean Irano-Turanian, Saharo-Arabian (partially Saharo-Sindian) and Sudanian (partially Sudano-Zambezian) regions. The Euro-Siberian region is one of the largest regions of the Holarctic kingdom occupying the greater part of Europe and large adjacent parts of Asia (Zohary, 1973). This latter region is not represented in Egypt.

According to Eig (1931-1932) Egypt is the meeting point of floristic elements belonging to at least three phytogeographical regions: the African Sudano-Zambesian; the Asiatic Irano-Turanian; the Afro-Asiatic Saharo-Sindian and Euro-Afro-Asiatic Mediterranean.

El Hadidi (1993) divided Egypt into 8 phytogeographical territories, two of which have subdivisions (Map 2), Cruciferae are represented in almost all these territories.

The Mediterranean region occupies a narrow belt along the Mediterranean Sea. This region is characterised by a more or less regular bipartition of the year into a hot dry summer and a rainy mild winter season. This region is hardly represented in Egypt because almost all of Egypt is covered with desert. As the desert is very close to the sea, Egypt is the most arid country in North Africa. But there are many Mediterranean elements represented in Egypt such as *Erysimum*, *Ricotia* and *Ochthodium*.

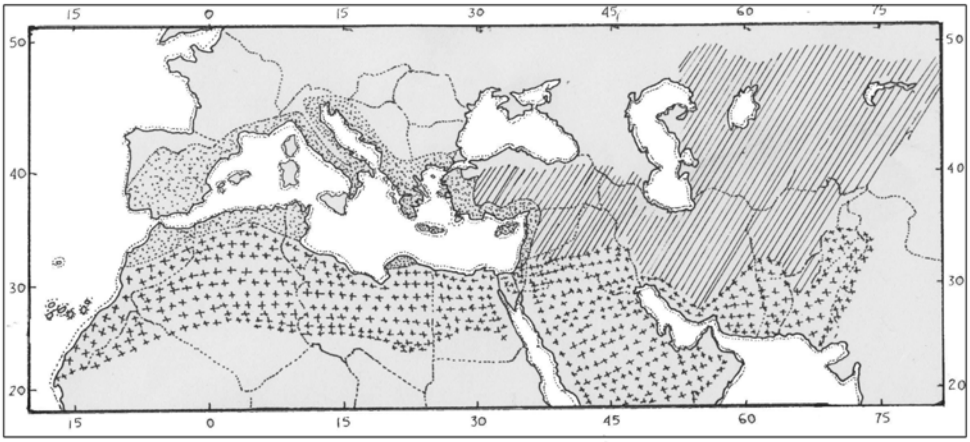
The Irano-Turanian region is characterized by hot arid summer and cold snowy winter. This region is home to about 900 crucifer species and was probably the center of origin for at least the oldest world taxa (Hedge, 1976). This region is also not represented in Egypt by endemic genera but it is represented by some elements which are represented in other regions such as *Arabidopsis*, *Arabis, Descurainia, Malcolmia*, *Matthiola, Nasturtium, Neslia, Notoceras, Rorippa, Sisymbrium* and *Neotorularia*. The Saharo-Sindian region is characterized by the uniformity of its climatic, topographical and edaphic features. This region includes the desertic regions of the Sahara, Arabia and Sind, and covers a broad zone with the east-west range covering almost 8000 km. Zohary (1973) has split this region into two independent regions; The Western-Saharo-Arabian and the Eastern Sudanian.

The Saharo-Arabian region is the West and Middle part of Saharo-Sindian region, most crucifer species of Egypt are represented within this region. It characterized by dry, hot desert conditions with annual rainfall ranging from 25 to 150 mm; most of the rain falls in the period November to January, and the rest of the year is more or less dry. There are only about 1500 species of flowering plants in this region (Hedge, 1976). Ozenda (1958) gave an account of 1200 species for the African part of this region. The Brassicaceae are well represented in this region.

The characteristic endemic genera of Brassicaceae for this region in Egypt are *Anastatica*, *Nasturtiopsis*, *Schimpera, Morettia* and *Eremobium*, while several other elements which are represented in other regions do also occur, such as *Arabidopsis*, *Arabis, Descurainia, Malcolmia*, *Matthiola, Nasturtium, Neslia, Notoceras, Rorippa, Sisymbrium* and *Neotorularia* (Map 3, 4, 5).

The Sudanian territory consists of Southwest Arabia and wide strips along the Gulf of Suez and Aqaba. Takhtajan (1985) and El-Naggar (1987) considered it not represented in Egypt, but Danin & Plitman (1987) claimed the contrary. The territory is represented specially in Sinai along wadis with many Sudanian semishrubs, shrubs and perennial grasses and I follow them in this respect.

In my present work there is only one endemic Brassicaceae species in Egypt: *Rorippa integrifolia* Boulos from the Sinai.



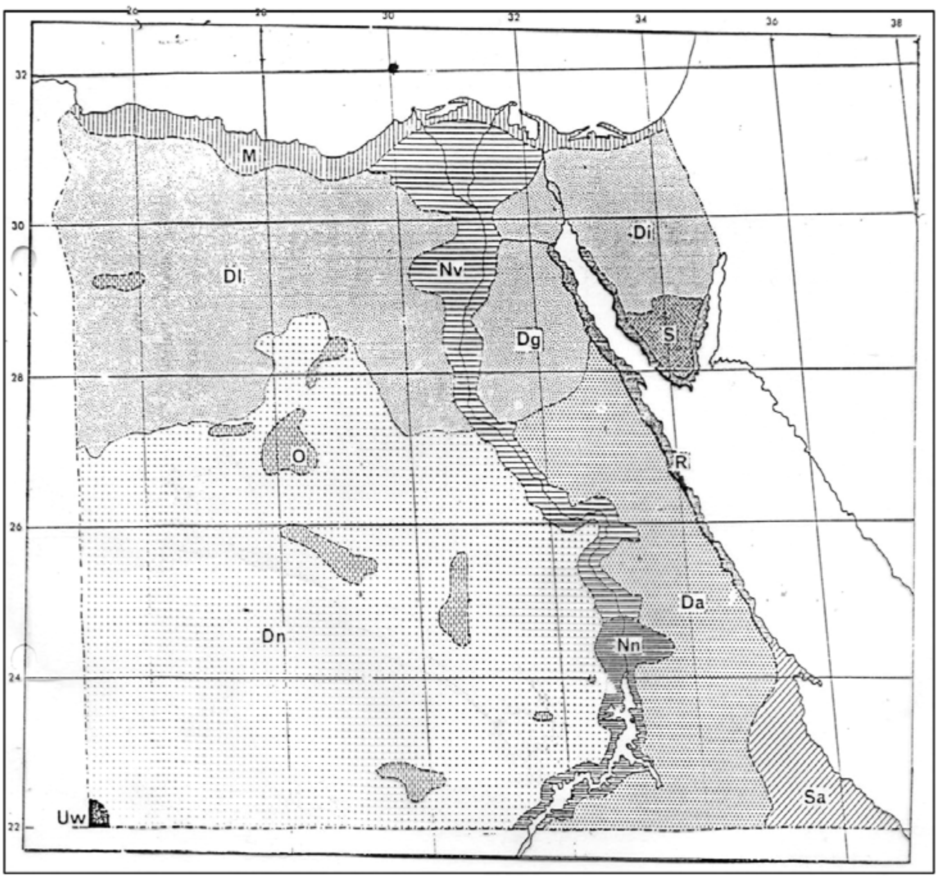
Map 1: The phytogeographical regions in the Middle East

The Mediterranean region

The Irano-Turanian region

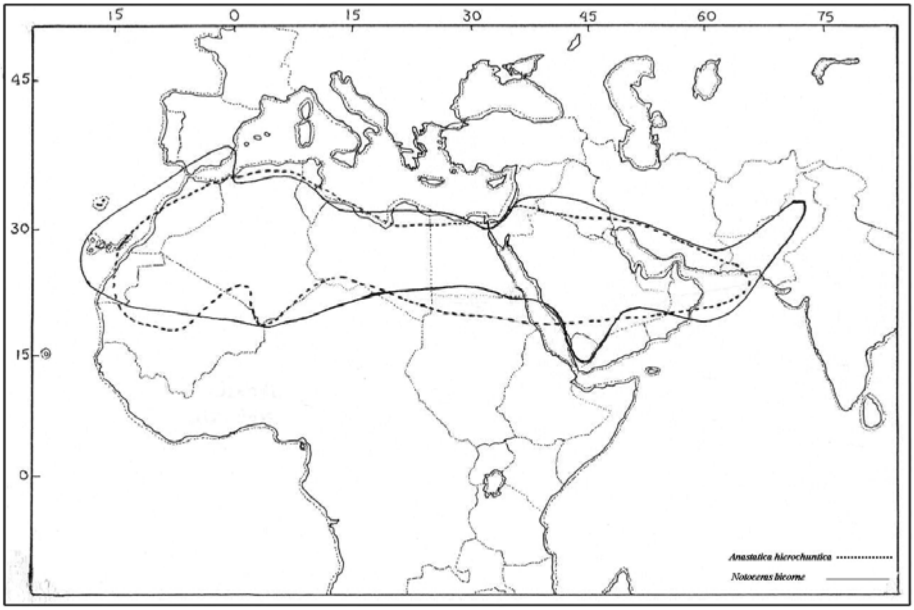
The Saharo-Arabian region

Adapted from Hedge, 1976.

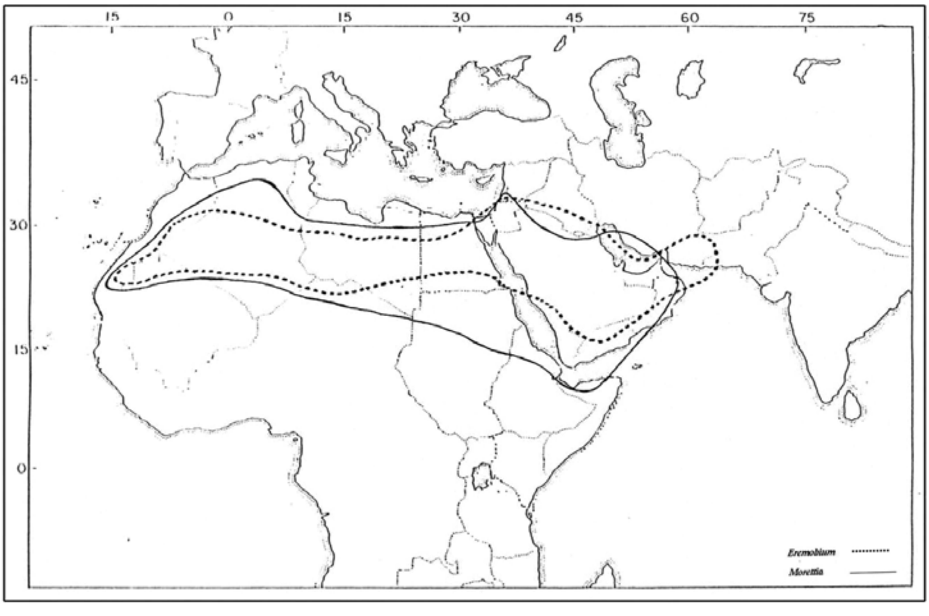


Map 2: Phytogeographical territories of Egypt. El Hadidi (1993).

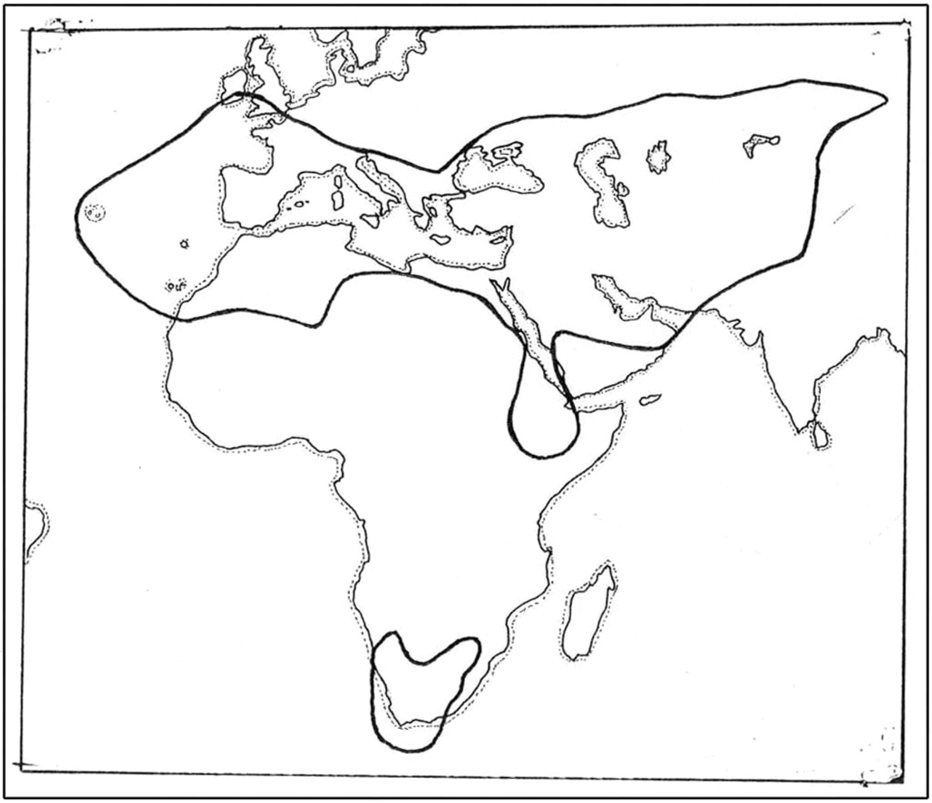
M, Mediterranean coastal belt. **D**, Deserts including: **DI**, Libyan Desert; **Dn**, Nubian Desert; **Di**, Isthmic Desert; **Dg**, Galala Desert; **Da**, Arabian Desert. **N**, Nile land including: **Nv**, Nile Valley; **Nn**, Nubian Nile. **O**, Oases. **S**, Sinai mountainous region between the Gulfs of Suez and Aqaba. **R**. Red Sea coastal plains including those of **Dg**, **Da** as well as those along the Gulfs of Suez and Aqaba. **Sa**, Sahelian scrub in Gebel Elba mountainous block, its coastal plains along the Red Sea, and their extension westwards through **Da**. **Uw**, Massif of Gebel Uweinat and the intersecting wadis.



Map 3: Distribution of *Anastatica hierochuntica* and *Notoceras bicorne*
Adapted from Hedge, 1976.



Map 4: Distribution of *Eremobium* and *Morettia*
Adapted from Hedge, 1976.



Map 5: Distribution of *Matthiola.* Adapted from Hedge, 1976.

1.3. USES AND ECONOMIC IMPORTANCE

The family Brassicaceae can be found in nearly all cultivated areas and occupy distributed sites, roadsides, waste grounds throughout the world, but particularly in temperate regions. They are grown as vegetables, oil crop, condiment, medicinal plants or ornamentals. *Brassica* is the most important genus, for it contains several vegetable, salad and medicinal plants. Species cultivated as vegetable and salad plants are Cabbage, Cauliflower, Brussels sprouts, Kale, Broccoli (all considered to be varieties of *Brassica oleracea* L.), turnip (*B. campestris* L.), Chinese or Indian mustard (*B. nigra* (L.) Koch). Other crops include the radish (*Raphanus sativus* L.), watercress (*Nasturtium officinale* R. Br.), Eruca (*Eruca sativa* L.) and cress (*Lepidium sativum* L.).

Cruciferous oil plants play an important role in the economy, especially in India. There are four types of *Brassica* seed oil in India: yellow sarson, brown sarson, toria and brown mustard.

These are taken from *B. campestris* L. and *B. juncea* (L.) Czern. The seed cake remaining after extraction of oils is used as feed for farm animals.

Animal feeds are supplied by cruciferous crops in the form of silage, seed meal left over after extraction, forage crops grazed in the field, and stored root fodder used for winter feeds. The characteristic glucosinolates produced by Cruciferae affect the use of many species economically. Glucosinolates are the precursors of the mustard oils which are responsible for pungency of most crucifers and evidently produced as an insect deterrent. In some crops such as mustard, radish, and horseradish may be responsible for toxic manifestations when used as animal feed or in human nutrition, because of this the production of silage from crucifers is limited. Seed meal is obtained from species such as *Brassica napus,* especially races with a low glucosinolate content (Heywood, 1993).

Luo Peng et al., (1997) notes that the seeds of *Descurainia sophia* contain a high amount of oil content (44.17 %) which suggests that this oil can be introduced for industrial utilization. Condiments are obtained from the fleshy roots of horseradish (*Armoracia rusticana* Gaertner, Meyer & Scherb.), while table mustard is prepared from a mixture of the seeds of the white mustard (*Sinapis alba* L.) and those of either the black or the Indian mustard.

The seeds and oil have been used as medicine. Watt (1889-1893) mentioned that species of Brassicaceae have medicinal properties. Mustard oil is used by Indians to anoint the body before bathing. It prevents excessive preservation and prickly heat, also protects the skin from the direct rays of the sun. A few drops taken after meals promate digestion and act as a mild cholagogue and diuretic. It is very efficacious as a stimulating liniment in Cough and Catarrh. *B. campestris* L. is used as a remedy for stomach and skin diseases such as elephantiasis. The seeds of *Brassica nigra* are used in medicine as poultice being a useful and simple rubefacient and vesicant. Mustard poultices prove highly serviceable in cases of febrile and inflammatory diseases, internal congestions, spasmodic, neuralgic and rheumatic affections. The seeds of *B. oleracea* are diuretic, laxative, stomachic and anthelmintic. The leaves form a good application in gout and rheumatism.

The seeds of *Lepidium sativum* L. are used as tonic, alterative, to treat hiccups, diarrhoea and skin diseases. *Sisymbrium irio* L. seeds are medicinal in the Arabic and Muhammadan pharmacopaeias. It is described as having expectorant, stimulant and restorative properties; it is also used externally as a stimulant poultice, and seeds are also used as a febrifuge. *Nasturtium officinale* R. Br. is widely known for its antiscorbutic and stimulant properties, and is also largely eaten to increase appetite.

The seeds of *Matthiola incana* (L.) R. Br. are used in infusion in cancer, as an expectorant and mixed with wine it is given as an antidote to poisonous bites.

Eruca oil is mostly used as lubricant and lamp oil. The oil cake is utilized as cattle feed and fertiliser. In Egypt, *Eruca* oil is used to prevent fall of hairs; Radish (*Raphanus sativus* L.) is eaten and known from 4000 years, and was found engraved on the walls of ancient Egyptian tombs and the temple of Karnak.

The most important ornamental crucifers include the wallflower (*Erysimum cheiri* (L.) Crantz, money plant (*Lunaria annua* L.), candytuft (*Iberis*), stock (*Matthiola incana* (L.) R. Br.), and rock cress (*Arabis* species). *Arabidopsis thaliana* L. is used as a model system for plant molecular biology and genetics.

1.4. OUTLINE OF THE THESIS, AIMS AND GENERAL OBJECTIVES

In the flora of Egypt, Brassicaceae are one of the four largest plant families, represented by about 102 species belonging to 55 genera, assigned to 9 tribes (El Hadidi et al., 1988). Boulos (1999) treated 104 species belonging to 53 genera. Species of the tribes Lepideae, Brassiceae and Alysseae (63 species belonging to 32 genera) have been the subject of earlier studies (El Naggar 1987, 1992, 1993; El Naggar & El Hadidi, 1998). The remaining species of Brassicaeae belong to the tribes Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae (O.E. Schulz′s system). These 39 species in 23 genera exhibit great diversity, as shown in the present systematic revision. The members of these tribes are distributed over a wide range of habitats: weeds of farmland and waste places; desert sub-shrubs or herbs; they occur in Mediterranean coastal land; the oases; the mountains of Sinai and Elba; as well as inland and in maritime salt marshes. The present work started in Egypt in 1998. Field studies for the collection of fresh materials were carried out by the author from localities in the Mediterranean coastal land, Western desert, Eastern desert, Nile valley, Gebel Elba and Sinai. In 2000, the author was awarded a grant to complete his study at the laboratories of Plant Science Department, Biosystematics group, Wageningen University, The Netherlands.

GENERAL AIMS

1. To revise systematically the species belonging to the tribes Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae and prepare an account on these Brassicaceae for the new issues of the Flora of Egypt.
2. To carry out detailed field studies for the collection of fresh materials required for the different purposes of the study. In this respect basic ecological observations are to be taken.

GENERAL OBJECTIVES:

1. To investigate gross-morphological characters for every taxon, variation and diversity in characters will be recorded from the available specimens (**Chapter 2**)
2. To study micro- and macromorphological characters of seeds for every taxon, using light and Scanning Electron microscopy, to decide on the importance of seed characters as a criterion for separating genera and species (**Chapter 3**).
3. To study pollen morphological characters and the range of variation present among species, for using these data in the taxonomy of the Brassicaceae (**Chapter 4**).
4. To use numerical taxonomy (UPGMA clustering and PCO analysis) to understand better the phenetic relationships between genera within a tribe and tribes within the family based on a large number of characters (vegetative parts, flowers, fruits, pollen grains and seeds) (**Chapter 5**).
5. To investigate these tribes by molecular approach (*mat*K gene). This will enable a comparison of morphological data with molecular data to understand better the phylogenetic relationships between genera within tribes and tribes within the family (**Chapter 6**).

2.

MORPHOLOGY AND SYSTEMATICS OF BRASSICACEAE IN EGYPT

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ABSTRACT

A systematic investigation of 45 taxa belonging to 23 genera of tribes Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae of the family Brassicaceae from Egypt. A full discussion for all morphological characters is provided; systematic treatment, based on macro-characters such as habit, leaf, floral, fruit, embryo and seed and micro-characters of trichomes, and artificial key applies the most reliable characters for the distinction of the genera. Some taxonomic and nomenclature problems in *Rorippa, Neslia, Eremobium, Malcolmia, Matthiola, Arabidopsis* and *Neotorularia* are discussed and changes proposed.
Eremobium aegyptiacum subsp. *longisiliquum* and *Matthiola longipetala* subsp. *kralikii* are recorded from Egypt for the first time. *Nasturtium indicum* is transferred from *Nasturtium* to the genus *Rorippa*; the number of species in this genus is reduced from two to one. In the genus *Neslia*, *N. apiculata* is treated as variety of *N. paniculata*. The number of species in this genus is reduced from two to one. *Neslia paniculata* is represented by two varieties, *N. paniculata* var. *paniculata* and var. *apiculata*. In the genus *Eremobium*, *E. diffusum* is considered as a synonym of *E. aegyptiacum* subsp. *lineare*; the number of species in *Eremobium* is reduced from two to one. *Eremobium aegyptiacum* is represented by three infra specific taxa, *E. aegyptiacum* subsp. *aegyptiacum*, subsp. *lineare* and subsp. *longisiliquum*.
In the genus *Maresia*, *M. nana* and *M. pygmaea* are treated as synonyms and transferred into the genus *Malcolmia*. The number of species in *Malcolmia* is changed from one to three. In the genus *Matthiola*, *M. elliptica* is transferred from this genus to the genus *Diceratella*; *M. livida* is considered as infra specific taxon of *M. longipetala*. The number of species in this genus is reduced from 6 to 4. *Matthiola longipetala* is represented by five infera specific taxa, *M. longipetala* subsp. *bicornis*, subsp. *hirta*, subsp. *kralikii*, subsp. *livida* and subsp. *longipetala*.

Key words: Morphology, Systematic, Key, Brassicaceae, Arabideae, Euclidieae, Hesperidieae, Lunarieae, Matthioleae, Sisymbrieae

2.1. MATERIALS AND METHODS

2.1.1. Plant material

The present study is largely based on herbarium material received on loan from B, BM, BR, E, HUJ, K, KSU, L, LY, NMGM, OXF & FHO and W, and collections kept in the following herbaria; B, CAI, CAIM, WAG and Sohag University herbarium (SHG, proposed abbreviation). In addition, fresh material of most of the taxa was studied and field observations were made from several localities of the Mediterranean region, Western desert, Eastern desert, Nile valley, Mountains of Sinai and Elba in Egypt.

The geographical localities of the studied taxa in Egypt were mapped according to the ecological territories proposed by El Hadidi (1993), (Map 2). Within each territory, specimens are sequentially arranged from the North to the South and from West to East. Besides the distribution maps for taxa of Egyptian origin, distribution maps for Middle East and around Mediterranean taxa were prepared.

2.1.2. Hairs

For SEM study 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 5100. After coating, the specimens were viewed with a Jeol JSM 5200 electron microscope at 20 KV.

2.1.3. Petals, Stamens and Fruits

Material used to study flowers and fruits is listed in tables 2.1 and 2.2. Petals and stamens from dried specimens were soaked in boiling water for 3-5 minutes, to remove the shrinking and examined by light microscope, measured with standardized ocular micrometer and drawn with the aid of a camera lucida.
For studying fruit shape, the fruits were drawn with a standard camera, Optica lb Brandt type.

Table 2.1. List of specimens used in studies of petal shape in Brassicaceae

Taxon	Collection No.	Origin of collections
1. Tribe Arabideae		
1. *Arabis alpina* L. sub sp. *caucasica* (Willd.) Briq.	1115	Ethiopia, prov. Begemder, Semien Mts (WAG)
2. *Arabis nova* Vill.	446	Bulgaria, M. Golo Bardo (CAI)
3. *Nasturtium officinale* R.Br.	764	Egypt, Abu Atwa, S. Ismailia (CAI)
4. *Rorippa indica* (L.) Hiern	s.n.	Egypt, Qena, El Mahrosa island (SHG)
5. *Rorippa integrifolia* Boulos	9	Egypt, Middle of Sinai, about 5 km before Ras Sedr (SHG)
6. *Rorippa palustris* (L.) Besser	20	Egypt, Along the canal of Ismailiya (SHG)
2. Tribe Euclidieae		
7. *Anastatica hierochuntica* L.	327	Egypt, Cairo-Suez road, km 95 from Cairo (CAI)
8. *Neslia paniculata* (L.) Desv.	130	Palestine, Jerusalem: Mt, Scopus (WAG)
9. *Ochthodium aegyptiacum* (L.) DC.	129	Palestine, Jerusalem: Mt, Scopus (BR)
10. *Schimpera arabica* Hochst & Steud.	s.n.	Saudi Arabia, As Summan (CAI)
3. Tribe Hesperideae		
11. *Eremobium aegyptiacum* (Spreng.) Asch. & Schweinf. subsp. *aegyptiacum*	29	Egypt, El Arish area beside the Airport, N. Sinai (SHG)
12. *Erysimum repandum* L.	15	Austria, Vienna, in fields (WAG)
13. *Leptaleum filifolium* (Willd.) DC.	s.n.	Egypt, Wadi Chafura, north Galala (BR)
14. *Malcolmia africana* (L.) R.Br.	2	Egypt, Deir el Rahba, Wadi el Arbain, S. Sinai (SHG)
15. *Malcolmia nana* (DC.) Boiss.	28	Egypt, El Arish-Rafah road, 23 km from El Arish (SHG)

Table 2.1. continued

16. *Malcolmia pygmaea* (Del.) Boiss.	22	Egypt, 26 km, Sidi Krer, Alex.-Matruh coastal road (SHG)
4.Tribe Lunarieae		
17. *Ricotia lunaria* (L.) DC.	630	Israel, Western upper Galilee (WAG)
5. Tribe Matthioleae		
18. *Diceratella eliptica* (DC.) Jonsell	17	Egypt, Gebel Elba, Wadi el Shallal (SHG)
19. *Matthiola arabica* Boiss.	12	Egypt, Wadi el Arbaien, S. Sinai (SHG)
20. *Matthiola fruticulosa* (L.) Maire	34	Egypt, Alexandria (K)
21. *Matthiola longipetala* subsp. *bicornis* (Sibth.) Ball	132	Turkey, Tassia, in sands near Saban Daği (BR)
22. *Matthiola longipetala* subsp. *hirta* (Conti) Greuter & Burdet	23	Egypt, Alex.-Matruh coastal road, near Burg el Arab (SHG)
23. *Matthiola longipetala* subsp. *kralikii* (Pomel) Maire	7	Egypt, Cairo-Alexandria desert road, 100 km from Alexandria (SHG)
24. *Matthiola longipetala* subsp. *livida* (Delile) Maire	27	Egypt, Cairo-Ismailiya desert road, 23 km before Ismailiya (SHG)
25. *Matthiola longipetala* (Vent.) DC. subsp. *longipetala*	25	Egypt, 28 km before Matruh, Alexandria-Matruh road (SHG)
26. *Matthiola parviflora* (Schousboe) R.Br.	270	Morocco, Marrakech (BR)
27. *Morettia canescens* Boiss.	10	Egypt, Wadi Feiran, S. Sinai (SHG)
28. *Morettia parviflora* Boiss.	16984/2	Saudi Arabia, Wadi Harjab, rocky hillsides (BR)
29. *Morettia philaeana* (Delile) DC.	3	Egypt, 35 km from Qena at the road Qena-Safaga (SHG)
30. *Notoceras bicorne* (Ait.) Caruel	1052	Egypt, Gebel Elba, Saddle between Gebel Asotriba and Makin (CAI)
6. Tribe Sisymbrieae		
31. *Crucihimalaya kneuckeri* (Bornm.) Al-Shehbaz, O'Kane & Price	49785	Egypt, Sinai, E slopes of Gebel Catherine (CAI)
32. *Descurainia sophia* (L.) Webb & Berth.	1475	Jordan, El-Jubeiha, university campus (B)
33. *Nasturtiopsis coronopifolia* (Desf.) Boiss.	s.n.	Egypt, Burg el-Arab (CAI)
34. *Neotorularia aculeolata* (Boiss.) Hedge & Léonard	5801	Iran, West of Jaz Murian (BR)
35. *Neotorularia torulosa* (Desf.) Hedge & Léonard	326	Palestine, Jerusalem-Jericho road (WAG)
36. *Olimarabidopsis pumila* (Stephan) Al-Shehbaz, O'Kane & Price	779	Syria, near Domascus, road of Zahroub to Merdj, Baustam el Mahar (L)
37. *Robeschia schimperi* (Boiss.) Schulz	170	Egypt, Mountains Sinai, between granitic rocks (B)
38. *Sisymbrium erysimoides* Desf.	19	Egypt, Gebel Elba, Wadi Drawina (SHG)
39. *Sisymbrium irio* L.	31	Egypt, S. Sinai, Deir el-Rahebat, Wadi Feiran, as weed in garden (SHG)
40. *Sisymbrium orientale* L.	11	Egypt, S. Sinai, Deir Feiran, Wadi Feiran (SHG)
41. *Sisymbrium polyceratum* L.	585	Fance, Asco, Island of Cornica (WAG)
42. *Sisymbrium runcinatum* Lag. ex DC.	2095	Spain, near Madrid (WAG)
43. *Sisymbrium septulatum* DC.	122	Egypt, mountains Sinai (L)

Table 2.2. List of specimens used in studies of fruit shape in Brassicaceae

Taxon	Collection No.	Origin of collections
1. Tribe Arabideae		
1. *Arabis alpina* L. sub sp. *caucasica* (Willd.) Briq.	18132	Morocco, High Atlas, S. from Marrakech (BM)
2. *Arabis nova* Vill.	543	Spain, Alcaras (WAG)
3. *Nasturtium officinale* R.Br.	764	Egypt, Abu Atwa, S. Ismailia (CAI)
4. *Rorippa indica* (L.) Hiern	s.n.	Egypt, Qena, El Mahrosa island (SHG)
5. *Rorippa integrifolia* Boulos	9	Egypt, Middle of Sinai, about 5 km before Ras Sedr (SHG)
6. *Rorippa palustris* (L.) Besser	20	Egypt, Along Ismailiya canal (SHG)
2. Tribe Euclidieae		
7. *Anastatica hierochuntica* L.	327	Egypt, Cairo-Suez road, km 95 from Cairo (CAI)
8. *Neslia paniculata* (L.) Desv. var. *apiculata* (Fisch., Meyer and –Lall.) Abdel Khalik	130	Palestine, Jerusalem: Mt, Scopus (WAG)
9. *Neslia paniculata* (L.) Desv. var. *paniculata*	s.n.	Germany, prov. Sachsen, Connern (LY)
10. *Ochthodium aegyptiacum* (L.) DC.	129	Palestine, Jerusalem: Mt, Scopus (BR)
11. *Schimpera arabica* Hochst & Steud.	s.n.	Saudi Arabia, As Summan (CAI)
3. Tribe Hesperideae		
12. *Eremobium aegyptiacum* (Spreng.) Asch. & Schweinf. subsp. *aegyptiacum*	29	Egypt, El Arish area beside the Airport, N. Sinai (SHG)
13. *Eremobium aegyptiacum* subsp. *lineare* (Delile) Abdel Khalik	124	Egypt, Sinai (BM)
14. *Eremobium aegyptiacum* subsp. *longisiliquum* (Coss.) Maire	s.n.	Egypt, Asswan (LY)
15. *Erysimum repandum* L.	15	Austria, Vienna, in fields (WAG)
16. *Leptaleum filifolium* (Willd.) DC.	s.n.	Egypt, Wadi Chafura, N. Galala (BR)
17. *Malcolmia africana* (L.) R.Br.	2	Egypt, Deir el Rahba, Wadi el Arbain, S. Sinai (SHG)
18. *Malcolmia nana* (DC.) Boiss.	28	Egypt, El Arish-Rafah road, 23 km from El Arish (SHG)
19. *Malcolmia pygmaea* (Del.) Boiss.	22	Egypt, 26 km, Sidi Krer, Alex.-Matruh coastal road (SHG)
4.Tribe Lunarieae		
20. *Ricotia lunaria* (L.) DC.	630	Israel, Western upper Galilee (WAG)
5. Tribe Matthioleae		
21. *Diceratella eliptica* (DC.) Jonsell	17	Egypt, Gebel Elba, Wadi Shallal (SHG)
22. *Matthiola arabica* Boiss.	12	Egypt, Wadi el Arbaien, S. Sinai (SHG)
23. *Matthiola fruticulosa* (L.) Maire	34	Egypt, Alexandria (K)
24. *Matthiola longipetala* subsp. *bicornis* (Sibth.) Ball	4379	Turkey, Tassia, near Sabadja (BR)
25. *Matthiola longipetala* subsp. *hirta* (Conti) Greuter & Burdet	23	Egypt, Alex.-Matruh coastal road, near Burg el Arab (SHG)
26. *Matthiola longipetala* subsp. *kralikii* (Pomel) Maire	7	Egypt, Cairo-Alexandria desert road, 100 km from Alexandria (SHG)

Table 2.2. continued

27. *Matthiola longipetala* subsp. *livida* (Delile) Maire	27	Egypt, Cairo-Ismailiya desert road, 23 km before Ismailiya (SHG)
28. *Matthiola longipetala* (Vent.) DC. subsp. *longipetala*	25	Egypt, 28 km before Matruh, Alexandria-Matruh road (SHG)
29. *Matthiola parviflora* (Schousboe) R.Br.	270	Morocco, Marrakech (BR)
30. *Morettia canescens* Boiss.	10	Egypt, Wadi Feiran, S. Sinai (SHG)
31. *Morettia parviflora* Boiss.	16984/2	Saudi Arabia, Wadi Harjab, rocky hillsides (BR)
32. *Morettia philaeana (*Delile) DC.	3	Egypt, 35 km from Qena at the road Qena-Safaga (SHG)
33. *Notoceras bicorne* (Ait.) Caruel	1052	Egypt, Gebel Elba, Saddle between Gebel Asotriba and Makin (CAI)
6. Tribe Sisymbrieae		
34. *Crucihimalaya kneuckeri* (Bornm.) Al-Shehbaz, O'Kane & Price	49785	Egypt, Sinai, E slopes of Gebel Catherine (CAI)
35. *Descurainia sophia* (L.) Webb & Berth.	1475	Jordan, El-Jubeiha, university campus (B)
36. *Nasturtiopsis coronopifolia* (Desf.) Boiss.	s.n.	Egypt, Burg el-Arab (CAI)
37. *Neotorularia aculeolata* (Boiss.) Hedge & Léonard	5801	Iran, West of Jaz Murian (BR)
38. *Neotorularia torulosa* (Desf.) Hedge & Léonard var. *scorpiuroides* (Boiss.) Hedge & Léonard	s.n.	Egypt, Burg el-Arab (CAI)
39. *Neotorularia torulosa* (Desf.) Hedge & Léonard var. *torulosa*	s.n.	Egypt, Cairo-Alexandria desert road (CAI)
40. *Olimarabidopsis pumila* (Stephan) Al-Shehbaz, O'Kane & Price	9874	Iran, Valadabad Qazvin (CAI)
41. *Robeschia schimperi* (Boiss.) Schulz	170	Egypt, Mountains Sinai, between granitic rocks (B)
42. *Sisymbrium erysimoides* Desf.	19	Egypt, Gebel Elba, Wadi Drawina (SHG)
43. *Sisymbrium irio* L.	31	Egypt, S. Sinai, Deir el-Rahebat, Wadi Feiran, as weed in garden (SHG)
44. *Sisymbrium orientale* L.	11	Egypt, S. Sinai, Deir Feiran, Wadi Feiran (SHG)
45. *Sisymbrium polyceratum* L.	585	Fance, Asco, Island of Cornica (WAG)
46. *Sisymbrium runcinatum* Lag. ex DC.	s.n.	Libya, El-Mekhali (SHG)
47. *S. septulatum* DC.	122	Egypt, mountains Sinai (L)

2.2. MORPHOLOGICAL CHARACTERS OF BRASSICACEAE

2.2.1. Habit

Plant habit varies from sub-shrubby in *Diceratella elliptica* and *Eremobium aegyptiacum* subsp. *longisiliquum* to perennial in *Arabis alpina, Nasturtium officinale, Matthiola arabica, Matthiola fruticulosa, Morettia canescens, Morettia parviflora* and *Morettia philaeana*. It is annual to short-lived perennial in *Descurainia sophia, Eremobium aegyptiacum* subsp. *lineare* and subsp. *aegyptiacum, Rorippa indica* and *Rorippa palustris* and annual in the rest of the taxa.

2.2.2. Leaf characters

On the whole the leaf characters are fairly important in the classification of Brassicaceae. There are two different types of leaves: cauline and basal ones.

The characters of the upper cauline leaves are quite important in distinguishing taxa from Egypt. The basal leaves arrangement, composition, apex and base have little taxonomic value in the Brassicaceae. The basal leaves are rosette-forming in many taxa of Brassicaceae as in *Arabis alpina, A. nova, Schimpera arabica, Nasturtiopsis coronopifolia, Malcolmia pygmaea, Diceratella elliptica, Crucihimalaya kneuckeri, Olimarabidopsis pumila,* most species of *Matthiola* and *Sisymbrium* and species of *Neotorularia*. The base of the upper cauline leaves is either sessile, petiolate or auriculate. Auriculate cauline leaves are rare: these are formed in *Arabis*, *Neslia paniculata, Nasturtium officinale* and distinguish *Olimarabidopsis pumila* from *Arabidopsis*. The sessile cauline leaves also separate *Crucihimalaya kneuckeri* from *Arabidopsis* which have petiolate stem leaves.

The leaves may be compound as in *Nasturtium officinale*; pinnatisect or 2-3 pinnatisect in *Ricotia lunaria, Descurainia sophia* and *Robeschia schimperi*; simple, linear-oblong as in *Eremobium aegyptiacum* and *Matthiola arabica*; spathulate in *Anastatica hierochuntica*; filiform in *Leptaleum filifolium*; ovate to elliptical in *Diceratella elliptica* and *Morettia parviflora,* or lyrate, pinnatified or lobed in most of the other taxa.

2.2.3. Indumentum

Trichomes constitute one of the most important characters in the classification of the Brassicaceae at different levels (tribal, generic, specific and infraspecific level).

Metcalfe & Chalk (1950) pointed out that the trichomes in Brassicaceae are variable in form, but always unicellular and very rarely glandular. Non-glandular trichomes are simple or unbranched T-, Y-shaped, 2-armed dendroid or peltate. Theobold et al. (1979) also observed unicellular 2-5 armed, stellate, scales and dendroid (branched) trichomes in the Brassicaceae. In the present investigation eglandular and glandular trichomes are observed (see figs. 2.1 & 2). The eglandular unicellular trichomes are: simple, vasculate, hooked, Y-shaped, appressed medifixed, dendroid or branched and stellate. Glandular trichomes consist of a multicellular stalk and a head (an apex) of one or more cells and unicellular which is in the terminal part globular or slightly club-shaped.

In Brassicaceae the plant parts vary from glabrous to densely hairy. In *Nasturtium officinale* and *Neotorularia aculeolata* are glabrous; in *Schimpera arabica, Leptaleum filifolium, Ochthodium aegyptiacum, Rorippa, Nasturtiopsis coronopifolia* and *Sisymbrium* have glabrous to sparsely simple hairs; vasculate and hooked trichomes are very rare: only in *Sisymbrium*

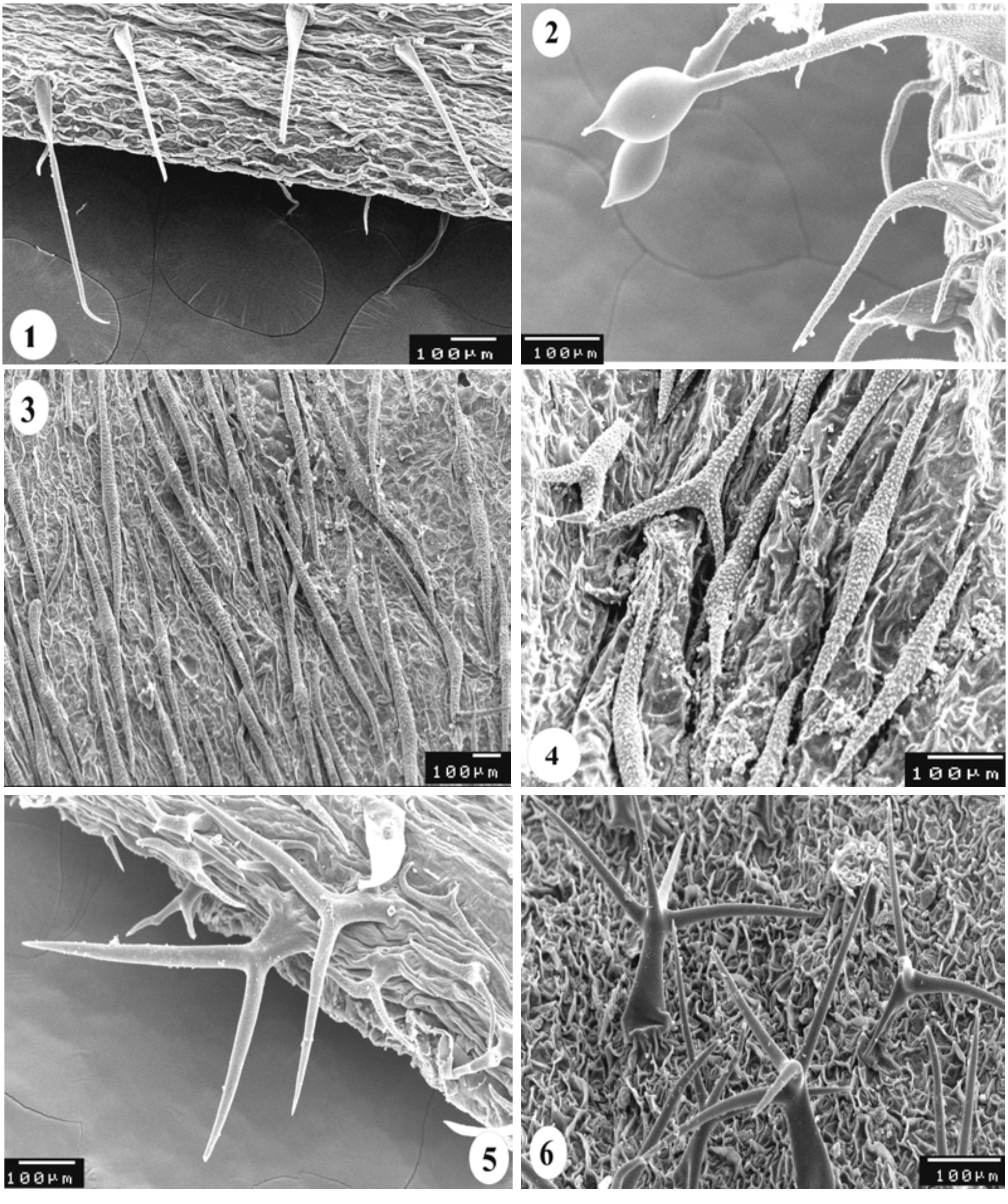


Fig. 2.1. SEM photographs of the indumentum. 1. Simple and hooked hairs. 2. Vasculate hairs. 3. Medifixed hairs. 4. Trifid hairs. 5. Y shaped hairs. 6. Branched hairs (3-4 fid).

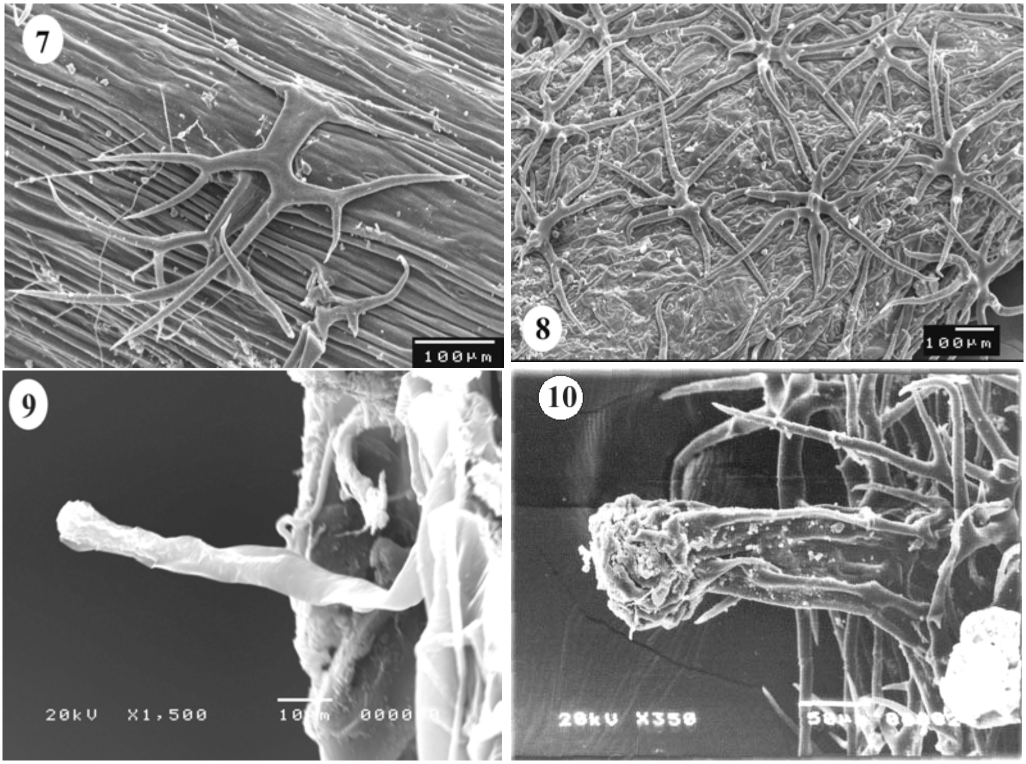


Fig. 2.2. SEM photographs of the indumentum. 7. Dendroid hairs. 8. Stellate hairs.
9. Glandular hairs (unicellular). 10. Glandular hairs (multicellular).

runcinatum; the trichomes are medifixed to trifid in *Erysimum repandum* and *Notoceras bicorne*; branched or forked in *Olimarabidopsis pumila, Crucihimalaya kneuckeri, Neslia paniculata, Malcolmia pygmaea* and *Arabis*; stellate to branched in *Anastatica hierochuntica, Malcolmia africana, Matthiola* and *Morettia*; stellate in *Eremobium aegyptiacum* and *Malcolmia nana*. Glandular hairs vary from a multicellular stalk with a head in *Matthiola arabica, Matthiola parviflora* and *Matthiola longipetala* to unicellular in *Descurainia sophia* and *Ochthodium aegyptiacum.*

2.2.4. Inflorescence

The inflorescences are usually racemes, terminal, ebracteate in most cruciferous genera. In a few genera it varies from terminal and axillary: in *Rorippa palustris, Morettia* and *Notoceras bicorne* to axillary in *Anastatica hierochuntica, Leptaleum filifolium* and *Sisymbrium polyceratum.*

Bracts only occur in *Erysimum repandum*, species of *Morettia, Sisymbrium polyceratum, Sisymbrium runcinatum* and sometimes in *Crucihimalaya kneuckeri.*

In the genus *Sisymbrium* the inflorescence plays an important role to distinguish between species. It varies from bracteate in *Sisymbrium polyceratum* and *S. runcinatum* to ebracteate in the rest of the species.

2.2.5. Pedicels

In some cases, the pedicel characters are of good taxonomic value, particularly in the fruiting stage. These can be either sessile to short or long; thick or thin; hairy or glabrous; erect, spreading or appressed to the stem. The pedicels vary from zero to short (0-3 mm) in *Anastatica hierochuntica, Leptaleum filifolium, Erysimum repandum, Robeschia schimperi, Notoceras bicorne, Morettia, Neotorularia*, and most species of *Matthiola,* while the remaining taxa have medium to long pedicels (4-20 mm). These are filiform in *Neslia paniculata, Ricotia lunaria, Malcolmia pygmaea, Sisymbrium irio, Olimarabidopsis pumila, Crucihimalaya kneuckeri, Descurainia sophia* and species of *Rorippa*, while in the rest of species the pedicels are more or less sturdy.

Pedicel length is of taxonomic value to separate taxa. It distinguishes between species of the genus *Neotorularia*, up to 2.5 mm long in *N. aculeolata* and up to 1.5 mm long in *N. torulosa*. In the genus *Matthiola*, the length of pedicels separate *M. arabica* (up to 5 mm long) from the rest of species of *Matthiola* (up to 1.5 mm long). In the genus *Arabis*, the pedicels are thinner than the fruit, hairy in *A. alpina* but as thick as the fruit and glabrous in *A. nova*. The shape and the length of pedicels differ clearly between species of *Sisymbrium*. These vary from filiform, long, thinner than fruit in *S. irio* to short, as thick as the fruit in *S. orientale, S. erysimoides* and *S. septulatum.*

2.2.6. Sepals

Brassicaceae usually have 4 free sepals in 2 opposite pairs. The position of the sepals varies from erect in the tribes Hesperideae, Matthioleae and Lunarieae to erect or spreading in the tribes Arabideae, Euclidieae and Sisymbrieae.

The base of the inner sepals varies from saccate in Arabidieae and Lunarieae; saccate or not in Hesperideae and Matthioleae to flat in Euclidieae and Sisymbrieae.

The shape of the sepals is of little taxonomic value. It varies from oblong, lanceolate, linear to either ovate or linear-oblong among taxa. The margin, apex, colour and the hairiness of the sepals are also of little taxonomic value.

Sepal persistence at fruit maturity plays an important role for separating species and subspecies. These can be either persistent in *Morettia philaeana* and *Eremobium aegyptiacum* subsp. *lineare* or caducous in the rest of the species. In the genus *Morettia*, these are persistent only in *M. philaeana* but caducous in *M. canescens* and *M. parviflora*. At subspecies level, sepals are persistent in *Eremobium aegyptiacum* subsp. *lineare* and caducous in *Eremobium aegyptiacum* subsp. *aegyptiacum* and subsp. *longisiliquum.*

2.2.7. Petals

There are usually 4 free, equal petals, in the form of a cross, which is reflected in the family name Cruciferae.

Shape: the shape of petals shows wide variation among taxa. It is linear-oblanceolate or oblong, spathulate to oblong-ovate, or obovate to orbicular, rarely obcordate as in *Ricotia lunaria,* see figs. 1-6.

Usually the petals are differentiated into a blade and a claw. The claw may be very distinctive and long as in *Neslia paniculata, Erysimum repandum, Leptaleum filifolium, Malcolmia africana, M. pygmaea, Arabis alpina, Rorippa integrifolia, Diceratella elliptica, Matthiola fruticulosa, M. parviflora,* species of *Morettia, Discurainia sophia, Sisymbrium erysimoides, S. orientale* and *S. septulatum,* or short and inconspicuous as in *Arabis nova, Nasturtium officinale, Rorippa indica, R. palustris, Ochthodium aegyptiacum, Schimpera arabica, Anastatica hierochuntica, Malcolmia nana, Nasturtiopsis coronopifolia, Crucihimalaya kneuckeri, Sisymbrium irio, S. runcinatum* and *S. polyceratum.*

Petals in *Eremobium aegyptiacum, Matthiola longipetala, M. arabica, Neotorularia, Robeschia schimperi* and *Olimarabidopsis pumila* are more or less linear-oblong, not clearly differentiated into a blade and claw.

Length: this is variable and of taxonomic value in Brassicaceae. The longest petals in *Ricotia lunaria, Diceratella elliptica, Matthiola arabica, M. fruticulosa* and *M. longipetala* measure 13-29 mm and the petals in *Leptaleum filifolium, Eremobium aegyptiacum, Malcolmia pygmaea, Matthiola parviflora, Morettia canescens, M. philaeana, Sisymbrium orientale* and *S. septulatum* measure 6-10 mm, however the shortest petals measure 1.1-6 mm in the other taxa. The petal length was found useful to separate two species of *Arabis* and also species of *Sisymbrium*.

Apex: it varies from emarginate in *Ricotia lunaria*; obtuse to slightly emarginate in *Schimpera arabica, Arabis alpina and Matthiola longipetala* subsp. *hirta*; truncate in *Neotorularia torulosa*; rounded to truncate in *Malcolmia pygmaea, Rorippa indica, R. integrifolia, Erysimum repandum* and *Sisymbrium orientale* to rounded in the rest of the taxa.

Margin: varies from entire to slightly undulate *in Matthiola fruticulosa, M. longipetala* subsp. *kralikii,* subsp. *livida* and subsp. *longipetala* to entire in the rest of the species.

Colour: is often used as a key character to distinguish between different taxa. This may be either white, cream, yellow and lemon yellow, or pink, violet or purple.

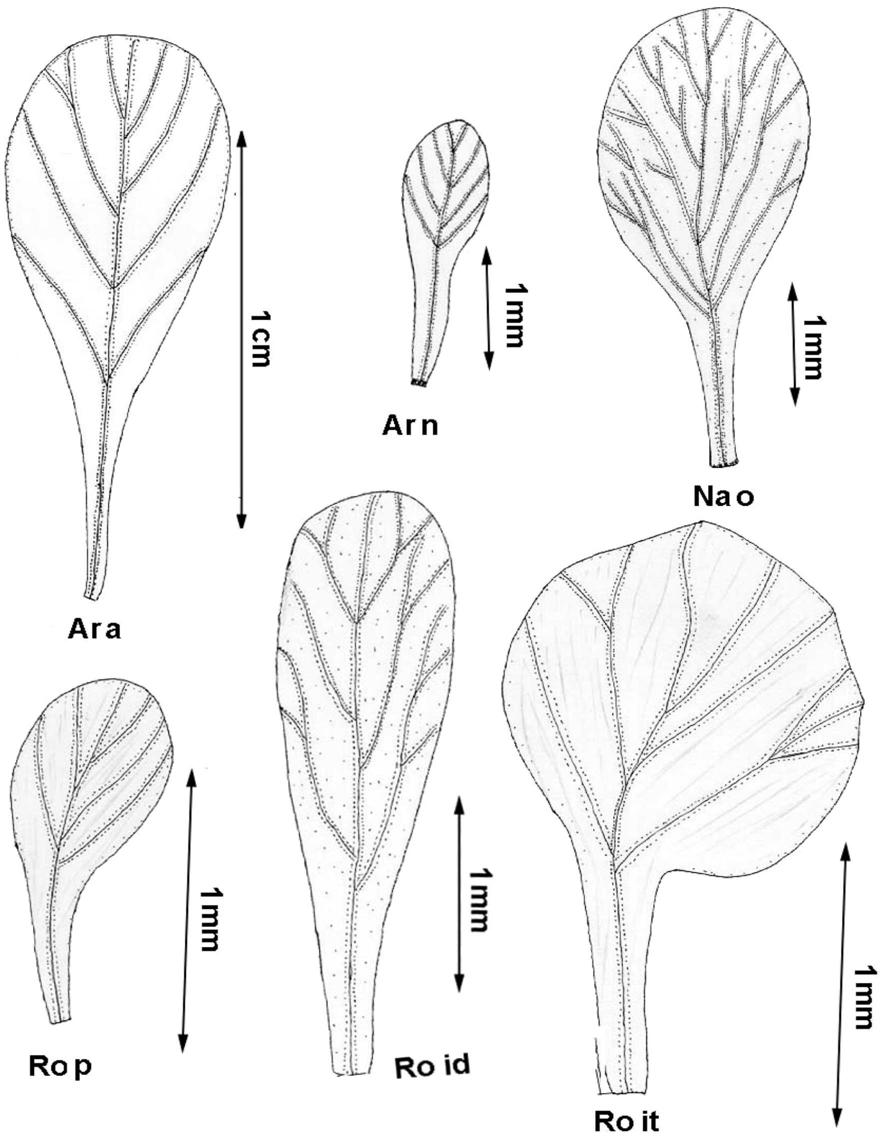


Fig. 2.3. Shape of petals. **Ar a**. *Arabis alpina.* **Ar n**. *Arabis nova*. **Na o**. *Nasturtium officinale.* **Ro p**. *Rorippa palustris.* **Ro id**. *Rorippa indica.* **Ro it**. *Rorippa integrifolia.*

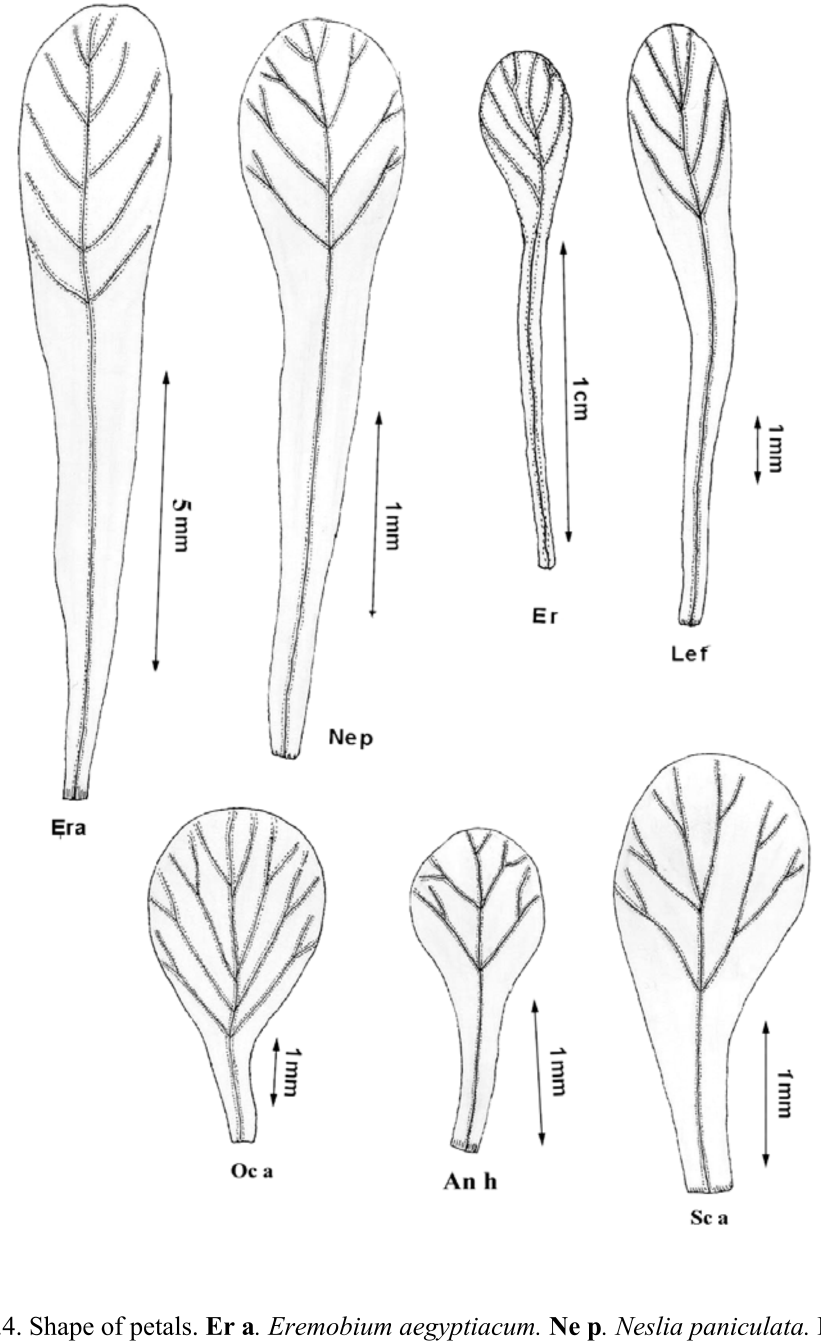


Fig. 2.4. Shape of petals. **Er a**. *Eremobium aegyptiacum.* **Ne p**. *Neslia paniculata.* **Er**. *Erysimum repandum.* **Le f**. *Leptaleum filifolium.* **Oc a**. *Ochthodium aegyptiacum.* **An h**. *Anastatica hierochuntica.* **Sc a**. *Schimpera arabica.*

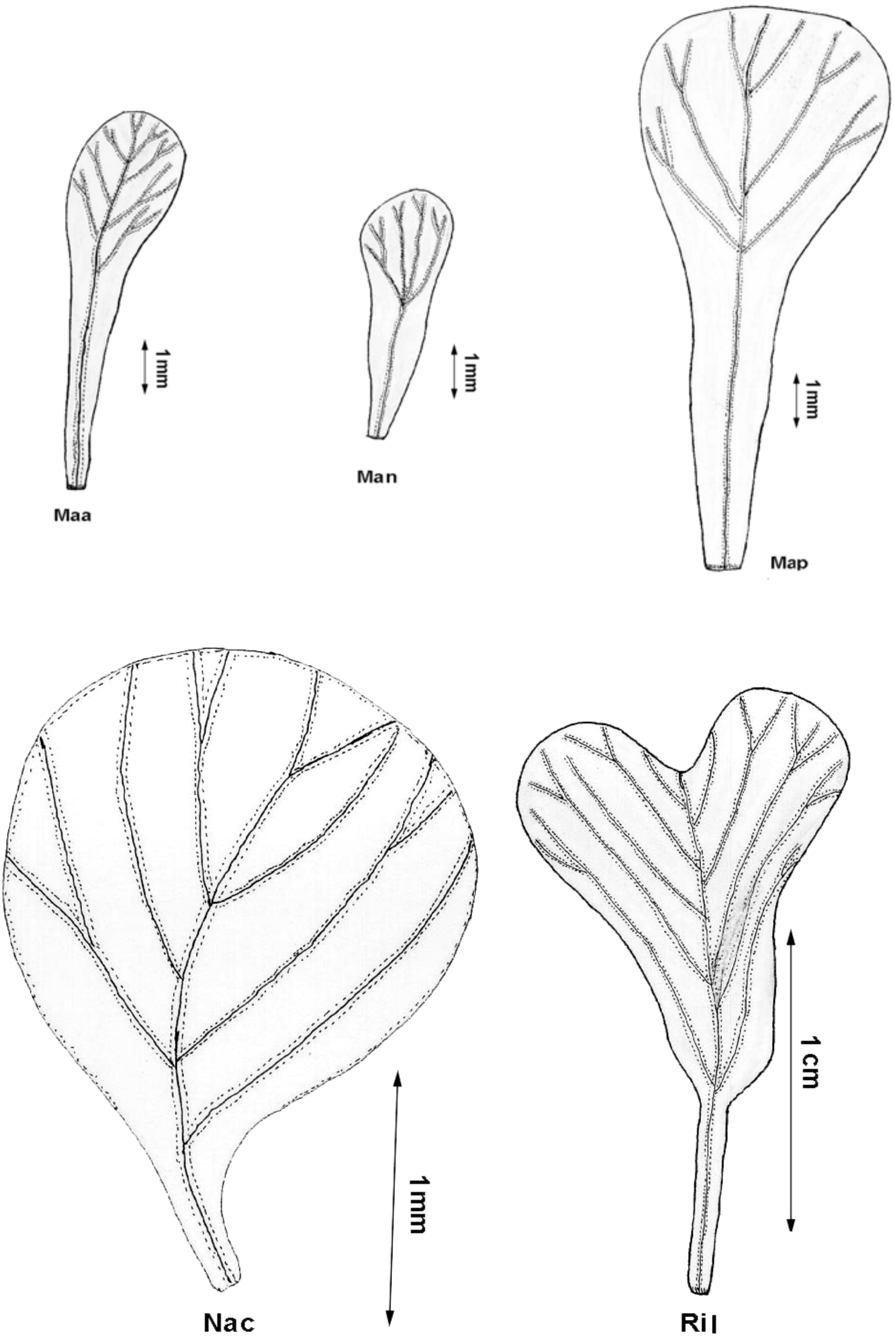


Fig. 2.5. Shape of petals. **Ma a**. *Malcolmia africana.* **Ma n**. *Malcolmia nana.* **Ma p**. *Malcolmia pygmaea.* **Na c**. *Nasturtiopsis coronopifolia*. **Ri l**. *Ricotia lunaria.*

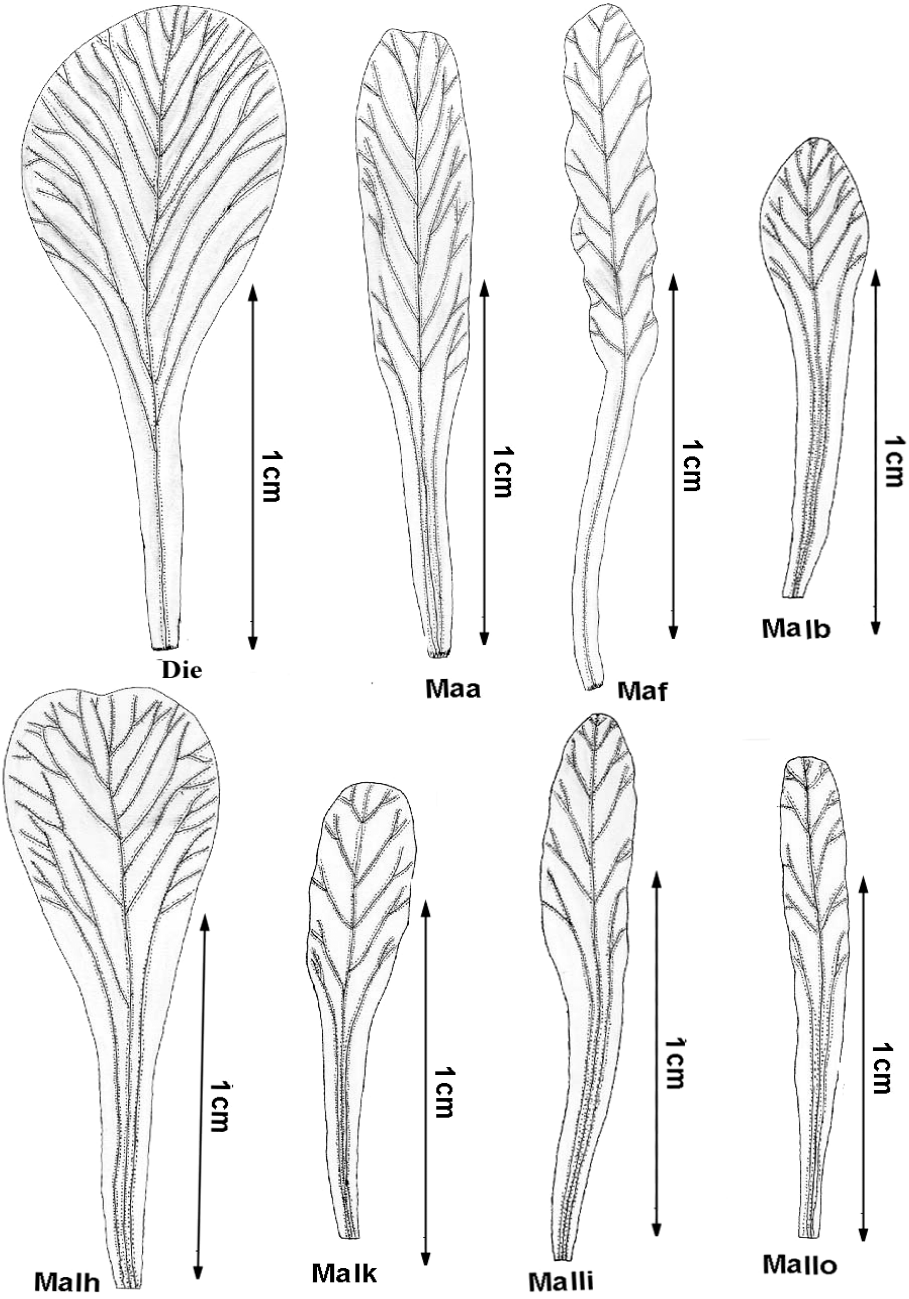


Fig. 2.6. Shape of petals. **Die**. *Diceratella elliptica.* **Maa**. *Matthiola arabica.* **Maf**. *Matthiola fruticulosa.* **Malb**. *Matthiola longipetala* subsp. *bicornis.* **Malh**. *Matthiola longipetala* subsp. *hirta.* **Malk**. *Matthiola longipetala* subsp. *kralikii.* **Malli**. *Matthiola longipetala* subsp. *livida.* **Mallo**. *Matthiola longipetala* subsp. *longipetala.*

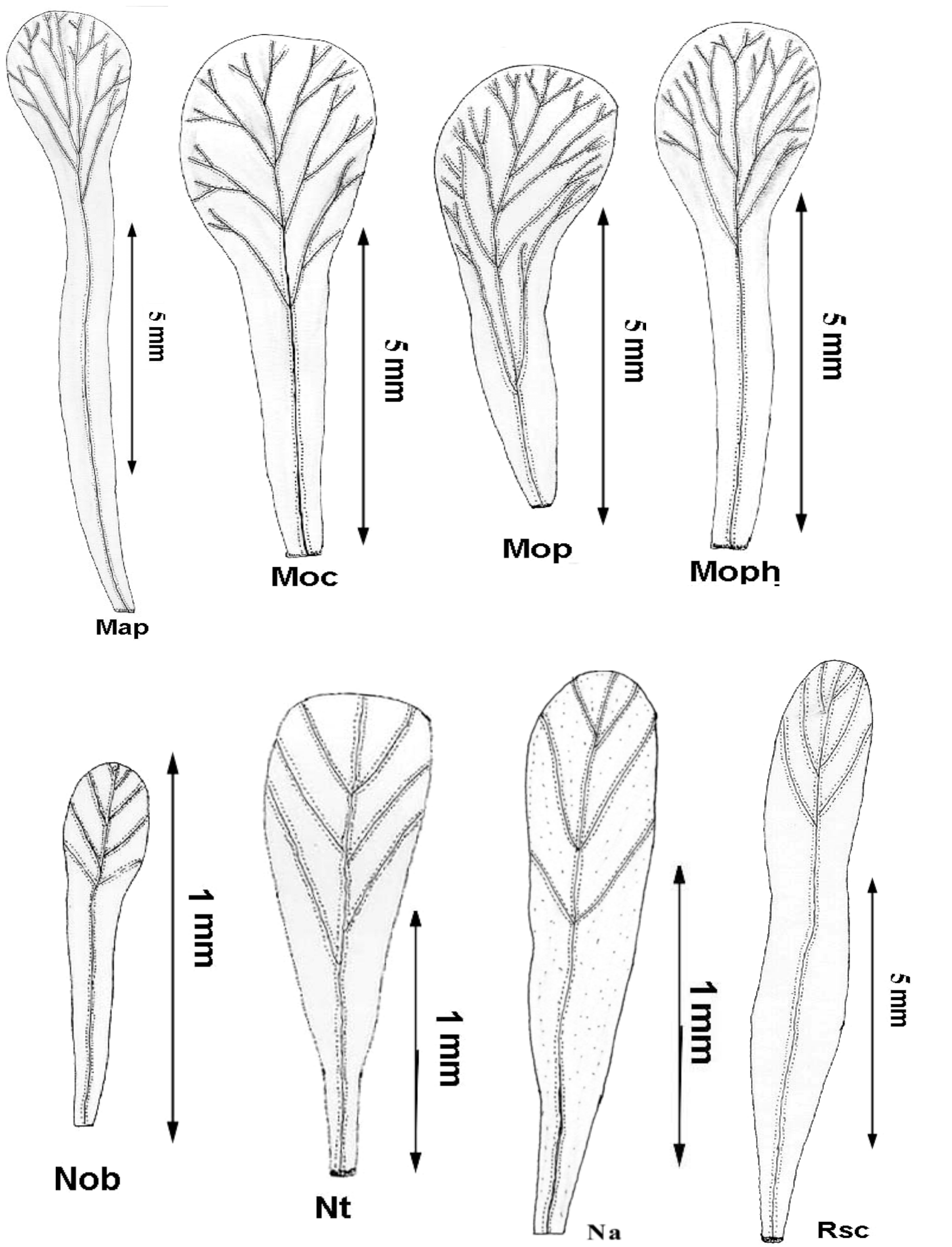


Fig. 2.7. Shape of petals. **Map**. *Matthiola parviflora.* **Moc**. *Morettia canescens.* **Mop**. *Morettia parviflora.* **Moph**. *Morettia philaeana.* **Nob**. *Notoceras bicorne.* **Nt**. *Neotorularia torulosa.* **Na**. *Neotorularia aculeolata*. **Rsc**. *Robeschia schimperi.*

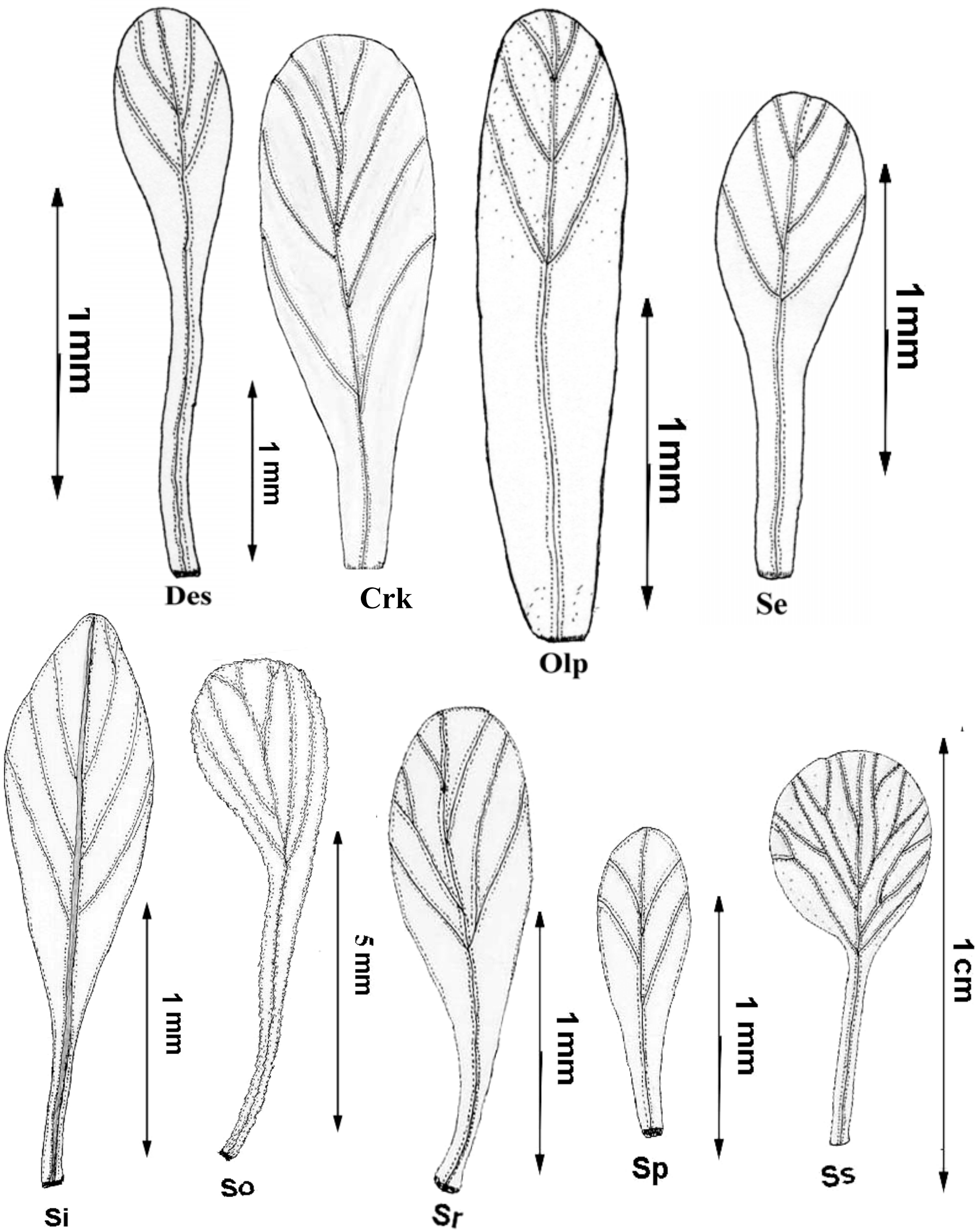


Fig. 2.8. Shape of petals. **Des**. *Descurainia sophia.* **Crk**. *Crucihimalaya kneuckeri.* **Olp**. *Olimarabidopsis pumila.* **Se**. *Sisymbrium erysimoides.* **Si**. *Sisymbrium irio.* **So**. *Sisymbrium orientale.* **Sr**. *Sisymbrium runcinatum.* **Sp**. *Sisymbrium polyceratum.* **Ss**. *Sisymbrium septulatum.*

2.2.8. Stamens

Brassicaceae flowers have six tetradynamous stamens; 2 outer short, and 4 inner long. Rarely they are less in number: 4 or 2 in *Leptaleum filifolium*. The variation of the length is found in the filaments: these range from 1 to 7.5 mm. The filaments are usually linear, free or sometimes broad at base, not toothed as in *Matthiola*, see figure 2.9.

The anthers are 2-thecous, longitudinally opening. Anthers are either linear in *Arabis nova* and *Rorippa indica*; ovoid in *Nasturtium officinale, Rorippa palustris, Neslia paniculata, Nasturtiopsis coronopifolia* and *Neotorularia aculeolata*; sagittate in *Rorippa integrifolia, Anastatica hierochuntica, Schimpera arabica, Eremobium aegyptiacum, Leptaleum filifolium, Malcolmia africana, Malcolmia nana, Ricotia lunaria, Crucihimalaya kneuckeri, Matthiola longipetala* subsp. *hirta, Matthiola parviflora, Morettia parviflora, Notoceras bicorne, Neotorularia torulosa* and *Sisymbrium* or oblong to ovoid-oblong or sagittate in the rest of the taxa.

Pollen grains: see chapter 4

2.2.9. Nectary glands

The presence or absence of nectaries has played an important role in classification of Brassicaceae. These are variable both in number and arrangement (Arber, 1931). Nectary characters have been used for distinguishing taxa at tribal and generic level (Hayek, 1911; Schulz, 1936; Deng Yan-bin & Hu Zheng-hai, 1995). Usually there are 4 glands: 2 lateral and 2 median ones.

Deng & Hu (1995) investigated the outer morphology of floral nectaries for 74 species and 1 variety, belonging to 9 tribes and 36 genera of Cruciferae and showed great diversity in number, shape, cuticle sculpture, composition, position and in existence of vascular bundles and verified these characteristics were different among genera of the same tribe and sometimes also varied in different species of the same genus. Deng & Hu (1995) divided the floral nectaries of Cruciferae into three types according to their distribution, morphology and structure: 1. Lateral nectary type: only lateral nectaries present; 2. Lateral and median nectaries type: both lateral and median (separate) nectaries present; 3. Annular nectary type: lateral and median nectaries united to form an annular nectary. Nineteen subtypes were distinguished within the three types. The lateral and median nectary types were considered to be primitive whereas the lateral type and the annular nectary type were advanced.

The study of nectary glands needs fresh material that was not always available, so I have not concentrated on this point.

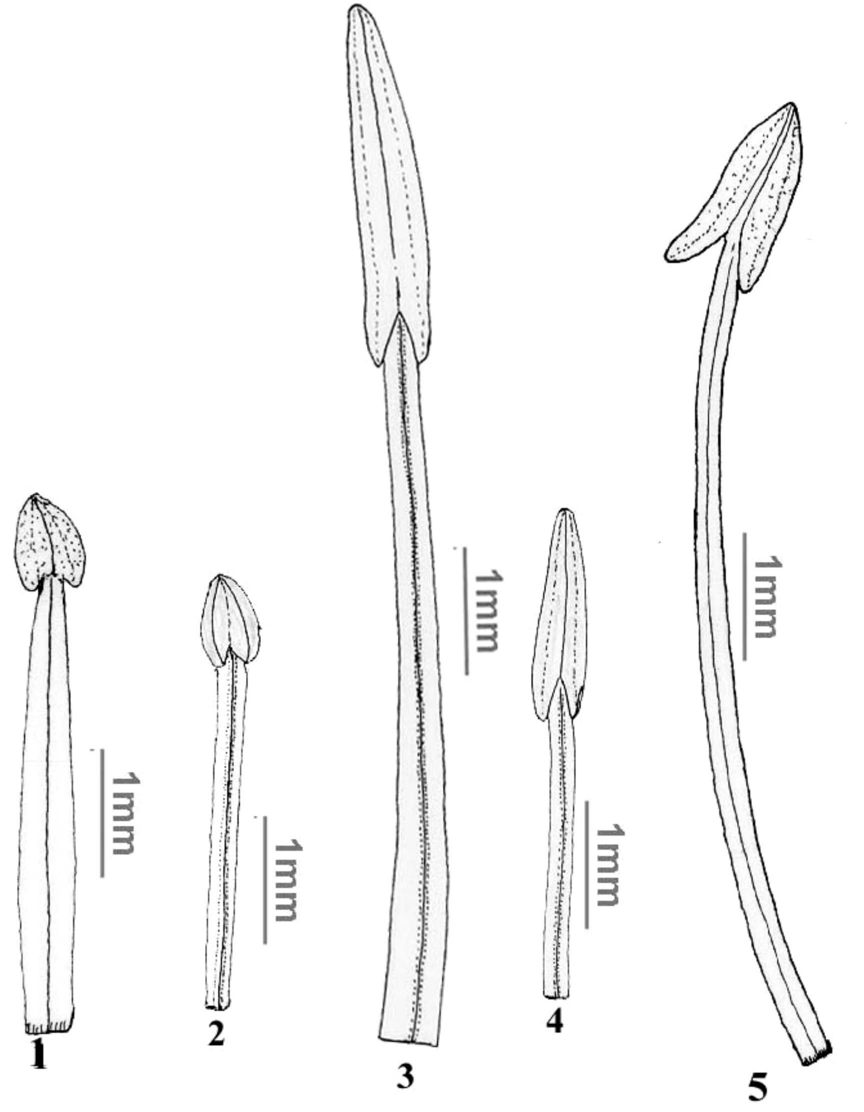


Fig. 2.9. Shape of stamens. **1**. Broad at base filament and ovoid anther. **2**. Linear filament and ovoid anther. **3**. Broad at base filament and oblong anther. **4**. Linear filament and oblong-sagittate anther.**5**. Linear filament and sagittate anther.

2.2.10. Stigma

The stigma may be depressed, capitate, connate, ovate, bi-lobed, divergent or decurrent. The stigma may be sessile as in *Octhodium aegyptiacum, Schimpera arabica, Leptaleum filifolium, Malcolmia africana, Diceratella elliptica, Matthiola fruticulosa, Matthiola parviflora* and *Matthiola longipetala,* or on a conspicuous style as in the rest of the taxa.

The stigma in most *Matthiola* species expands to give 2 lateral horns. The patent of lateral horns shows a great variation between species and subspecies of *Matthiola*. It ranges from horizontal to slightly curved in *Matthiola longipetala* subsp. *livida* and subsp. *longipetala*; horizontal or upcurved or deflexed in *Matthiola longipetala* subsp. *kralikii*; straight or upcurved in *Matthiola fruticulosa, M. parviflora* and *M. longipetala* subsp. *hirta* to straight or strongly incurved as in *M. longipetala* subsp. *bicornis*.

The length of lateral horns varies from 2.5-3 mm in *Matthiola fruticulosa*; 3-5 mm in *Matthiola parviflora* to 2-8 mm in *Matthiola longipetala.* Only in *Matthiola parviflora* the stigma has two small appendages next to he lateral horns.

2.2.11. Fruit

Fruits of the Brassicaceae are so diverse that they are the most reliable structures for the proper identification of tribes, genera and species, see figs. 2.10-14. The fruit character figures in any key.

Length: It shows wide variation and important value in the Brassicaceae. It has been used in the classification of the family since the time of Robert Morison (1860). Usually Brassicaceae are divided into 2 artificial main groups based on the fruit length/width ratio. The first group has a long and narrow fruit l/w > 3 (siliqua) and the second one a short and broad fruit l/w < 3 (silicula). This character is of help at tribal level, as in tribes Euclidieae and Lunarieae where the fruit is a silicula, whereas other tribes I studied have a siliqua.

In *Schimpera arabica*, the fruit is composed of two parts, the lower part is fertile and the upper is sterile and beak-shaped. In the genus *Neslia* the fruit has an umbo (boss) or not, and this character let many authors separate it into two species. In my present work, I treated *Neslia* as one species with two varieties: var. *apiculata* and var. *paniculata*, because the only difference is the presence or absence of boss or umbo. The geographical distribution is not distinct for two species (one can find both varieties in the same area). In *Eremobium aegyptiacum*, the length of fruit separates this species into 3 subspecies; subsp. *lineare* (1.1-2.2 cm); subsp. *aegyptiacum* (2.5-4 cm) and subsp. *longisiliquum* (3-6 cm).

The width of the fruit at the base is somewhat of diagnostic value in the genus *Morettia*. The broadest siliqua in *Morettia philaeana* measures 2-3 mm but in *M. canescens* and *M. parviflora,* it ranges from 1-2 mm. The fruit in *M. philaeana* and *M. canescens* is straight or slightly curved but strongly curved in *M. parviflora*.

Dehiscence: The fruit valves in Brassicaceae may readily open from below to above as in the tribe Sisymbrieae; dehiscent or tardily dehiscent as in tribes Lunarieae, Arabideae and Hesperideae; indehiscent as in the tribe Euclidieae or indehiscent or tardily dehiscent as in the tribe Matthioleae.

Valves: These range from winged as in *Anastatica hierochuntica*; horned as in *Notoceras bicorne* to wingless in the rest of the taxa. Valves may be keeled and pitted inside as in

Diceratella elliptica; not keeled and smooth inside as in species of *Matthiola*; convex as in *Rorippa, Sisymbrium* and *Arabis nova* or flat as in *Arabis alpina* and *Ricotia lunaria*.

Venation in the valves varies from absent as in *Rorippa palustris, Anastatica hierochuntica, Ochthodium aegyptiacum, Schimpera arabica, Ricotia lunaria* and *Neotorularia aculeolata*; 3 nerves (1 main and 2 lateral) as in *Morettia canescens, Sisymrium irio, S. orientale, S. polyceratum* and *S. septulatum* to 1 main nerve in the rest of the species. The venation in valves of *Neslia paniculata* and *Leptaleum filifolium* is more or less reticulate in addition to one main nerve.

The valve surface may be tuberculate as in *Ochthodium aegyptiacum* and *Schimpera arabica,* while the rest of the taxa range from glabrous to more or less hairy.

The septum: varies from delicate or absent in *Ricotia lunaria*; thick (firm) as in the tribe Euclidieae, *Leptaleum filifolium, Diceratella elliptica, Matthiola arabica, M. longipetala, Neotorularia torulosa, Sisymbrium orientale, S. polyceratum* and *S. runcinatum* to thin (membranous) in the rest of the taxa.

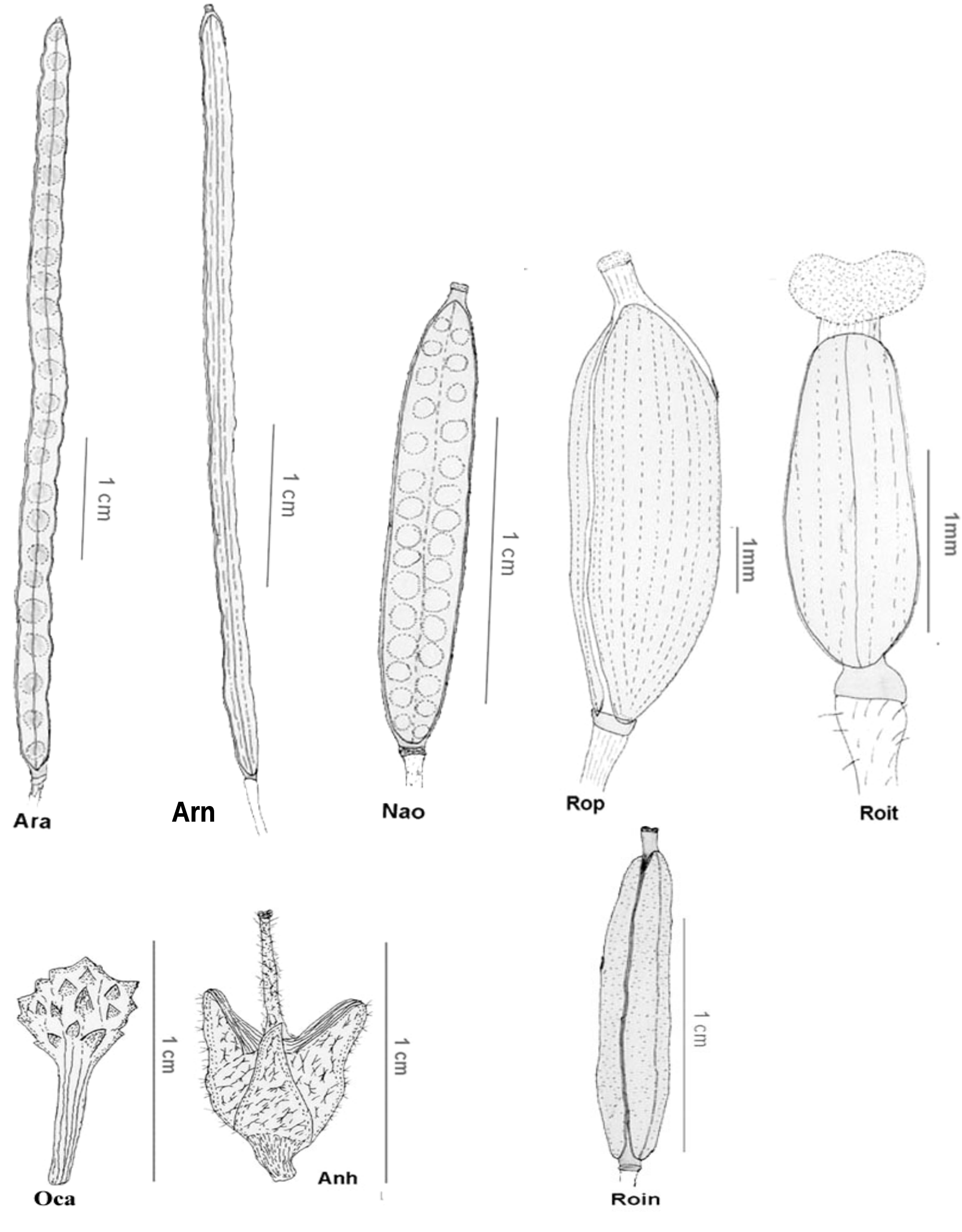


Fig. 2.10. Fruit shapes in Brassicaceae. **Ara**. *Arabis alpina*. **Arn**. *Arabis nova*. **Nao**. *Nasturtium officinale*. **Rop**. *Rorippa palustris*. **Roit**. *Rorippa integrifolia*. **Roin**. *Rorippa indica*. **Oca**. *Ochthodium aegyptiacum*. **Anh**. *Anastatica hierochuntica.*

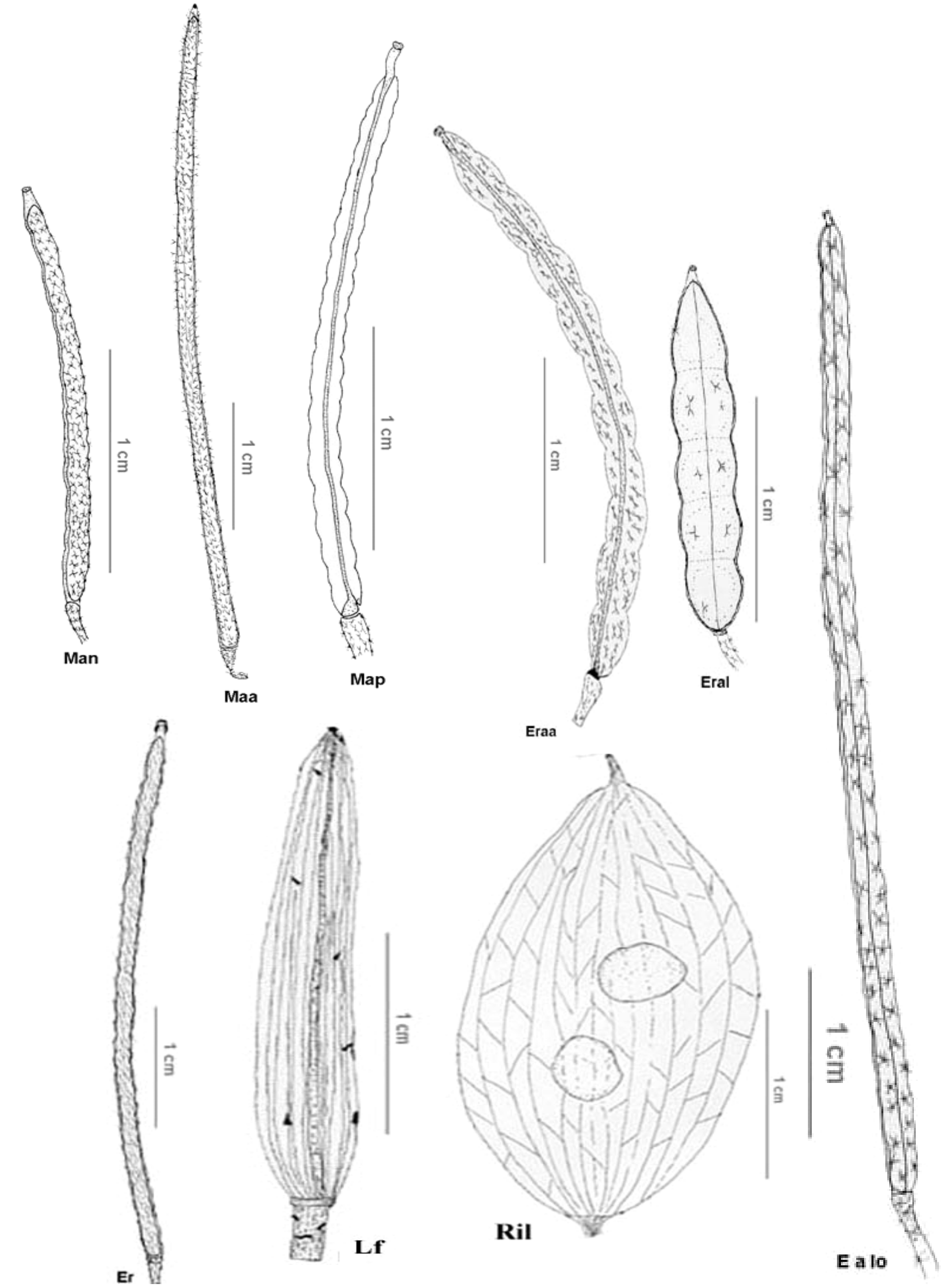


Fig. 2.11. Fruit shapes in Brassicaceae. **Man.** *Malcolmia nana.* **Maa**. *Malcolmia africana.* **Map**. *Malcolmia pygmaea.* **Eraa**. *Eremobium aegyptiacum* subsp. *aegyptiacum.* **Eral**. *Eremobium aegyptiacum* susp. lineare. **Ealo**. *Eremobium aegyptiacum* subsp. longisiliquum. **Ril**. *Ricotia lunaria.* **Lf**. *Leptaleum filifolium.* **Er**. *Erysimum repandum*.

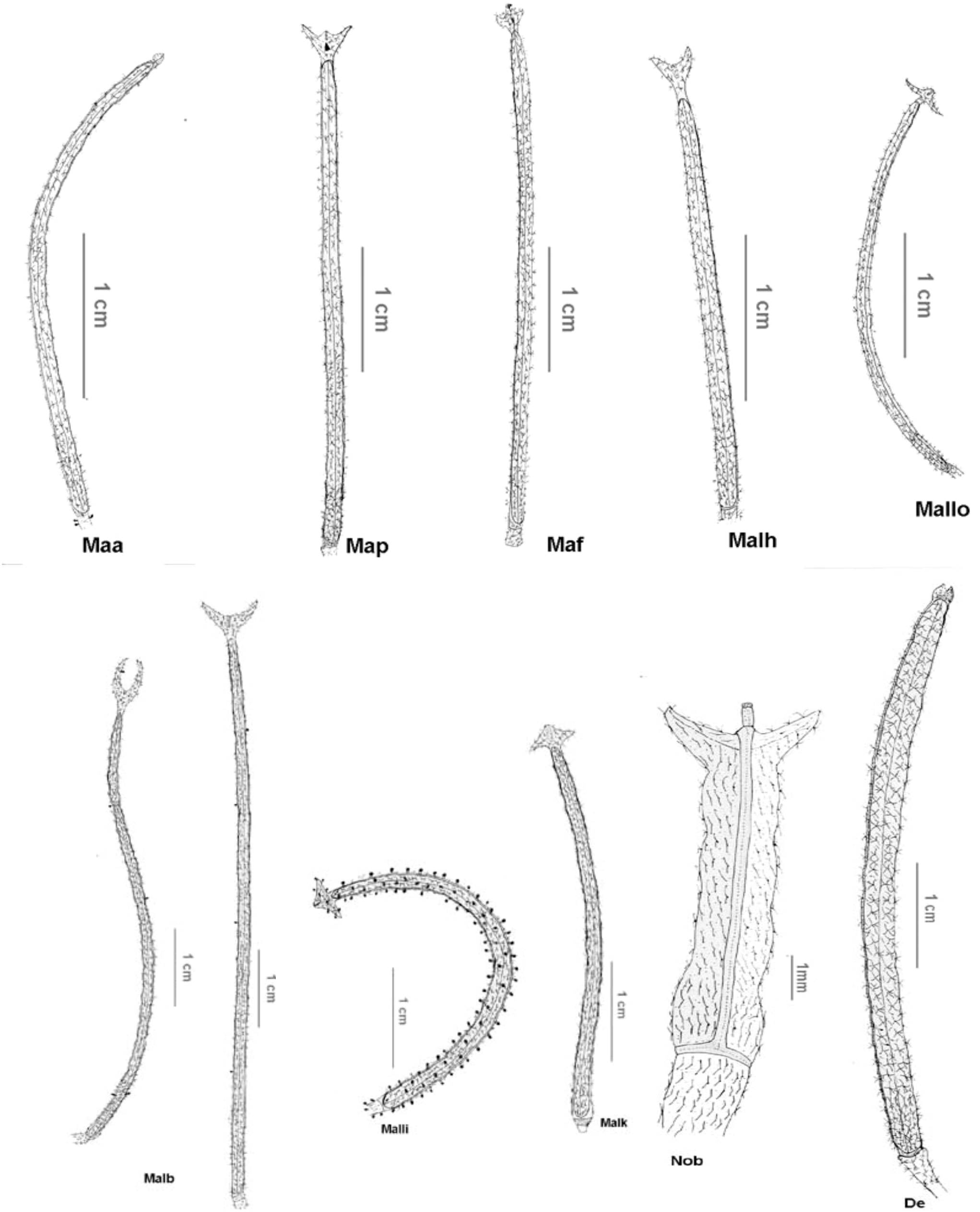


Fig. 2.12. Fruit shapes in Brassicaceae. **Maa**. *Matthiola arabica*. **Map**. *Matthiola parviflora*. **Maf**. *Matthiola fruticulosa*. **Malh**. *Matthiola longipetala* subsp. *hirta*. **Mallo**. *Matthiola. longipetala* subsp. *longipetala.* **Malb**. *Matthiola longipetala* subsp. *bicornis.* **Malli**. *Matthiola longipetala* subsp. *livida*. **Malk**. *Matthiola longipetala* subsp. *kralikii.* **Nob**. *Notoceras bicorne*. **De**. *Diceratella elliptica*.

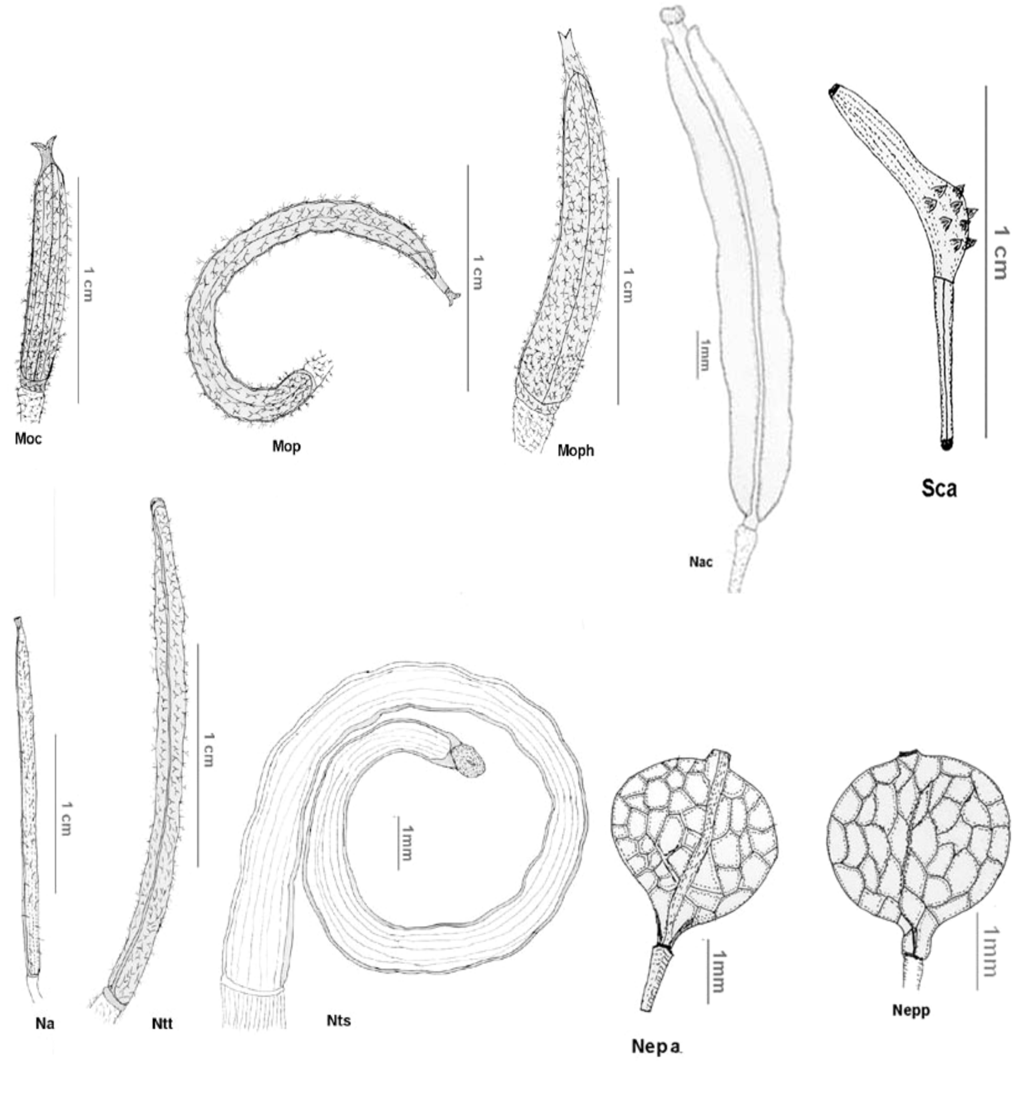


Fig. 2.13. Fruit shapes in Brassicaceae. **Moc**. *Morettia canescens*. **Mop**. *Morettia parviflora*. **Moph**. *Morettia. philaeana.* Nac. *Nasturtiopsis coronopifolia.* **Sca**. *Schimpera arabica.* **Na**. *Neotorularia aculeolata.* **Ntt**. *Neotorularia torulosa* var. *torulosa.* **Nts**. *Neotorularia torulosa* var. *scorpiuroides.* **Nepa**. *Neslia paniculata* var. *apiculata.* **Nepp**. *Neslia paniculata* var. *paniculata.*

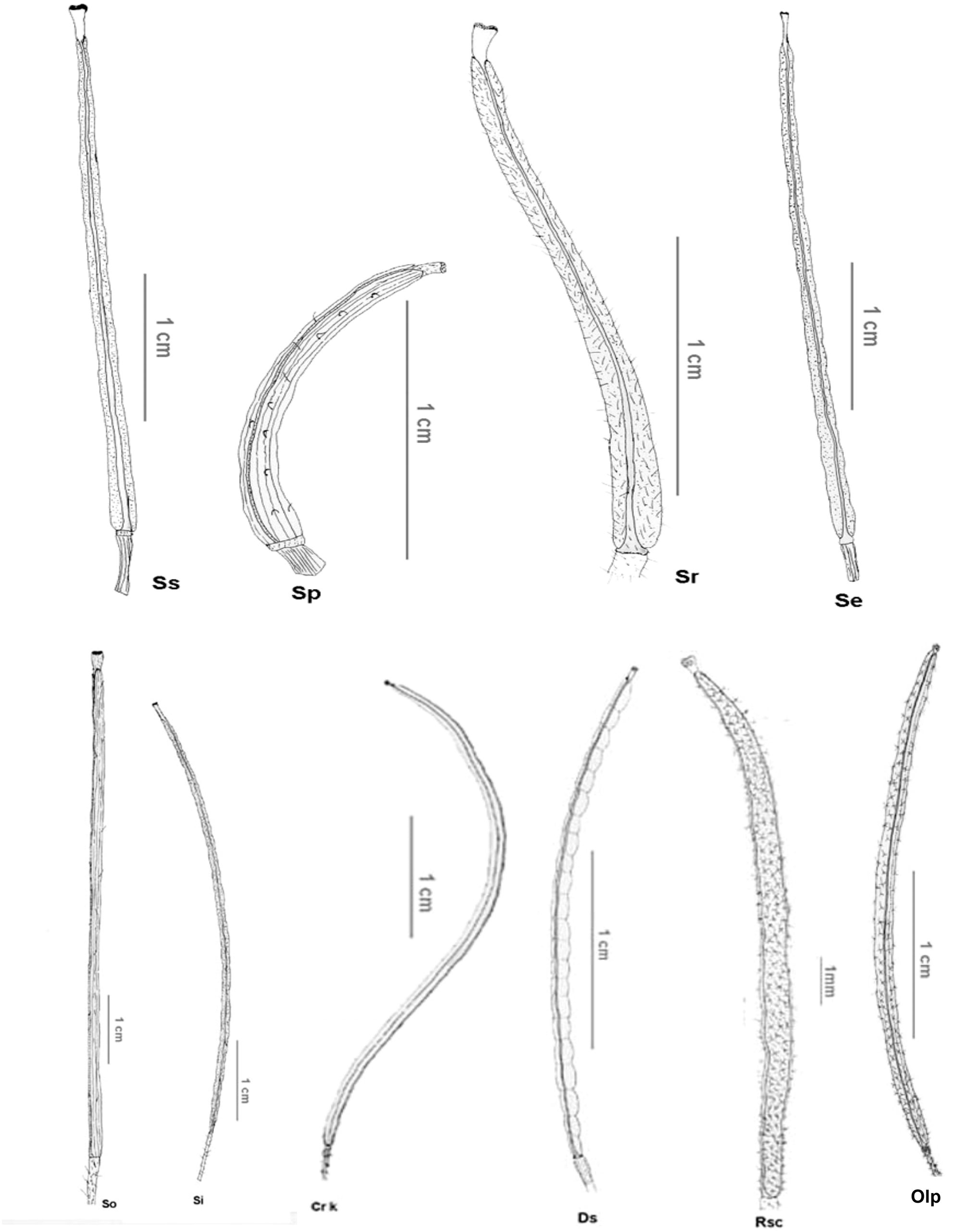


Fig. 2.14. Fruit shapes in Brassicaceae. **Crk**. *Crucihimalaya kneuckeri.* **Ds**. *Descurainia sophia.* **Olp**. *Olimarabidopsis pumil.* **Ros**. *Robeschia schimperi.* **Ss**. *Sisymbrium septulatum.* **Sp**. *Sisymbrium polyceratum.* **Sr**. *Sisymbrium runcinatum.* **Se**. *Sisymbrium erysimoides.* **So**. *Sisymbrium orientale*. **Si**. *Sisymbrium irio*.

2.2.12. Seeds

Seed shape, size, colour and coat structure: See chapter 3.

Seed number: This ranges from 1 in *Schimpera arabica*, 2 in *Anastatica hierochuntica, Neslia paniculata* and *Ochthodium aegyptiacum*, 3-8 *in Ricotia lunaria, Notoceras bicorne* and *Eremobium aegyptiacum* subsp. *lineare* to more than 8 seeds in the rest of the taxa. Seeds may be arranged in two rows in each locule as in *Nasturtium officinale*, *Leptaleum filifolium, Nasturtiopsis coronopifolia* and species of *Rorippa,* or one row in the rest of the taxa.

Embryo: (fig. 2.15), Radicle/cotyledons position is a significant character to distinguish among tribes. In Brassicaceae there are 3 different types of this position: Conduplicate is common in tribe Brassiceae (El Naggar, 1987); incumbent and accumbent are present throughout the rest of the family. This character can vary inside the tribe; in tribes Euclidieae and Hesperideae both accumbent and incumbent occur, in the tribe Euclidieae, accumbent in *Anastatica hierochuntica* and incumbent in the rest of the tribe, and in the tribe Hesperideae accumbent in *Eremobium* and incumbent in the rest of tribe.

2.2.13. Habitat

Brassicaceae are known to occur in a wide range of habitats in Egypt. *Sisymbrium irio* is a weed of cultivation, *Diceratella elliptica* and *Anastatica hierochuntica* are desert subshrubs or herbs. *Matthiola longipetala* and *Malcolmia nana* occur in the Mediterranean coastal region, *Olimarabidopsis pumila, Schimpera arabica, Crucihimalaya kneuckeri,* and *Sisymbrium septulatum* belong to the mountains of the Sinai. *Nasturtium officinale* and *Rorippa palustris* are found in humid places such as channel banks.

Concluding remarks:

The most important characters in classification of Egyptian Brassicaceae are:

1. Fruit (length, dehiscence, septum, valves): of major importance in recognizing tribes, genera, species and infra-specific taxa.
2. Flower: sepals; petals (colour, shape); filaments, anther; stigma; nectary glands: important at tribe, generic and specific level.
3. Seeds: embryo, seed number: important at tribal and generic level.
4. Indumentum: at tribal level.

Characters of limited taxonomic value are:

5. Habit (annual, short perennial, perennial).
6. Leaf characters (position, blade shape, petiole, margin, apex)
7. Inflorescence (position, bracteate, ebracteate).
8. Habitat (desert, weed, channel banks).

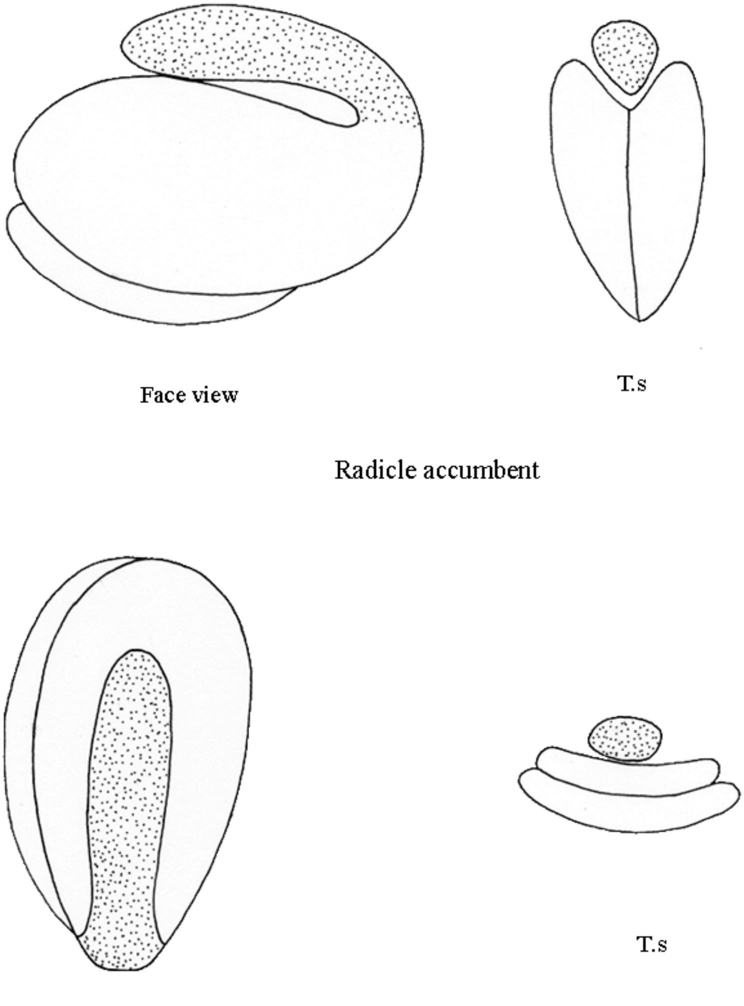


Fig. 21.5. Embryo shapes (radicle / cotyledons positions).

2.3. SYNOPSIS OF EGYPTIAN TAXA OF BRASSICACEAE

Species are arranged alphabetically within tribes according to O.E. Schulz, Pflanzenfamilien, ed. 2, 17B (1936).
Subspecies names followed by two asterisks ** are new records for the flora of Egypt, subspecies and varieties followed by one asterisk * are new combinations.

1. Tribe Arabideae DC.
1.1. ***Arabis alpina*** L. sub sp. ***caucasica*** (Willd.) Briq**.**
1.2. ***Arabis nova*** Vill.
1.3. ***Nasturtium officinale*** R.BR.
1.4. ***Rorippa indica*** (L.) Hiern
1.5. ***Rorippa integrifolia*** Boulos
1.6. ***Rorippa palustris*** (L.) Besser.
2. Tribe Euclidieae DC.
2.1. ***Anastatica hierochuntica*** L.
2.2. ***Neslia paniculata*** (L.) Desv. var. ***apiculata*** Abdel Khalik *****
2.3. ***Neslia paniculata*** (L.) Desv. var. ***paniculata*** *****
2.4. ***Ochthodium aegyptiacum*** (L.) DC.
2.5. ***Schimpera arabica*** Hochst and Steud.
3. Tribe Hesperideae O.E. Schulz
3.1. ***Eremobium aegyptiacum*** (Spreng.) Asch. & Schweinf. subsp. ***aegyptiacum*** *****
3.2. ***Eremobium aegyptiacum*** (Spreng.) Asch. & Schweinf. subsp**.** ***lineare*** (Delile) Abdel Khalik *****
3.3. ***Eremobium aegyptiacum*** (Spreng.) Asch. & Schweinf. subsp. ***longisiliquum*** (Coss.) Maire ******
3.4. ***Erysimum repandum*** L.
3.5. ***Leptaleum filifolium*** (Willd.) DC.
3.6. ***Malcolmia africana*** (L.) R.Br.
3.7. ***Malcolmia nana*** (DC.) Boiss.
3.8. ***Malcolmia pygmaea*** (Del.) Boiss.
4. Tribe Lunarieae O.E. Schulz
4.1. ***Ricotia lunaria*** (L.) DC**.**
5. Tribe Matthioleae O.E. Schulz

5.1. ***Diceratella elliptica*** (DC.) Jonsell

5.2. ***Matthiola arabica*** Boiss.

5.3. ***Matthiola fruticulosa*** (L.) Maire

5.4. ***Matthiola longipetala*** (Vent.) DC. subsp. ***bicornis*** (Sibth.) Ball

5.5. ***Matthiola longipetala*** (Vent.) DC. subsp. ***hirta*** (Conti) Greuter and Burdet

5.6. ***Matthiola longipetala*** (Vent.) DC. subsp. ***kralikii*** (Pomel) Maire **

5.7. ***Matthiola longipetala*** (Vent.) DC. subsp. ***livida*** (Delile) Maire

5.8. ***Matthiola longipetala*** (Vent.) DC. Subsp. ***longipetala***

5.9. ***Matthiola parviflora*** (Schousboe) R.Br.

5.10. ***Morettia canescens*** Boiss.

5.11. ***Morettia parviflora*** Boiss.

5.12. ***Morettia philaeana*** (Delile) DC.

5.13. ***Notoceras bicorne*** (Ait.) Caruel.

6. Tribe Sisymbrieae DC.

6.1. ***Crucihimalaya kneuckeri*** (Bornm.) Al-Shehbaz, O'Kane and Price

6.2. ***Descurainia sophia*** (L.) Webb and Berth.

6.3. ***Nasturtiopsis coronopifolia*** (Desf.) Boiss.

6.4. ***Neotorularia aculeolata*** (Boiss.) Hedge & Léonard

6.5. ***Neotorularia torulosa*** (Desf.) Hedge and Léonard var. ***scorpiuroides*** (Boiss.) Hedge & Léonard

6.6. ***Neotorularia torulosa*** (Desf.) Hedge and Léonard var. ***torulosa***

6.7. ***Olimarabidopsis pumila*** (Stephan) Al-Shehbaz, O'Kane and Price

6.8. ***Robeschia schimperi*** (Boiss.) Schulz

6.9. ***Sisymbrium erysimoides*** Desf.

6.10. ***Sisymbrium irio*** L.

6.11. ***Sisymbrium orientale*** L.

6.12. ***Sisymbrium polyceratum*** L.

6.13. ***Sisymbrium runcinatum*** Lag. ex DC.

6.14. ***Sisymbrium septulatum*** DC.

2.4. SYSTEMATIC TREATMENT

Brassicaceae Burnett, Outl. Bot. 1123 (1835).

Syn.**:** Cruciferae A. L. De Jussieu, Gen. Plant. 237 (1789).

Annual, biennial or perennial herbs, sometimes woody at the base, rarely shrubs or subshrubs. Glabrous or with simple and/or branched hairs, stellate, vascular or glandular, appressed or petiolate. Stems erect, ascending or procumbent, sometimes rooting at nodes, green, sometimes purple in colour. Leaves alternate or spirally arranged, exstipulate, simple or rarely compound, often rosulate at base, petiolate or sessile to amplexicaul. Inflorescence racemose or corymbose, simple or branched, terminal, rarely axillary, ebracteate, or rarely bracteate. Flowers usually hermaphrodite, actinomorphic, rarely zygomorphic, hypogynous, 4-merous, sessile or pedicellate. Sepals 4, in 2 pairs, erect or spreading, the inner pairs often saccate at base. Petals 4, cruciform, alternating with sepals, free, often with distinct claw. Stamens 6, tetradynamous (2 outer short and 4 inner long) rarely 4 or 2; filaments linear or dilated below, sometimes winged; anthers dithecous, sagittate, oblong or ovate, opening longitudinally. Pollen grains stenopalynous, usually 3-colpate, oblate-prolate to subspheroidal, reticulate. Nectar glands variously arranged at the base of filaments and take different shapes. Ovary bicarpellate, syncarpous, 1-2 celled, one- or many-ovuled on two parietal placentas; septum false being formed by placental outgrowths, in fruit become membranous, submembranous or stiff. Style simple, present or absent. Stigma capitate or bilobed, lobes sometimes decurrent. Fruit a siliqua or silicula, dehiscent (opening from below by two valves) or indehiscent, hairy or glabrous; valves membranous to coriaceous and thick, flattened or keeled, sometimes winged or appendaged, with 1 to many veins. Seeds 1 to many in 1-2 rows, in one locule, oblong, ovate, suborbicular or orbicular, winged or not, mucilaginous on wetting or not, surface texture variable. Radicle accumbent or incumbent, rarely longitudinally folded.

Key to the tribes of family Brassicaceae (Cruciferae)

1a. Fruit mostly beaked; cotyledons almost longitudinally folded (conduplicate)……………….
…………………………………………………..……Tribe Brassiceae (El Naggar, 1987)

1b. Fruit usually beakless; radicle accumbent or incumbent………..………..……………..…..2

2a. Fruit a silicula (up to 3 x as long as wide), except in *Farsetia* a siliqua …..…………...…...3

2b. Fruit a siliqua (more than 3 x as long as wide)………………..……………..…………...6

3a. Fruit indehiscent, nut-like; valves thick…………………………………..…Tribe Euclidieae

3b. Fruit dehiscent, flattened; valves thin…..……………………………………..……………4

4a. Fruit with narrow septum; radicle incumbent or accumbent……………………..…………..
……………………………………………..…..…....Tribe Lepidieae (El Naggar, 1987)

4b. Fruit with broad septum; radicle accumbent………………………..………………..…..5
5a. Plants glabrous or with simple hairs only……………………………….....Tribe Lunarieae
5b. Plants covered with stellate, adpressed medifixed, and furcate hairs…………….…………
…………………………………………….…...Tribe Alysseae (El Naggar & El Hadidi, 1998)
6a. Fruit almost horned; radicle accumbent……………………..…………......Tribe Matthioleae
6b. Fruit not horned; radicle accumbent or incumbent………………..……………………..7
7a. Radicle accumbent; hairs simple, branched or absent…………..………….Tribe Arabideae
7b. Radicle incumbent, rarely accumbent; hairs simple, vasculate, bifid, stellate, forked or glandular………………………..………………………………………….……..8
8a. Sepals erect; fruit tardily dehiscent; hairs simple, bifid, stellate or forked………………...
……………………………………………………………………......Tribe Hesperideae
8b. Sepals spreading to erect, rarely erect; fruit readily dehiscent; hairs simple, vasculate, branched, glandular or glabrous……………………………………...…....Tribe Sisymbrieae

Key to the genera and species

1a. Fruit a silicula (short and broad); as long as wide or less than 3 x longer than wide……….**2**
1b. Fruit a siliqua (long and narrow); at least 3 x as long as wide………………………………**6**
2a. Fruit dehiscent, flattened; hairs simple or glabrous; leaves trifoliate or pinnate; petals large, emarginate at apex……………………...……..…………………………**12. Ricotia lunaria**
2b. Fruit indehiscent, not flattened; hairs simple, branched, glandular or glabrous; leaves simple, lanceolate or oblanceolate; petals small, entire at apex……………...**3. (Euclidieae)**
3a. Fruit beaked…..……………………………………………………**7. Schimpera arabica**
3b. Fruit without a beak ……………………………………………………..……………….**4**
4a. Fruit winged at apex; pubescent with stellate and dendroid hairs; radicle accumbent.……………………………………….……………**4. Anastatica hierochuntica**
4b. Fruit wingless; glabrous; radicle incumbent………………………..……………………**5**
5a. Fruit irregular ovoid, densely tuberculate; septum thick; style short, pyramidial; plant covered with simple and glandular hairs……………………..**6. Ochthodium aegyptiacum**
5b. Fruit subglobose, with or without boss (umbo); valves reticulate; septum submembranous; style apiculate; plant covered with spreading branched hairs……..…**5. Neslia paniculata**
6a. Fruit almost horned, hairy…………………………………………………..**7. (Matthioleae)**
6b. Fruit hornless, glabrous or hairy……………………………………………………..……**10**
7a. Subshrubs; leaves elliptic to ovate, petiolated; valves keeled……**13. Diceratella elliptica**
7b. Perennials or annuals; leaves lanceolate, linear, oblanceolate or obovate, petiolate or sessile; valves not keeled…………………………………………………………….…**8**
8a. Fruits up to 2 cm long, tetragonous, appressed to stem; stigma capitate or bi-lobed…..…..**9**

8b. Fruits up to 7 cm long, linear to terete, erect or spreading; stigma ovoid or with two horns……………………………………..…………………………..**14. Matthiola**

9a. Fruits up to 7 mm long, with two apical horns, covered with bipartite hairs; stigma capitate…………………………………………………...……**16. Notoceras bicorne**

9b. Fruits up to 2 cm long, hornless, covered with stellate and branched hairs; stigma 2-lobed, persistent ……………………………..……………………………..…**15. Morettia**

10a. Fruit dehiscent, glabrous; seeds in two rows or rarely one row in each locule; radicle accumbent……………………………………………………………...….**11. (Arabideae)**

10b. Fruit dehiscent or tardily dehiscent; seeds in one row or rarely two rows in each locule; radicle incumbent or rarely accumbent……………………………………………..…**13**

11a. Plant covered with simple, bifid or branched hairs; lower leaves in a rosette; fruit up to 6 cm, linear-oblong; seeds in one row in each locule…….………………………..….**1. Arabis**

11b. Plant glabrous or with simple hairs; lower leaves not in a rosette; fruit up to 1.9 cm long, oblong-ellipsoid to short oblong; seeds in two rows in each locule…………………...…**12**

12a. Aquatic perennial, up to 70 cm long; leaves imparipinnate; stem prostrate to ascending, hollow, lower nodes with fibrous roots…………………………**2. Nasturtium officinale**

12b. Annual or short-lived perennial, in wet habitat, up to 50 cm long; leaves linear-lanceolate to oblong-lanceolate or pinnatisect; stem erect or decumbent, not hollow, lower nodes without fibrous roots……………..…………………………………..………**3. Rorippa**

13a. Annual or perennial; sepals erect; fruit tardily dehiscent; radicle incumbent or accumbent; stamens 6 or 4 or 2………………………………………….…...……**14. (Hesperideae)**

13b. Annual; sepals spreading; fruit readily dehiscent; radicle incumbent; stamens 6. ………………………………………………………..……….……**18. (Sisymbrieae)**

14a. Dwarf annual, up to 8 cm long; plant glabrous or with simple hairs; leaves linear or thread like, pinnatisect with filiform lobes; flowers axillary, solitary or in pairs; stamens 4 or 2; seeds in two rows in each locul………………………………....**10. Leptaleum filifolium**

14b. Perennial or annual herb, up to 40 cm long; covered with 2-fids, 3-fids, stellate, simple or branched hairs; flowers terminal, numerous; stamens 6; seeds in one row in each locule……………………………………………………………………………..**15**

15a. Leaves linear-oblong, entire, sessile; plant covered with stellate hairs; stem prostrate or ascending….…………………………………………...…**8. Eremobium aegyptiacum**

15b. Leaves oblong-lanceolate, oblanceolate or ovate, dentate or pinnatifid, rarely entire; plant covered with branched, simple, stellate or 2-3 fid hairs; stem erect or ascending………**16**

16a. Petals yellow, outside covered with hairs; plant covered with 2 or 3-fid hairs……………………………………………...……….**9. Erysimum repandum**

16b. Petals white, pink or violet, outside glabrous; plant covered with simple, branched or stellate hairs……………………...……………………………….…**11. Malcolmia**

17a. Plants always covered with glandular hairs; leaves 2 or 3 pinnatisect with narrow, short lobes; fruiting pedicels 0.7-2 cm long ……..…………………..…**21. Descurainia sophia**

17b. Plants never covered with glandular hairs; leaves simple, lyrate-pinnatifid, pinnatisect or linear-oblong; fruiting pedicels 0.1-1 cm long……………………………………...**19**

18a. Plant glabrous or covered with simple, branched hairs; leaves pinnatifid, pinnatisect; seeds in one or two rows in each locule…………………………………………..….**20**

18b. Plant glabrous or covered with simple, hooked or clavate, and a few stellate and branched hairs; leaves simple, linear-oblong, lyrate-pinnatifid, dentate; seeds in one row in each locule…………………………………………………………………...…...**21**

19a. Fruit hairy; fruiting pedicels 1-2 mm long; seeds in one row in each locule……. ………………………………………………………....**22. Robeschia schimperi**

19b. Fruit glabrous; fruiting pedicels 4-10 mm long; seeds in two rows in each locule……………………………….……..…...**19. Nasturtiopsis coronopifolia**

20a. Plant glabrous or covered with simple, hooked or clavate hairs; valves 3-nerved... …………………………………….……………………..**23. Sisymbrium**

20b. Plant covered with simple, and a few stellate and branched hairs; valves 1-nerved or not nerved……………………………………………………….……………**21**

21a. Cauline leaves petiolate; fruit apex recurved or contorted; fruiting pedicels as thick as fruit, 1.5-2.5 mm long……………………………………...…..**20. Neotorularia**

21b. Cauline leaves auriculate, sessile or cunate into a petiole-like base; fruit apex straight to slightly curved; fruiting pedicels thinner than fruit, 3-10 mm long……………………...**22**

22a. Cauline leaves auriculate; petals yellow; fruit hairy; septum pitted; fruiting pedicels 3-5 mm long ……………………...…………………………..**18. Olimarabidopsis pumila**

22b. Cauline leave sessile or cunate into a petiole like base; petals mauve; fruit glabrous; septum complete; fruiting pedicels 4-10 mm long………..**17. Crucihimalaya kneuckeri**

1. Tribe Arabideae DC.

Syst. Nat.11: 146, 161 (1821)

Hairs simple, branched or absent. Sepals more or less spreading. Filaments linear, without appendages. Median nectar glands present, sometimes united with the transversal ones to a ring. Stigma capitate or bilobed. Fruit siliqua, linear or narrow-oblong, dehiscent. Radicle accumbent.

1. Arabis L.

Sp. Pl. ed. 1: 664 (1753); L. Gen. Pl. ed.5: 298 (1754); O.E. Schulz in Pflanzenfam. ed. 2, 17B: 542-547 (1936); Huang et al. Taiwania, 40 (4): 385-390 (1995).

Annual or perennial herbs, canescent with simple, bifid or branched hairs, rarely glabrous. Stem erect or ascending, simple or branched. Lower leaves in arosette, more or less petiolated; upper leaves sessile, amplexicaul, frequently dentate. Inflorescences often bracteate at base. Flowers pedicellate. Sepals erect, saccate at the base. Petals white, yellow to violet, spathulate with ashort claw, larger than sepals. Stamens 6; filaments free, narrow, without appendages; anthers oblong-linear; style short; stigma capitate or 2-lobed. Fruiting pedicels erect or spreading, filiform. Fruits siliqua, linear-oblong, dehiscent, usually compressed; valves flattened or convex with 1-veined; septum membranous. Seeds in one row in each cell, compressed, ovoid, wingless or wide winged; radicle accumbent.

About 120 species in temperate Europe and Asia, N. America and mountains in tropical Africa, two species in Egypt.

Key to the species:

1. Perennial; petals 1-1.2 cm long; fruiting pedicels thinner than fruits, hairy; fruit torulose……..………....……………….…………...…...……**1. Arabis alpina** subsp. **caucasica**.
2. Annual; petals 2.5-3.5 mm long; fruiting pedicels as thick as fruits, glabrous; fruit not torulose……………………………………………………………….…………….…..**2. A. nova**.

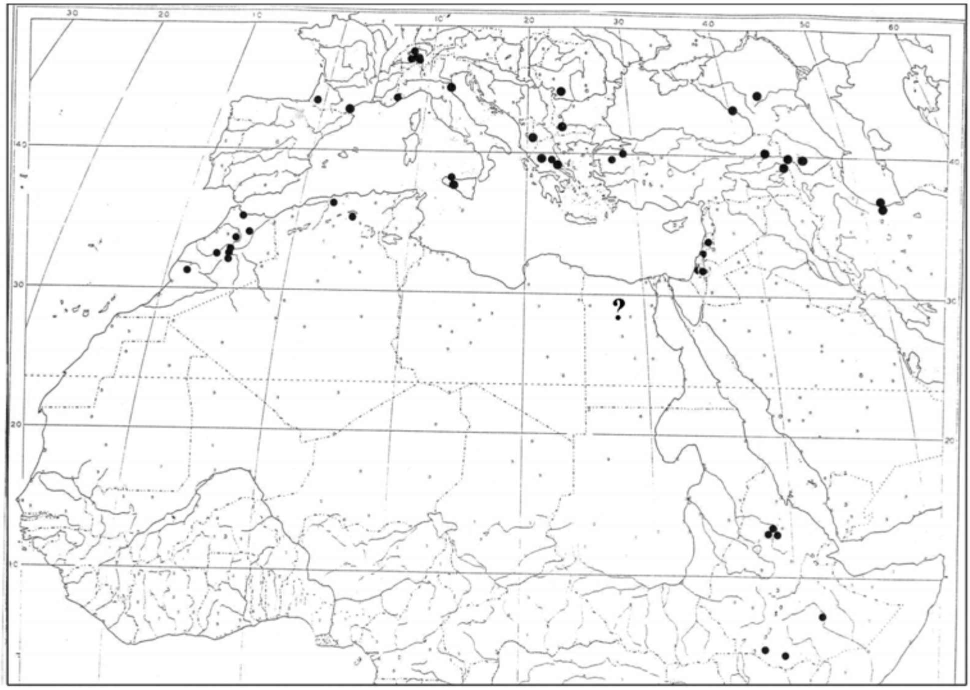
1. **Arabis alpina** L., Sp. Pl. ed. 1: 664 (1753) subsp. **caucasica** (Willd.) Briq., Prodr. Fl. Corse 2(1): 48 (1913); Maire, Fl. Afr. Nord, 13: 317 (1967); Collenette, Illust. Flow. Pl. Saudi Arabia, 193(1985); Tutin et al. Fl. Eur. ed. 2, vol.1: 356 (1993); El Hadidi & Fayed, Taeckholmia 15: 43 (1994-1995); Boulos, Fl. Egypt Checklist 40 (1995); Boulos, Fl. Egypt 1: 194 (1999).

Basionym: *Arabis caucasica* Willd., Enum. Pl. Hort. Berol. Suppl.45 (1814).

Type: Described from a plant cultivated in Berlin Botanical Garden (holotype: B).

Heterotypic synonyms: *Arabis albida* Stev., Cat. Hort. Gorenk. 51 (1812); Coss., Compend. 2: 117 (1883-1887). Type: in Saxosis montium Tauriae and Caucasi Iberici, Steven. 4. Fl. May (B, holotype).
Arabis viscosa DC., Syst. Nat.2: 216 (1821). Type: in Alpibus Samamisicis Persiae septentrionalis (Fisch. ex Herb. Pall.) 4. Fl. Jun. (not seen).
Turritis verna Desf., Fl. Atlant. 2: 92 (1798). Type: In Atlante near to Belide (not seen).
Icon: Boulos, Fl. Egypt 1: 198, t. 36 (3) (1999).
Perennial herbs, 10-25 cm, canescent or tomentose with simple, bifid or dendroid hairs. Stems erect or procumbent, simple or branched near the base, cylindrical. Basal leaves 1.3-5 x 0.5-1.8 cm, sessile or petiolated 0.4-1.4 cm, mostly rosulate, obovate-oblong to spathulate, obtuse or subacute at apex, entire or sparsely serrate, hairs with 2-5 forks; cauline leaves 1.7-3.6 x 0.7-2.4 cm, sessile, oblong to lanceolate, auriculate ± amplexicaul, dentate, acute at apex. Inflorescences ebracteate, elongating in fruit. Flowers pedicellated 3-7 mm. Sepals 5-7 mm, oblong, saccate at the base, hairy from outside. Petals white 1-1.2 cm long, obovate, obtuse or slightly emarginate in apex lamina and a long narrow claw. Filaments 5-8 mm, linear, free; anthers sagittate to oblong, 1.2-1.5 x 0.6 mm; style short; stigma capitate to slightly depressed. Fruiting pedicels 0.9-1.5 cm, hairy, spreading to erect. Fruits 3.5-6 x 0.2 cm, siliqua, linear, glabrous, compressed, torulose, dehiscent, erect to spreading; valves with 1distinct midrib, glabrous; septum hyaline, membranous. Seeds in one row in each cell, light brown, compressed, suborbicular, 1.3-1.5 x 1.2-1.3 mm, wide winged; radicle accumbent.
Fl. & fr.: March-May.
Habitat: on waste land, shaded slopes.
Uses: this plant is suitable for the rock garden or along the edge of herbaceous borders. Busch (1939) describes this as an excellent nectar plant and a suitable ornamental, one of the first flowering species in spring.
Distribution: Europe, W. Asia and Mediterranean region (Map 6)

SPECIMENS EXAMINED:
ALGERIA: Chrea (above Blida), shady schist rocks, Davis 59101 (BM); Mts. Magris, in dry calcareous area, 1700 m, Juin 327 (B).
CONGO K: Rukimi, prov. Kivu. Terr. Goma, P. Bampas 2966 (WAG); Kiondo, Albert National park, G. de Witte 8491 (WAG).
ETHIOPIA: 20 miles south Goba, J. W. Ash 3532 (WAG); Gara Mullata Mts. in the moist forest, W. Burger 1899 (WAG); about 100 km N. of Addis Ababa, Blue Nile road, between Fitche and Deba Libanos near the Portuguese bridge, W. de Wilde 10857 (WAG); prov. Bagemder, in valley of side stream of Jinbar Wanz, Semien Mountains National Park, V. Magda 160 (WAG); prov. Bagemder, Semien mountains, Geech area, B. E. Nievergelt 1115 (WAG); among rocks in regions of the top of mountain Semien near Silke, Schimper 997 (BR); 23 km from Kulubi, road longhe, along road, E. Westphal 2388 (WAG).



Map 6: Distribution of *Arabis alpina* subsp. *caucasica*

KENYA: Mt. Kenya, Naru Moru Track, Camp 2, Coe & Kirika 267 (WAG).
MOROCCO: West Rif, Jebel Lakraa, A. Boratynsk & A. Romo R-8531/3 (BM); Cedrus forest, 25 km S. of Azrou, W. de Wilde 2616A (WAG); Foum Kheneg, between Azrou and J. Hebri, W. de Wilde 2856 (WAG); Meknes, Aguelmane Azigza, 1600m, J. Fdez et al. 7183 (B); 34 km from Azrou on road to Midelt. River bed banks and adjacent NE facing limestone cliffs, Gavin Stark 617 (NMGM); Taza, around summit of Djebel Tazzeka Schistose, Gavin Stark 1313 (NMGM); Mts. Atlas, in calcarious soil, E. Jahandiez 330 (B); high Atlas, S. from Marrakech, 2 km below Ski resort of Oukaimeden on road to valley of Ourika, S. L. Jury 18132 (BM).
RAWANDA: Eastern slope of Muhavura, P. Auquier 2615 (WAG).
TANZANIA: Arusha region, Arumeru Dist., Mt. Meru, Roy E. Gereau 1622 (WAG); Arusha prov. Mt. Meru, E. slope, Orvo Vitikainen 9567 (WAG).
AZERBIJAN: Baku, Kuba, Alexeenko s.n., 30/7/1898 (B).
IRAN: Mazandaran prov., Elburz Mts. Hazarchal Valley, K. A. McDougall 9 (BR); Elburn, pale Fungneé, Burraw, Bornmüller 1354 (B).
ISRAEL: Mont jow, Deyrolle 948 (BR); Mt. Hermon, 5 Km NW of Arne, A. Danin s.n., 19/6/1974 (HUJ); Hermon, military post on the hill mountain forest, I. Hernstant s.n., 4/5/1972 (BR).
LEBANON: near Faraya, sheltered rock faces, Polunin 5326 (B).
BULGARIA: Rila-Sibirage, M. Bäbler s.n., 10/8/1960 (B); Mt. Pirin, alpine rocky and grasslands in Kazana, B. Kuzmanov 76212 (B); Gudaute near river Avatchara, V. Vašák s.n., 20/6/1971 (B); Fergana, in Kamzabad, V. Vašák s.n., 27/4/1972 (B); Mts. Gegamski Ararat, Khach-Karer, V. Vašák s.n., 9/7/1975 (B).
CANARY ISLANDS (Spain): Tenerifa, Canadas to Teyde, in rocks, E. Bourgeau 1247 (WAG).

FRANCE: near Alin (Bhōme), M. Gandoger 188 (LY); East slope, Mt. Canigou, de Wilde & Dorgelo s.n., 25/6/1956 (WAG); Mt. Canigou, near Chalet, de Wilde & Dorgelo s.n., 25/6/1956 (WAG).
GREECE: Creta, Lasithi, in mts Lazaro, Chr. Leonis 26 (LY); Ziree mountains, near Trikala, T. G. Orphanides 374 (WAG); Ioanninon, Trikalon, Mt. Peristeri, Mt. Irapos, 5 km WSW of Chalikion, Björn Aldén A3814 (B).
ITALY: near shady rocks, mountain Pizzuta, A. Pavillon s.n., 23/5/1855 (WAG); in shady limestone, near mountain of Alp. Busamlira, H. Ross 3 Fl., 5, 6 Fr. (WAG); Mts. Madonie, S. of Piano Battaglia, Werner and Marsam 24458 (B); Palermo, in calcareous soil, Hermann Ross s.n., April, 1903 (B).
NETHERLANDS: Leiden, R.B. Bosch s.n., 1892 (WAG); Goes, E. de Vries 34 (WAG); Wageningen, K. J. Hensen s.n., 8/5/1962 (WAG).
SWEDEN, LAPLAND: Abisko, Sam Segal 279 (WAG).
SWITZERLAND: Lauterbrunnen-Zweilutschen, Brandhorst 336 (WAG); Grutschalp, Brandhorst 336a (WAG); Kandersteg, Golitschen, Brandhorst 336c (WAG); Eigergletscher, J. Valckenier Suringar s.n., 1924 (WAG); Stafelalp, SW of Zermatt s.n., 19/7/1964 (WAG).
TURKEY: prov. Artvin, forest edges, H. Ern 6539 (B); Kvesvedagh, Haussknecht 5510 (B); porov. Agri, Tendürek Dagh, Raus 4364 (B); Tauria, dist. Simpheropol, Mts Tschatyr-Dagh, near Angara-burun Mts, V. Vasak s.n., 15/5/1991 (BR); Ulu Dagh, near Bursa, road side in Abies-Fagus forest, J. de Wilde 4023 (WAG).
MACEDONIA: Bistra Planian SW of Mavrovo, Van Ooststroom & Hennipman 24096 (B).

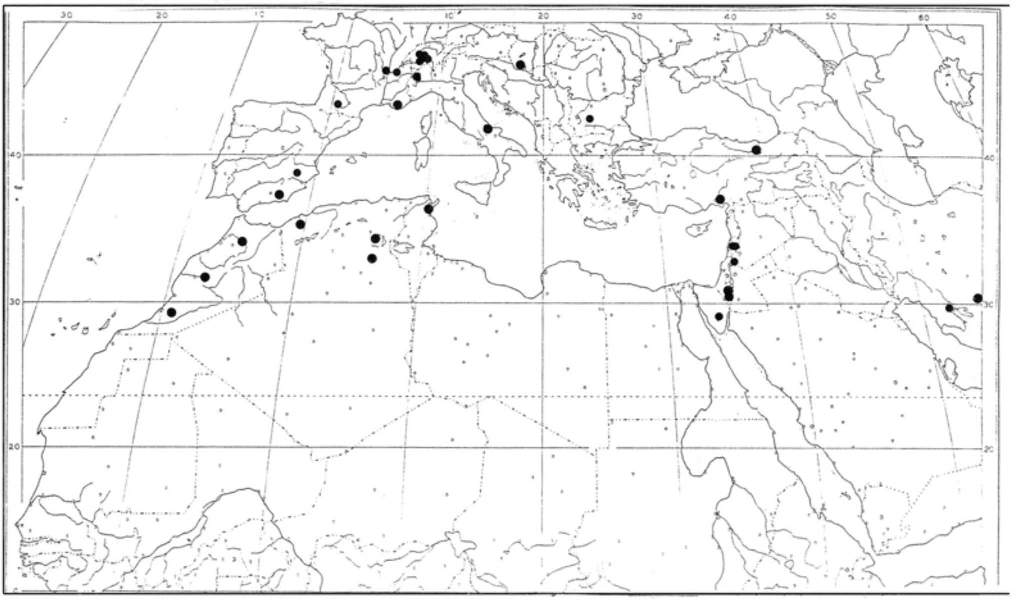
2. **Arabis nova** Vill., Prosp. Hist. Pl. Dauphine 39 (1779); Cullen in Fl. Turkey 1: 428 (1965); Zohary, Fl. Pal. 1: 279 (1966); Hedge in Fl. Iran 57/28.2: 203 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 177 (1974); Jafri, Fl. Libya 23: 140 (1977); Hedge & Lamond, in Fl. Iraq 4, 2: 1005 (1980); Tutin, T. G. et al. Fl. Eur. ed. 2, 1: 355 (1993); Boulos, Fl. Egypt 1: 194 (1999).
Type: France, Dauphine, M. Lictard (P).
Homotypic synonym: *Arabis nova* Vill. var. *sinica* (Boiss.) Täckholm, Publ. Cairo Univ. Herb. 5: 36 (1974).
Arabis sinaica Boiss., Diagn. Pl. Orient. Ser. 1,8: 21 (1849).
Type: in shady area at Wadi Arbain, Arabiae Petreae (Boiss.). (not seen)
Heterotypic synonyms: *Arabis auriculata* Lam., Encycl. 1: 219 (1783). Type: in land mobili Asia minor (Auch. 4118), Lyciae (Bourg) (not seen).
Arabis auriculata Lam. var. *sinaica* (Boiss.) Boiss., Fl. Orient.1: 169 (1867). Type: in shady area at Wadi Arbain, Arabiae Petreae (Boiss.) (not seen).
Arabis montbretiana Boiss., Ann. Sci. Nat. sér. 2, 17: 53 (1842). Type: Ak-Dag in DC. ex Aleppo No.98 (not seen).
Arabis cadmea Boiss., diagn. Pl. Orient. sér. 1, 8: 21 (1849). Type: in Pinguibus arenosis Cadmi orientalis supra Cotossan in Carid alt. 5000-6000 m 1842 (not seen).
Icon: Jafri, Fl. Libya 23, 138, t. 42 G (1977).
Annual herbs, 5-20 cm, with scattered simple or 2-4 branched hairs. Stem simple, erect or suberect ± zigzag above. Basal leaves 1-2.5 x 0.4-1.2 cm, petiolate 3-5 mm, obovate-oblong, dentate-crenate to subentire; cauline leaves 1-2 x 0.4-0.6 cm, ovate or cordate-sagittate at base, amplexicaul, toothed to entire, acute. Racemes many flowered, ebracteate. Flowers pedicellate

4-7 mm. Sepals 1.5-2 mm long. Petals 2.5-3.5 mm, white, spathulate. Filaments 2-2.5 mm, linear; anthers 0.6 mm; style thin, 2mm long; stigma minute, depressed. Fruiting pedicels 0.5-1.5 cm, as thick as fruit, glabrous. Fruits 2-5 x 0.1 cm, siliqua, linear, erect-spreading, glabrous, acute; valves convex with 1-nerved; septum membranous. Seeds in one row in each locule, 0.7-1 x 0.3-0.4 mm, oblong-ovoid, light brown, wingless; radicle accumbent.

Fl. & fr.: March-May.

Habitat: Sheltered crevices, mountain slopes.

Distribution: Europe, Crimea, Cyprus, Syria, Lebanon, Palestine, Israel, Jordan, Turkey, Caucasus, Iraq, Iran, W. Pakistan, Afghanistan, India, C. Asia and N. Africa (Egypt to Morocco) (Map 7).



Map 7: Distribution of *Arabis nova*

SPECIMENS EXAMINED:

ALGERIA: in rocks between Batna and Biskra, El-Ksour, S. Choulette 305 (B, LY); top of Oran plateau, Gebel Beguira, A. Faure s.n., 20/4/1927 (B); Batna, in Gebel Zougourt near Santaine, G. Rouy s.n., 26/4/1892 (LY).

EGYPT: S. Sinai, near the Monastry of Catherine, in fissures of steep smooth granite rocks, A. Danin & A. Shmida s.n., 24/4/1968 (HUJ); S. Sinai, on the step way to Gebel Musa, V. Täckholm et al. s.n., 11/5/1956 (CAI).

MOROCCO: Middle Atlas, Ifrane, Erik Wall s.n., 15/4/1934 (B); Marrakech, Collado of Tizi N test, Gomez-Campo 4705 (B); Meknes in Auluz, Gomez-Campo 4914 (B).

TUNISIA: NW of flanks of Gebel Zaghouan, G. Wagenitz 1216 (B).

ISRAEL: Negev highlands, Nahal Elot slopes, A. Danin et al. 21.026 (B); Negev highlands, Borot Loz, 22 km SW of Mizpe Ramon, A. Danin s.n., 20/4/1992 (B); Negev, above Nahal Elot, A. Liston 26281 (HUJ).
INDIA: Kashmir, Malashahi Bagh, Gauderbal, Hassan Dar 551 (BR).
IRAN: in mountains between Chabbis and Kerman, Bunge s.n., 4/1859 (LY); Prov. Shiraz, road Shiraz-Kazerum, J. Lambinon 76/96 (BR).
LEBANON: Bzoumar, near Jounie, Polunin 5252 (B); Bcharre, in loose volcanic soil, Polunin 5347 (B).
SYRIA: Golan, Odem forest, near Masaada, shallow soil on basalt, A. Danin et al. 48. 014 (B).
BULGARIA: Mt. Golo Bardo, on West slope on top Ostrica, Vyhodcevsski 446 (CAI).
FRANCE: Grenoble (Isere river), C. Billot 1813 (WAG); in wooded and calcarious soil, in Luc (Var), H. Hanry et al. 3316 (LY); Alpes Mts, J. Léonard 4049 (BR); Marcieu, near Mure river (Isere), J. Sauze 5187 (BR).
HUNGARY: Ercsi, grasses, A. Tauscher 1497 (LY).
ITALY: Valley near Aosta, R. Hand 975 (B); hills near Callstadt, in Palatinta, H. Schultz 5 (LY).
SPAIN: mountains of Alcaras, E. Bourgeau 543 (WAG); Aldeira, Gorge of Gallego, prov. Granada, Valdes et al. 474/88 (B).
SWITZERLAND: Nendaz, on old walls (Valois), Denys Coquoz s.n., 10/6/1951 (BR); Moutorge, between Pitton and Vex, Lagger s.n., 1841 (WAG); Valois, Val de Bagnes, A. Lawalree 20273 (BR); Valois, Val de Bagnes, A. Lawalree 20665 (BR); Forclaz (Valois), C. Vanden Berghen 26 (BR); Biddes, Oferson s.n., 22/5/1950 (BR).
TURKEY: Samsak, Gümüshane, C. Haussknecht 5509 (LY); prov. Icel, N. side of the Cilician Gate, mountain slopes W of the road to Ankara-Adana, W. J. Vader 1241 (B).

2. **Nasturtium** R. Br.

In Ait., Hort. Kew. ed. 2, 4: 110 (1812); O.E. Schulz in Pflanzenfam. ed. 2, 17 B: 551-555 (1936); Al-Shehbaz & Price, Novon 8: 124-126 (1998).

Perennial, rhizomatous aquatic herbs, glabrous or with sparsely simple hairs. Stem ascending, simple or branched, hollow, angular. Leaves pinnate, with 3-6 pairs of leaflets. Inflorescence ebracteate, elongating in fruit. Flowers small. Sepals spreading, saccate at the base. Petals white, spathulate, about twice as long as the sepals. Stamens 6; filaments simple, without appendages, linear; anthers short, ovate-sagittate, obtuse; style small, thin; stigma capitate. Lateral nectar glands horse-shoe shaped, open outwards; middle glands absent. Fruiting pedicels long, spreading or ascending. Fruits dehiscent, glabrous, turgid, more or less flattened; valves subconvex, membranous, with one midrib; septum membranous. Seeds in two rows in each locule, ovoid, brown, narrow-winged, with numerous polygonal depressions; radicle accumbent.

Six species from temperate Europe to C. Asia, in N. Africa and America, also in the mountains of tropical E. Africa; one species in Egypt.

1. **Nasturtium officinale** R. Br., in Ait. Hort. Kew. ed. 2, 4: 110 (1812); Bentham & Hooker, Gen. Plant., vol. 1: 68 (1862-1867); Boiss., Fl. Orient. Vol.1: 178 (1867); Oliver, Fl. Trop. Afr. Vol.1: 58 (1868); O.E. Schulz, in Pflanzenr. 86 (IV, 105): 151 (1924); Täckholm, Stud. Fl.

Egypt ed. 1: 342 (1956); Coode, M. & Cullen, in Fl. Turkey 1: 430 (1965); Zohary, Fl. Pal.1: 277 (1966); Hedge, in Fl. Iran 57/28.2: 214 (1968); Nouv., Fl. Syria 2: 124 (1970); Täckholm, Stud. Fl. Egypt ed. 2: 176 (1974); Jafri, Fl. Libya 23: 141 (1977); Hedge & Lamond, in Fl. Iraq 4, 2: 1012 (1980); Collenette, Illust. Flow. Pl. Saudi Arabia 204 (1985); Tutin, T. G. et al. Fl. Eur. Ed. 2, vol.1: 346 (1993); El Hadidi & Fayed, Taeckholmia 15: 42 (1994-1995); Boulos, Fl. Egypt Checklist 39 (1995); Boulos, Fl. Egypt 1: 192 (1999).

Type: in Britain (Asch.) (holotype: K; isotype: L).

Heterotypic synonyms: *Rorippa nasturtium-aquaticum* (L.) Hayek, Sched. Fl. Styr. Exs. No.170: 22 (1905).

Sisymbrium nasturtium-aquaticum L., Sp. Pl. ed. 1: 657 (1753). Type: Sweden, herb. Linn.836/1 (holotype: LINN; isotype: L).

Icon: Jafri, Fl. Libya 23, 142, t.43 (A-E) (1977).

Aquatic perennial herbs, 20-70 cm, glabrous. Stems prostrate to ascending, sometimes floating, hollow, angular and fiberous rooting below. Lower leaves 1.8-7 cm long, petiols 1-2 cm, imparipinnate, with 2-7 pairs of leaflets; lateral leaflets (pinna) broadly ovate or elliptical, the terminal ones round-ovate, always larger, all leaflets entire to slightly sinuate, obtuse; cauline leaves shortly auriculate. Inflorescence ebracteate, elongating in fruits. Flowers pedicels 2-5 mm. Sepals 3-4 mm, lanceolate. Petals 4-7 mm, white, spathulate. Filaments 4-5 mm, free, linear; anthers 1 mm, yellow, ovate, obtuse; style 1 mm, thin; stigma capitate. Fruiting pedicels 6-11 mm, spreading or ascending. Fruits 0.8-1.7 x 0.2-0.25 cm, short siliqua, glabrous, oblong-linear, straight to incurved; valves with distinct midrib, subconvex; septum membranous, white. Seeds many, in two rows in each cell, ovoid, brown, 0.9-1 x 0.75-0.9 mm, narrow winged, polygonal depressions on each face; radicle accumbent.

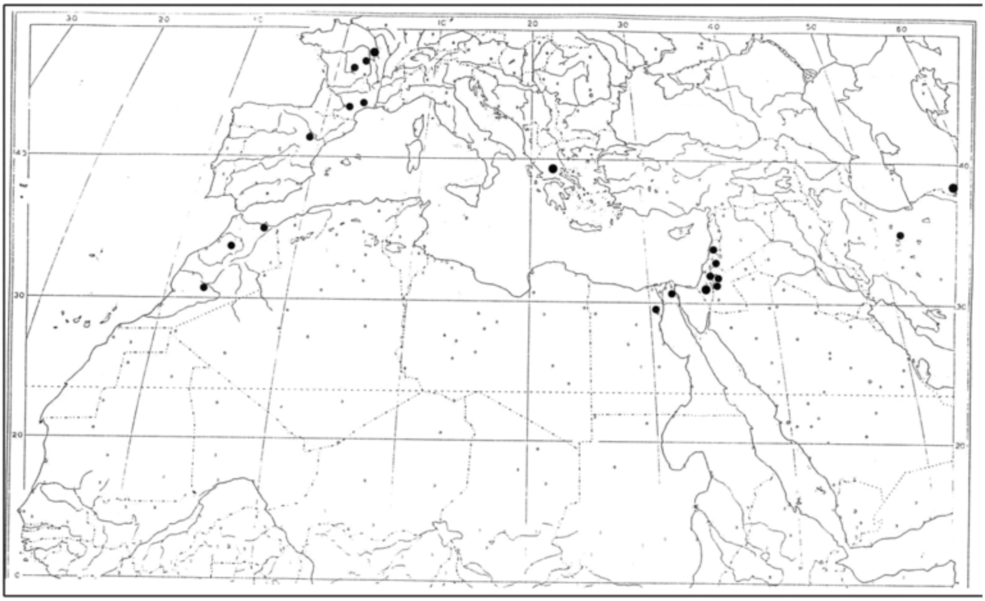
Fl. & fr.: April-July.

Habitat: water channels.

Vernacular names: Rashad Al-Mai (Egypt), Kuzele, Kobani (Iraq), Waterkers (Netherlands), Crecione (Italy), Berro (Spain), Cresson (France), Wasser Kresse (Germany), Water Cress (England) and Agrião in (Brazil).

Uses: This species is much cultivated as salad plant in Britain and other parts of Europe. Watt (1891) states that it has been widely appreciated for its antiscorbutic and stimulant properties and is widely eaten as an appetiser in India.

Distribution: Europe (except the extreme North), Cyprus, Aegaean Isles, Iran, Iraq, Syria, Lebanon, Palestine, Arabia, Turkey, Caucasus, W. Pakistan, Afghanistan, India, C. Asia, Macaronesia, Ethiopia, Cameroon, Sao Tome, N. Africa (Morocco to Egypt) (Map 8), and introduced and cultivated in America.



Map 8: Distribution of *Nasturtium officinale*

SPECIMENS EXAMINED:

CAMEROON: Maneng-ouba Mts near lake in Caldera, A.J.M. Leeuwenberg 9950 (WAG); market of Victoria, Westphal 9928 (WAG).

EGYPT: **Nv**: between Kafr Mahfous and Beni Osman, Faiyum, El Hadidi s.n., 20/11/1968 (CAI). **Di**: Abu Atwa, S. of Ismailiya, A. El Bakry 764, 840 (CAI).

MOROCCO: Taddert, Marrakesh-Ouarzazate road, High Atlas, Chaworth 13 (BM); Taza, 2 km E. of Boured, on road to Taza, Gavin Stark 1225 (NMGM); Abarakko, south Rabat, H. Sebotsmam 245 (WAG).

SAO TOME & PRINCIPE: track leading from Nova Moca towards Lagoa Amelia, J. E. de Wilde 328 (WAG).

IRAN: km 46 NW. Kashan, Babakhanlou-Amin 6423 (CAI).

ISRAEL: Negev, Eig, Zohary, Feinbrun 33870 (HUJ).

LEBANON: P. Mouterde 140 (CAI).

PALESTINE: in Jeruasalem and Hebron, Kotschy 486 (B).

SYRIA: Golan, nature Reserve (Bajuria), Grumusol and margins of a vernal pool, A. Danin et al. 43. 020 (B).

JORDAN: Jericho, B. T. Lowne s.n., April 1863 (OXF & FHO).

TURKMENISTAN: Ashkhabad, Al de Bunge s.n., 10/4/1859 (LY).

FRANCE: Chére, village of Graire, Al. Jullien-Crosnier 1605 (WAG); Corsica, 500 m side stream of Asco, village Scala di santa region, Sam Segal 444 (WAG); Casica st. Florent, Oleander valley, near stream, Sam Segal 217 (WAG); near Montpellier, source of Lesse river, Sissingh s.n., 6/2/1938 (WAG); Dept. Hairet, Roukille near Malesherbes, G. Ruy 9895 (LY).

GREECE: M. Korax, near Musinitza, Chr. Leonis 322 (LY).

GERMANY: Schleswig- Holstein, Harmsen 983 (WAG); Sachsen, Dresden, Hubner s.n., 6/7/1837 (WAG); near Gutsdorf, Pommern, P. Sydom s.n., 18/7/1878 (LY); Rheinufer near Bingen, Wirtgen 733 (WAG).

IRELAND: Dublin, E. slope, W. de Wilde and W. Kock, 98 (WAG).

NETHERLANDS: Apeldoorn in canals, H. J. Ankersmit s.n., 6/1872 (WAG); Vogelenzang, C. Braat 198 (WAG); the Hafme near side Bimckhorstlaam, Brandhorst 54 (WAG); Oostvoorne, M. Bremer s.n., 30/6/1907 (WAG); Wageningen, Bornse Steeg in canal, A. M. de Regt 10/7/1958 (WAG); Noordingh near Leiden, A. Jongkindt s.n., 13/7/1869 (WAG); Prov. Gelderland, Vaassen-Epe, H. J. Kok-Ankersmit s.n., 28/6/1878 (WAG); Spijkenisse, prov. Zeeland, Koorneelf 332 (WAG).
SPAIN: Seo d'Urgel, Pyrenees, E. Bourgeau 415 (WAG).
SWEDEN: Scania, Verpinge near Lund, O. Schlyter 33 (LY).

3. **Rorippa** Scop.,

Fl. Corn. ed. 1: 520(1760); O.E. Schulz in Pflanzenfam. ed. 2, 17B: 554 (1936); Jonsell, B., Svensk Bot. Tidsk., Bd 65: 293-307 (1971); Stuckey, R., Sida, 4(4): 279-430 (1972); Jonsell, B., Svensk Bot. Tidsk. 68: 377-396 (1974).

Annual, biennial or short lived perennial herbs, glabrous or sparingly to densely hirsute with simpe hairs. Stems erect or decumbent, simple or branched. Leaves petiolate to sessile, oblong-oblanceolate, the margin irregulary serrate, incised, entire or pinnatisect, the apex acute. Racemes ebracteate. Flowers pedicellated. Sepals caducous, the inner ones saccate at base. Petals yellow, as long as or longer than sepals, clawed. Stamens 6; filaments free, linear, without appendages; anthers small, sagittate; style short; stigma capitate or 2-lobed. Fruiting pedicels ascending divergent or slightly to strongly recurved. Fruits oblong-ellipsoid, glabrous, dehiscent, straight or slightly curved upward; valves convex, without midrib or a week median vein. Seeds in two rows in each locule brown, ovoid; radicle accumbent.
About 90 species chiefly of the N. temperate zone, three species in Egypt.

Key to the species:
1a. Annual 8-21 cm, pubescent with simple hairs; leaves narrowly, linear-lanceolate, entire to slightly dentate-crenate…………………………………………………….……......**2. R. integrifolia**
1b. Annual or short-lived perennial, longer than above (15-50 cm), glabrous or slightly hairy; leaves oblong-lanceolate, pinnatisect……………………………………………………..…**2**
2a. Fruit 4-8 x 2-3 mm, straight to slightly curved………………..……..…...….**3. R. palustris**
2b. Fruit 1-1.9 x 0.2 cm, straight……………………..……………….……………..… **1. R. indica**

1. **Rorippa indica** (L.) Hiern, Cat. Afr. Pl.1: 26 Add. & Corr. (1896); L. H. Bailey, Rhodora 18: 155 (1916); Hochreutiner, Candollea 2: 370 (1925); Hedge in Fl. Iran, no.57/28.2: 217 (1968); Boulos, Fl. Egypt 1: 193 (1999).
Basionym: *Sisymbrium indicum* L., Mantissa 1: 93 (1767). Type: in India, herb. Linn.836/52 (holotype: LINN; isotype: L).

Homotypic synonyms: *Nasturtium indicum* (L.) DC., Syst. Nat.2: 199 (1821).

Clandestinaria indica (L.) Spach, Hist. Nat. Veg. Phan. 6: 429 (1838); El Hadidi & Fayed, Taeckholmia 15: 42 (1994-1995).

Heterotypic synonym: *Nasturtium niloticum* Boiss., Diagn. Pl. Orient., Ser.1, 8: 19 (1849). Type: upper Egypt, near river Nile, Kotschy, 324. (holotype: B).

Rorippa micrantha (Roth) Jonsell, Svensk Bot. Tidsk. Bd 68: 377-396 (1974).

Sisymbrium micranthum Roth, Nov. Plant. Spec.: 324 (1821). Type: India orientalis, B. Heyene, in herb. Roth (holotype: B).

Icon: Jafri, in Fl. of West Pakistan no.55: 190, t.26 (1973).

Annual or short-lived perennial, 15-50 cm, glabrous or rarely covered with sparsely simple hairs especially in young branches and leaves. Stems erect or a scending, branched, hollow, angular. Basal leaves 3.6-10.7 x 0.7-3.2 cm, petiole 1.5-4 cm, oblong to obovate, pinnatisect with sharply incised lobed leaflets; cauline leaves 2.5-9 x 1.1-2.5 cm, sessile to short petiole 0.3-0.5 cm, auriculate, lyrate to pinnatisect. Racemes ebracteate, many flowers, elongated. Flowers small, pedicels 1.5-2 mm. Sepals 1.5-2 mm, oblong. Petals 3-4 mm, yellow, narrow-spathulate. Filaments 2-2.5 mm, free; anthers 0.75 x 0.25 mm, linear; style short, thinner than fruit, 1-1.5 mm; stigma capitate to 2-lobed. Fruiting pedicels 2-3 mm, spreading or ascending. Fruits 1-1.9 x 0.2 cm, straight, glabrous, thick; valves glabrous, 1-nerved; septum membranous. Seeds in two rows in each locule, red-brown, ovoid, with slightly winged, 0.8-1 x 0.7-0.8 mm; radicle accumbent.

Fl. & fr.: March-May.

Habitat: weeds in cultivated lands.

Distribution: Pakistan, India, Himalaya, Indonesia, Iran, Egypt, Sudan, Ethiopia, Somalia, Uganda, Kenya, Tanzania, Rwanda, Zaire, Zambia, Congo, Angola, Mozambique, and Madagascar (Map 9).

SPECIMENS EXAMINED:

EGYPT: **Nv**: Qena, El Mahrosa island, M. Fawzy s.n., 9/1/1995 (SHG); Qena, Arment El-Dabeia, M. Fawzy s.n., 28/2/1995 (SHG); Luxor, sandy bank in Nile, G. H. Runkewiz s.n., 5/2/1939 (CAI); Luxor, G. Täckholm s.n., 24/1/1927 (CAI); Luxor, along Nile, L. Kralik 37/20 (WAG); Aswan, Nile bank, M. Abdallah s.n., 15/4/1959 (CAIM); banks of the Nile opposite Siheil, Kralik s.n., 16/2/1848 (LY); Aswan, Siheil island, G. Täckholm s.n., 17/1/1927 (CAI); Aswan, Nile bank, Gazeret el Nabatat, A. Khattab s.n., 28/3/1962 (CAI, CAIM); E Goled, Nile bank, Samir Ghabbour s.n., 18/3/1967 (CAI); Dongola, weed in fields, Samir Ghabbour s.n., 7/4/1967 (CAI).

ETHIOPIA: Kenya-Ethiopia boundary, Moyale, near wells in valley, B. Gillett 13565 (B).

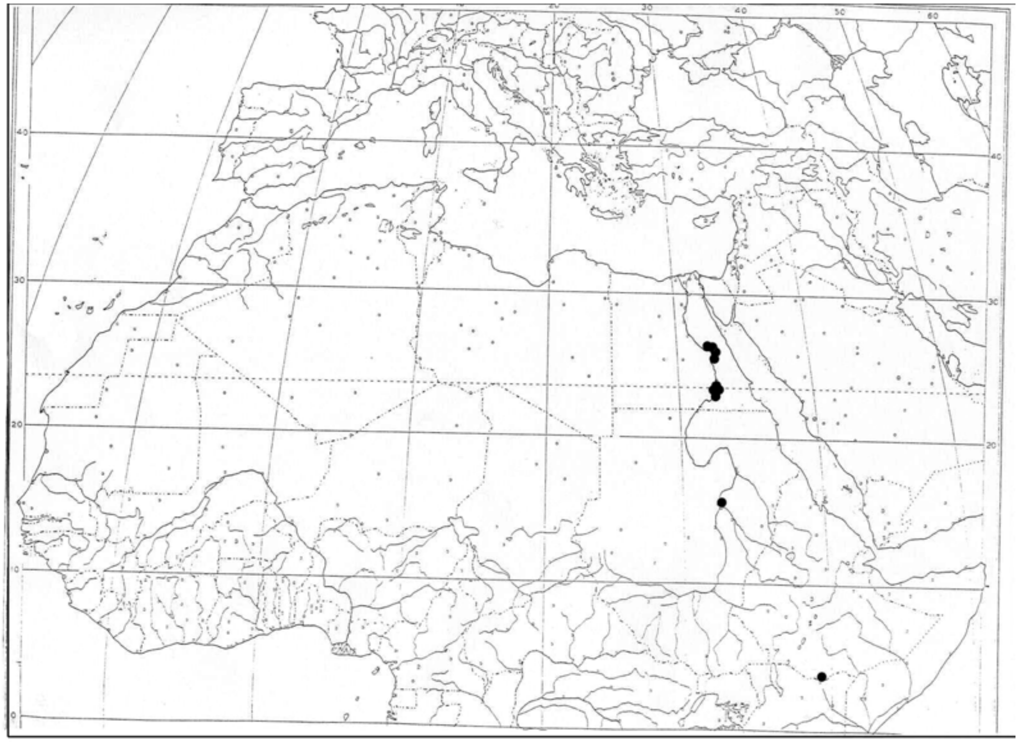
SUDAN: on the banks of the Blue Nile, near Khartum, Kotschy 324 (B).

TANZANIA: Mamba, near Chikulwe Ufipa, A. Bullock 3456 (B); Moshi District on sandy banks, Drummond & Hemsley 1314(B).

INDONESIA: Java, Jakarta (Batavia), Hb. Lugd. Batav. s.n., (L); Pasuruan, Jeswiet 600 (WAG).

PHILIPPINES: island of Mindanao, A. D. Elmer 10667 (LY).

TAIWAN: Tomita-Cho, Tainoku-Shi, T. Tanaka & Shimada 11117 (B).



Map 9: Distribution of *Rorippa indica*

2. Rorippa integrifolia Boulos, Candollea 19: 210 (1964); Täckholm, Stud. Fl. Egypt ed. 2: 177 (1974); El Hadidi & Fayed, Taeckholmia 15: 43 (1994-1995); Boulos, Fl. Egypt Checklist 40 (1995); Boulos, Fl. Egypt 1: 193 (1999).

Type: Wadi El-Arousiya, Gebel El-Maghara, North Sinai (CAI).

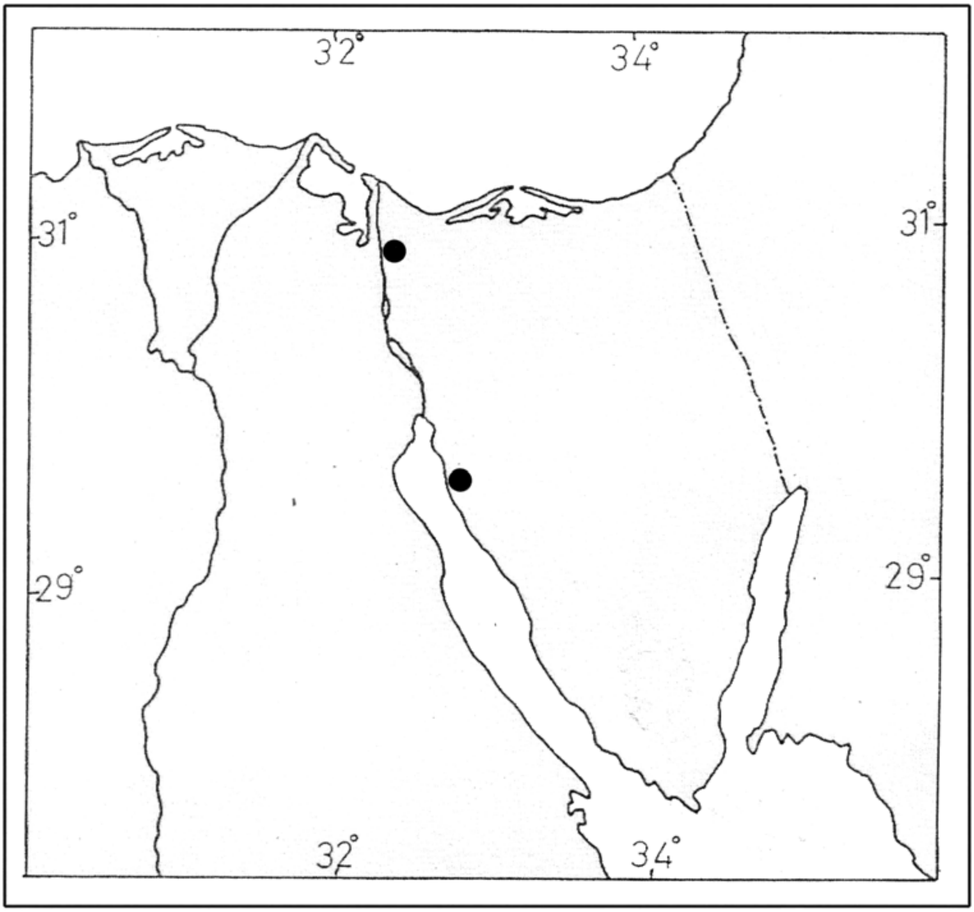
Icon: Boulos, Candollea 19: 212, Fig. 3 (1964).

Annual herbs 8-21 cm, pubescent with simple hairs. Stem erect, simple or branched, cylindrical, hollow. Leaves 0.5-1.7 x 0.2-0.3 cm, sessile, narrowly linear-lanceolate, the margin entire to dentate-crenate, the apex obtuse to acute. Raceme ebracteate. Flower pedicels 2-4 mm. Sepals pale green, 2 mm, oblong-lanceolate, hairy. Petals yellow 3-3.5 mm, obovate to orbicular, apex rounded to truncate. Filaments 1.5-2 mm; anthers sagittate, 0.75 mm long; style short, thick, 1 mm long; stigma capitate or slightly 2-lobed. Fruiting pedicels 4 mm, usually longar than fruit, hairy, spreading. Fruit dehiscent, 3 x 1.5 mm, linear, slightly curved, glabrous; valves convex, with a weak midrib; septum membranous. Seeds in two rows in each locule, orange-brown, ovoid to ellipsoid, compressed, 0.8-1 x 0.5-0.75 mm; radicle accumbent.

Fl. & fr.: March-April.

Habitat: sandy soil.
Distribution: Endemic to Egypt (Sinai) (Map 10).
SPECIMENS EXAMINED:

EGYPT: **M**: El Kantarah Lake, Sirbonis, El Arish, Laurent s.n., March-April 1903 (BR). **Di**: Sinai, about 5 km before Ras Sedr, K. Abdel Khalik 9 (SHG).

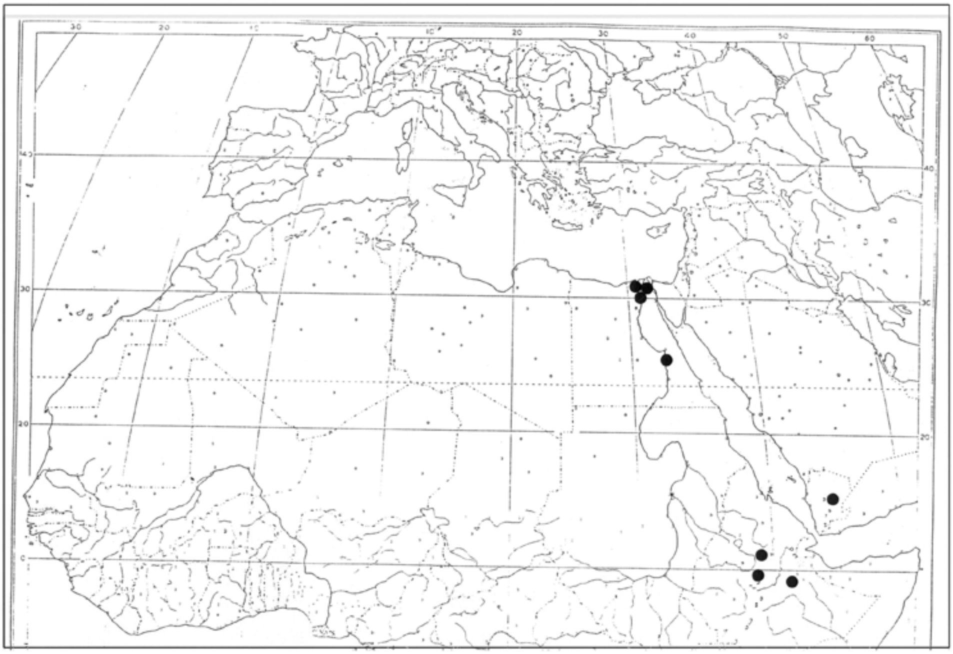


Map 10: Distribution of *Rorippa integrifolia*

3. **Rorippa palustris** (L.) Besser, Enum. Pl. Volhyn. 27 (1822) subsp. **palustris** Stuckey, R., Sida 4(4): 356 (1972); Tutin, T. G. et al. Fl. Eur. Ed. 1, Vol.1: 345 (1993); El Hadidi & Fayed, Taeckholmia 15: 43 (1994-1995)); Boulos, Fl. Egypt Checklist 40 (1995); Boulos, Fl. Egypt 1: 193 (1999).
Basionym: *Sisymbrium amphibium* L. var. *palustre* L., Sp. Pl. ed. 1: 657 (1753).

Type: in Europae Septentrionalioris aquosis, herb. Linn. 836/19 (holotype: LINN; isotype: L).
Homotypic synonyms: *Sisymbrium palustre* (L.) Leyser, F. Hal. Ed. 2, No.679: 166 (1783).
Nasturtium palustre (L.) DC., Syst. Nat.2: 191 (1821).
Rorippa islandica sensu Täckholm, Stud. Fl. Egypt ed. 2: 177 (1974).
Icon: Boulos, Fl. Egypt 1, 198, t 36, 1-2 (1999).
Annual or short-lived perennial, 20-40 cm, glabrous or with sparse simple hairs. Stem erect or ascending, simple or branched upward. Leaves petiolated to subsessile 2-3 cm, slightly auriculate and clasping or not, oblong to obovate 3-9 x 1-4 cm, glabrous or sparingly simple hairs, lyrate, pinnatisect to pinnatified, the lobes margin irregularly serrate, incised or repand, the apex narrowly to broadly acute or attenuate. Racemes terminal and axillary, the terminal one developing earliest. Flowers in richly branched racemes, pedicels 2-3 mm. Sepals 1.7-2.2 mm, caducous, ovate to oblong, flat to somewhat saccate. Petals 1.5-2.5 mm, yellow, oblong to spathulate. Filaments 1.5 mm long, free; anthers ovoid, 0.3 mm; style 0.5-1 mm long; stigma capitate. Fruiting pedicels 3-6 mm, ascending, divergent, slightly to strongly recurved, glabrous. Fruit 4-8 x 2-3 mm, oblong-ellipsoid, straight or slightly recurved upward; valves smooth, glabrous, not reaching the point down to the point of attachment; septum membranous. Seeds in two rows in each locule, cordiform to ovoid, 0.5-0.9 x 0.3-0.6 mm, brownish; radicle accumbent.
Fl. & fr.: April-June.
Habitat: canal banks and moist ground.
Distribution: Europe, Asia, America and Africa (Map 11).

SPECIMENS EXAMINED:
EGYPT: **Nv**: Sakha, N. D. Simbson, s.n., 16/9/1922 (CAI); Along the canal of Ismailiya, K. Abdel Khalik 20 (SHG); Gyza, J.R. Shabetai, s.n., 7/5/1936 (CAIM); Luxor, East of the Nile, J.R. Shabetai, s.n., 7/5/1936 (CAIM)
ETHIOPIA: Idli valley, about 43 km on the road Harrar to Jijiga on rather humid place in riverbed, W. de Wilde 4960 (WAG); Kombolcha, moist, rocky riverbed, W. de Wilde 9694 (WAG); About 30 km. NE of Addis Ababa, along Asmara road, W. de Wilde 10917 (WAG).
CHINA: Excursion to Hanka and Mandchouria, M. Hugo Bohnhof 34 (LY).
YEMEN: Anis, J. Wood 1944 (BM).
BELGIUM: Dendermonde, Dike of river Schelde near bridge over the river, E. Robbrecht 1541 (WAG).
NETHERLANDS: Renkum, Uiterwaarden near Van Gelder, R.J. Bijlsma 457.1 (WAG); river bank near Wageningen, C.H. Jongkind et al. 3835 (WAG); prov. Overijssel, N.W, De Weerribben, Spookgat, S. Segal s.n., 1965 (WAG); Amsterdam, near Stadionkade, P. Vermeulen s.n., 3/6/1951 (WAG).
SWEDEN: Upland, Uppsala, E. Fries 19 (LY).



Map 11: Distribution of *Rorippa palustris*

2. Tribe **Euclidieae** DC.

Syst. Nat.2: 149, 420 (1821)

Hairs simple, branched, glandular or absent. Sepals erect or spreading; inner ones often not saccate at base. Filaments entire, linear. Median honey glands present or absent. Stigma capitate or shortely bilobed or more rarely with the lobes divaricate. Fruit an indehiscent silicula, of a single fertile 1-4 seeded segment, firm. Radicle incumbent or accumbent.

4. **Anastatica** L.

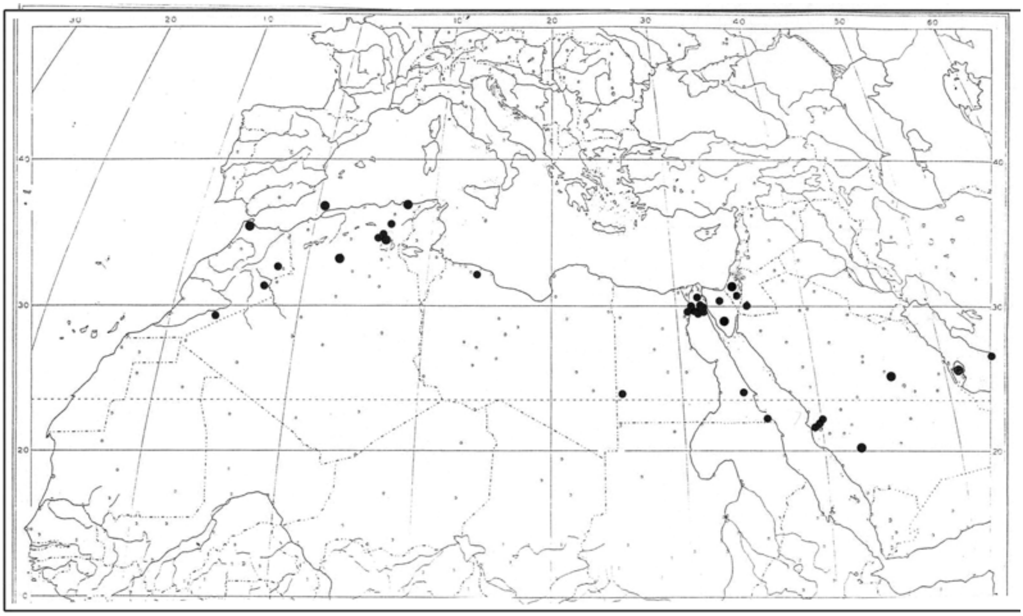
Sp. Pl. ed. 1: 641(1753); L., Gen. Pl. ed.5: 290 (1754); O.E. Schulz in Pflanzenfam. ed. 2, 17B: 467-468 (1936).

Small annual herbs, densely pubescent with stellate appressed and dendroid hairs. Stems dichotomously branched, procumbent or ascending. Leaves simple, spathulate, tapering to a petiole, obtuse or acute, entire to toothed. Inflorescences short, compact. Flowers axillary, small, rather sessile. Sepals erect, almost equal at the base, not saccate at the base. Petals spathulate, white. Stamens 6; filaments linear, free, with delated base; anthers sagittate. Lateral

nectar glands in pairs, each semi-lunar; middle glands absent. Ovary globose, bilocular with 1-2 ovules in each locule; style long, 2-lobed, persistent; stigma capitate. Fruiting pedicels more or less sessile. Fruit silicule, short, ovate with two cup-shaped appendages (wings) at the apex, dry, indehiscent but dehiscing when wet; septum thick; beak subulate, indurate. Seeds compressed, ovoid, brownish, up to 4; radicle accumbent.
A monotypic genus.

1. **Anastatica hierochuntica L.,** Sp. Pl., ed. 1: 641(1753); Boiss., Fl. Orient.1: 316 (1867); Muschler, Manual Fl. Egypt 1; 404 (1912); Täckholm, Stud. Fl. Egypt ed. 1: 346 (1956); Ozenda, Fl. Sahara Septen. Cent.217 (1958); Maire, Fl. Afr. Nord,13: 193 (1967); Zohary, Fl. Pal.1: 276 (1966); Hedge in Fl. Iran 57/28.2: 123 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 183 (1974); Jafri, in Fl. Libya 23: 119 (1977); Hedge & Lamond, in Fl. Iraq, vol.4, 2: 933 (1980); Friedman, J. & Z. Stein, Israel, Journal of Ecology 68: 43-50 (1980); Collenette, Illust. Flow. Pl. Saudi Arabia 192 (1985); El Hadidi & Fayed, Taeckholmia 15: 45 (1994-1995); Boulos, Fl. Egypt Checklist 42 (1995); Boulos, Fl. Egypt 1: 203 (1999).
Type: Along the Red Sea; Cairo; sandy areas of Palestine, herb. Linn. 821.1 (holotype: LINN; isootype: L).
Icon: Jafri, Fl. Libya 23, 118, t.36 F-K (1977).
Annual herb, 3-13 cm tall, decumbent, densely pubescent with stellate and dendroid hairs. Stem dichotomously branched, becoming hard and woody in fruits, often rolled inwards under dry conditions. Leaves 0.6-2.5 x 0.3-1.1 cm, spathulate, obtuse or acute, entire to toothed toward the apex, the lower ones petiolated 0.3-2.2 cm, upper ones subsessile to sessile, most of them are falling after flowering. Flowers axillary, small, more or less sessile. Sepals 1.5-2 mm, erect, not saccate at the base. Petals 2.5-3 mm, white, spathulate. Filaments 1.5-2 mm, linear, free; anthers 0.5-0.75 mm, sagittate; style 3-4 mm persistent and forming abeak; stigma capitate. Fruiting pedicels more or less sessile. Fruit 4-6 x 3-4 mm, silicule, indehiscent, ovoid, two locules, 1-2 seeds in each locule; septum thick; lateral fruit appendages at the apex (wings). Seeds 1-1.9 x 1-1.7 mm, compressed, ovoid, wingless, brownish; radicle accumbent.
Fl. & fr.: March-May.
Habitat: Sandy runoff in rocky deserts.
Vernacular names: Keff-Mariam; Kaff-Fathma-bint Ennebi (Arabic); Rose of Jericho (English).
Uses: Ibn al-Bitar (c.1240), mentioned that women use it in pessaries to stimulate conception. Dickson collected this plant from Kuwait and Arabia, and she was told that the plant is surrounded by ancient folk legends and much used as a charm by women at childbirth, the seeds are used in a superstitious way by women in labour (Forskal).

Distribution: Saudi Arabia, Jordan, Israel, Palestine, Syria, Iraq, Iran, Pakistan, Kuwait, Arab Emirates, North Africa (Egypt to Morocco) and Mauretania (Map 12).



Map 12: Distribution of *Anastatica hierochuntica*

SPECIMENS EXAMINED:

ALGERIA: Department of Constantine, Environs of Biskra, in calcarious soil, B. Balansa 46, 597 (LY, OXF & FHO); Biskra, in calcium-rich clay soils, B. Balansa 884 (BM, WAG); Mostaganem and Biskra, B. Balansa s.n., 1/4/1883 (LY); Biskra, in dry clay soil, L. Chevallier 12 (WAG); Biskra, Doumergue 21 (LY); Biskra, A. Jordan s.n., 4/3/1877 (LY); near Metlili, in Mizab, L. Kralik 7 (LY, OXF & FHO); Between Hassi bel Gabourb and Anguid, M. Meyer s.n., April, 1981 (B); prov. Constantine, V. Reboud 299 (LY); Biskra, in hillside, Ch. Schmitt 107 (LY).

EGYPT: **Nv**: near Cairo, A. Keller 153 (BM); near Cairo, Kotschy 6720 (BM); near Cairo, A. Wiest 547 (BM, OXF & FHO); Cairo-Alexandria desert road, a few km N of Giza pyramids, Dorothy Hillcoat 14 (BM). **Di**: a branch of Wadi El-Mizeririe, near Gebel El-Maghara, N. Sinai, L. Boulos s.n., 25/4/1959 (CAI); in the desert road N of Wadi Tumilat, on the road to Ismailiya, Täckholm et al. s.n., 15/4/1960 (CAI); Wadi Hagoul, 86 km of Cairo-Suez road, M. Hassan s.n., 5/2/1982 (CAI); Cairo-Suez road, km 95 from Cairo, Täckholm et al. s.n., 13/5/1960 (CAI); Suez road 116 km from Cairo, Täckholm et al. s.n., 17/6/1960 (CAI); Suez road kilo 35, Luckman Lawand s.n., 12/10/1956 (CAI); Upper plateau of Wadi Liblab, El Hadidi s.n., 13/11/1952 (CAI). **Dg**: Wadi Abar near Suez, El Hadidi s.n., 15/2/1956 (CAI); affluent of wadis, Wadi Wirag, M. Hassan s.n., 23/3/1982 (CAI); Wadi Abar, G. Ataqa, Suez, Imam and Abdel Fadeel s.n., 15/2/1956 (CAI); Suez between Aboud's factory and G. Ataqa, Mohamed Naguib s.n., 8/3/1954 (CAI); Wadi Hof, William Abdallah Girgis s.n., 27/4/1962 (CAI); Wadi Hof, M. T. Hefnawy s.n., 14/4/1930 (CAI); beside Wadi Hof station near Helwan, Ibrahim s.n., 3/6/1963 (CAI); on the mountain slope between Wadi Hof and Wadi Hammat, Botany Department excursion s.n., 16/4/1954 (CAI); El Maadi-Katamiya, Kilo 15, M. Hassan s.n., 30/3/1982 (CAI); Mountain near Wadi el-Rokhama, between Maadi and Suez, G. Täckholm s.n., 15/4/1926 (CAI).

R: Gebel Hamata, Red Sea district, Täckholm et al. s.n., 7/2/1961 (CAI). **Dn**: Gilf Kebir, Wadi Abdel-Malik, J. Léonard 5072 (BR). **S**: S. Sinai, near Deba'at el-Ker'ai, Danin s.n., 31/5/1969 (HUJ). **Sa**: Gebel Elba district, Täckholm et al. s.n., 13/11/1962 (CAI).
LIBYA: Km 42 between Zelten and Waha Sable, J. Léonard 4671 (BR).
MOROCCO: Agdz, J. Lewalle 9300 (BR); Erfoud, J. Lewalle 11373 (BR); Prov. Tata, Akka, J. Lewalle 13779 (BR); Taldes Ouedziz, Rissani, Hamada, Oberprieler & Voget s.n., (B).
ARAB EMIRATES: Hafit area, El-Ghonemy 79/500 (NMGM).
IRAN: in sands of Island Kischm, Bornmüller 60 (OXF & FHO).
ISRAEL: North Negev, Tureiba, H. Bushary 303417 & 303418 (HUJ); S. Negev, near Kibbutz Shizafon, Wadis in gravel plain, A. Danin et al. 29.001 (B).
JORDAN: Wadi Araba, 50 km S of Ghor Safi, 20 km of the main road to Aqaba, Dawud Al-Eisawi 2434 (B).
PAKISTAN: Makran, between Gwadar and Suntsar, H. Rechinger 32995 (B).
SAUDI ARABIA: Al-Baha, Al-Farhan 285 (KSU); Al Kharrarah, the area 5 km away towards the Northeast, Boulos 11077 (B); E Djedda, Kruijt 312a/58 (L); Near Djedda, W. Schimper 819 (BM, L, OXF & FHO); Wadi Hammah, W. Schimper 207 (B, L, OXF & FHO); Raudat Al-Khram, Thomas 1344 A (KSU).

5. **Neslia** Desv.

J. Bot. Appl.3: 162 (1814)

Annual herbs, densely pubescent with branched hairs. Stems erect, branched above. Lower leaves petiolate, oblong-lanceolate to linear, entire to dentate; upper leaves sessile, sagittate, dentate, acute. Racemes ebracteate, elongated in fruit. Flowers small, pedicellate. Sepals erect, not saccate at the base. Petals yellow, longar than sepals, spathulate. Stamens 6; filaments linear; anthers short, ovoid. Ovary two locules, 4-ovuled; style as long as ovary; stigma short, capitate. Fruiting pedicels filiform, spreading to ascending, elongated in fruit. Fruit silicule subglobose, bi-locular, indehiscent, 1 seed per locule, reticulately wrinkled, falling when ripe; septum rigid-membranous. Seeds suborbicular, brown; radicle incumbent.
Monotypic genus, two varietes in Europe, the mediterranean region and S W to E temperate Asia.

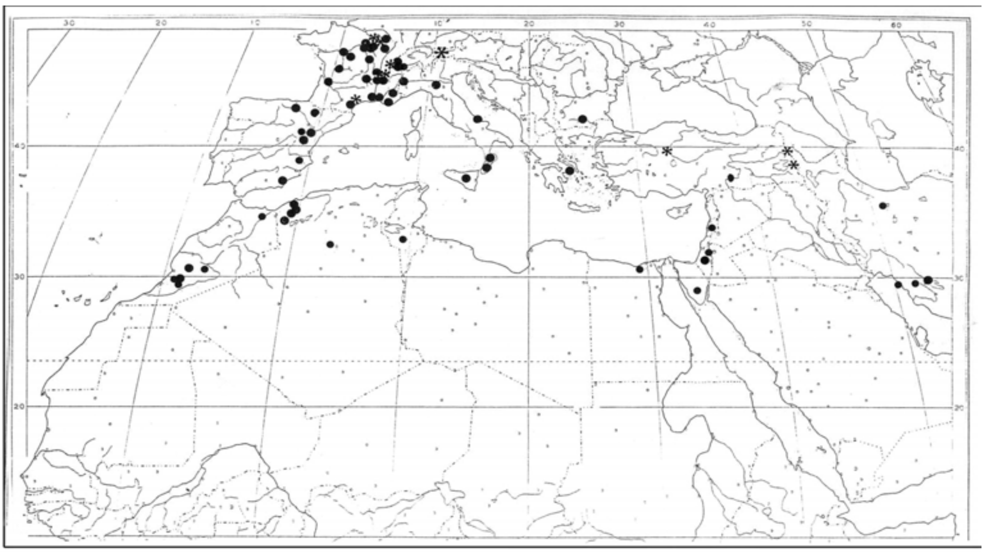
1. Neslia paniculata (L.) Desv. In J. Bot. App.3: 162 (1814)
Basionym: *Myagrum paniculatum* L., Sp. Pl.1: 641 (1753).
Type: Described from Europe, herb. Linn. 819/10 (holotype: LINN).
Homotypic synonym: *Neslia paniculata* (L.) Desv. subsp. *thracica* (Velen) Bornm., Oesterr. Bot. Zeitschr.44: 125 (1894); Täckholm, Stud. Fl. Egypt ed. 2: 205 (1974).
Icon: Jafri, Fl. Libya 23, 121, t.37 A-F (1977).
Annual herbs, 9-35 cm long, densely pubescent with spreading-branched hairs. Stem erect, branched above more or less roughly hairy. Basal leaves 1.2-3.5 x 0.3-0.7 cm, hirsute, oblong-lanceolate, sagittate, entire to dentate, acute, narrowed into a stalk 0.4-2 cm; upper leaves 0.7-5 x 0.2-1.2 cm, sessile, lanceolate to linear, sagittate-auriculate, dentate, acute. Racemes

corymbose-paniculate, elongating in fruit. Flowers small, pedicellate. Sepals 1.5-2 mm long, erect, hairy in outside, not saccate at the base. Petals 2-2.8 mm, yellow, spathulate, differentiated into a distinct claw and blade, rounded at the apex. Filaments 1.5-2 mm, linear; anthers short, ovoid. Ovary 1 x 1 mm, ovoid; style 1 mm long, as long as ovary; stigma short, capitate. Fruiting pedicels 3-9 mm long, spreading or ascending, filiform. Fruit silicule, two locules, subglobose, 2-4 x 1.7-3 mm, with or without umbo(boss), glabrous; valves reticulate, distinctly 1-veined. Seeds one per locule, 1.5 x 1.3 mm, brown, ovoid to suborbicular; radicle incumbent.

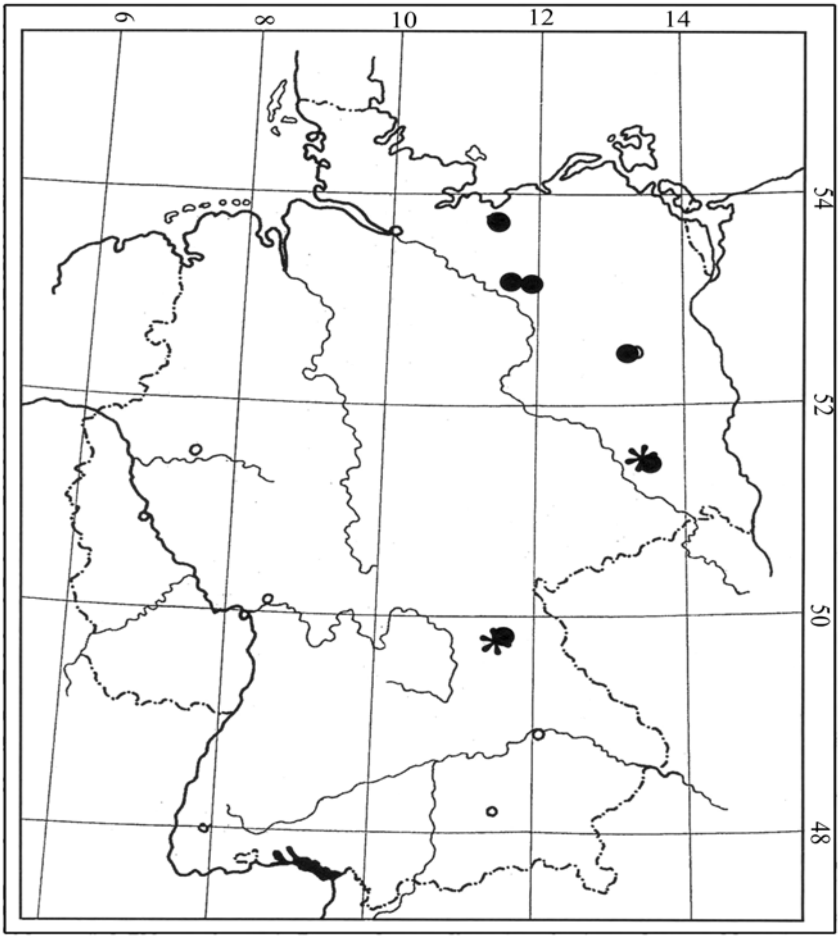
Fl. & fr.: March-May.

Habitat: Usually a weed in cultivated areas of the Mediterranean area and Sinai.

Distribution: Europe, N. Africa (Egypt to Morocco), S W and C Asia, Cyprus, Syria, Lebanon, Palestine, Israel, Turkey, Iran and Pakistan (Map 13, 14).



Map 13: Distribution of *Neslia paniculata* var. *apiculata* •
and var. *paniculata* *



Map 14: Distribution of *Neslia paniculata var. apiculata* * and var. *paniculata* • in Germany

Two vareities are recognized.

1. **Neslia paniculata** (L.) Desv. In J. Bot. App.3: 162 (1814) var. **apiculata** (Fisch., Meyer and Ave-Lall.) Abdel Khalik stat. nov.

Basionym: *Neslia apiculata* Fisch., Mey. & Ave-Lall., Ind. Sem.Hort. Petrop. 8: 68 (1842). Type: E. Caucasus (not seen).

Homotypic synonym: *Neslia paniculata* (L.) Desv. In J. Bot. App. 3: 162 (1814) subsp. *apiculata* (Fisch., Meyer and Ave-Lall.) Maire & Willer in Maire, Fl. Afr. Nord 13: 201 (1967).

Heterotypic synonym: *Neslia paniculata* (L.) Desv. subsp. *thracica* (Velen) Bornm., Oesterr. Bot. Zeitschr. 44: 125 (1894); Täckholm, Stud. Fl. Egypt ed. 2: 205 (1974).

Neslia thracica Velen., Österr. Bot. Zeitschr. 41: 122 (1891).

Fruits with umbo (boss) after the style has been shed.

SPECIMENS EXAMINED:

ALGERIA: Oran, Gambelta, Doumergme 153 (LY); el Aricha to Mekoïdom, Doumergme s.n., 18/5/1894 (LY); Laghouat, in fields, Chevallier 152 (WAG); Ain-el Hadjar, Doumergme s.n., 3/1893 (LY); Tenira, near Sidi Bel Abbes, A. Faure s.n., 11/4/1931 (B).

EGYPT: **M**: Maruit, B. G. Bolland 2/3/1913 (CAIM). **S**: Sinai mountains, H. C. Hart 1883 (BM); Sinai mountains, W. Schimper 158 (BM, K).

MOROCCO: Tazeroualt: Fghirmillul, Gebel Tafraoute and Kerkar, E. Cosson s.n., 1876 (LY); Cifermit and Ida Oubakil, E. Cosson s.n., 1867 (LY); near Titeki between Tafraoute and Irherm, 1500 m dry limestone river bed in valley, P. Davis 48823 (BM); Surroundings between Hotel Alpina, Idnr, bare field, J. Dorgelo et al. 5219 (WAG); Forest El Jaba, between Al-Hajeb and Ifrane, 18 km NW Ifrane, J. Dorgelo et al. 2564 (WAG); Taza, 27 km from Taza, along minor road to Bab-Bou-Idir, Gavin Stark 1095 (NMGM).

TUNISIA: Matmata, in fields, C.J. Pitard 39 (NMGM, WAG).

AFGHANISTAN: without location, Volk 81 (B).

ISRAEL: Jerusalem, Mt. Scopus, Amdursky 130 (WAG); Dead sea Valley, a depression between Hamey Yesha and mouth of Nahal Hever, Danin 33899 (HUJ).

IRAN: Karaj, D. Gauha 245 (B); Khark island, N Iran, Kotschy 6 (WAG); near village Gere between Abushir and Shiraz, Kotschy 64 (LY, WAG).

LEBANON: Harissa, Polunin 5289 (B).

TURKMENISTAN: 35 km SW of Ashkhabad, central Kopet-Dagh mountains, V. Hihitun & Ivanov 3014 (WAG).

BULGARIA: in campis near Sadovo, V. Stribrny s.n., 30/7/1896 (B); in wheat near village Cepelure, S. Bulgaria, A. Jordan 12 (LY); in fields near Sadovo, V. Střibrny s.n., 23/6/1896 (LY).

FRANCE: Arrondissement Gien (Loire), Buisson 353 (LY); Vacherauville, Meuse area, NE France, Bullemont 2402 (LY); Seillans (Var), M. Buysman 1068 (LY); Beaurieux, in fields, Camaqmier s.n., 7/1906 (LY); cultivated fields, at Aveyrom, Milhars, H. Coste s.n., 21/5/1897 (LY); Vemdeuve, near Vienne, B. de Contes s.n., 18/5/1872 (LY); Ruelle near Angoulême, L. Duffort 450 (LY); high Alpes, near Amdré, Flavien Brachet s.n., 17/5/1894 (LY); Chinon, Foucauld s.n., 6/1880 (LY); Aulnay, Foucauld s.n., 7/1884 (LY); Alpes, Gaps, near St. Meuse, A. Faure s.n., 24/5/1896 (LY); Limagne fields between crops, Frere Gastide s.n., 7/1881 (LY); Satmrnim, Héribamg s.n., 27/7/1900 (LY); Hourdimes near Poitiers (Vienne), E. Jousset s.n., 17/6/1873 (LY); Lyon, on the city, A. Jordan 187 (LY); area of Batna (Coust), Leframc s.n., 1858 (LY); without location, Lesdain s.n., 8/1895 (LY); Beanvieux, in fields, Magnier s.n., 18/7/1906 (LY); Blois (Loire), L. Mashommet s.n., 1861 (LY); Plaime between Sailles and Bougontet, E. Mussat s.n., 31/5/1851 (LY); Mamteam near Malesherbes (Loire), G. Rouy 957 (LY); Seine and Oise, fields in Marcomsais, G. Rouy s.n., 30/7/1882 (LY); Hautes-Alpes, Siguret near Embrun, G. Rouy s.n., 3/7/1885 (LY); Herault region, Yvignac, B. Semnem s.n., 17/5/1894 (LY); Pont-a-Mousson (Meurthe), Sall. s.n., (WAG); Aude, Sigean, in fields, Sennen s.n., 19/5/1903 (LY); near Montpellier, Caumelle, E. Vitou s.n., 20/4/1899 (LY).

GERMANY: prov. Sachsen, Cőnnern, A. Matthies s.n., 30/6/1901 (LY); Bavaria, Mittel Franken, near Pommelsbrunn, Jos. Meister 1006 (LY).

GREECE: in wheat field near Athens, de Heldreich 64 (LY); Athens, in fields, Chr. Leonis 453 (LY).

ITALY: Caltanissetta, Giovanni 356 (LY); Apulia, S side of mt. Gargano, SE San Giovanni Rotando, P. Hiepko 24 (B); prov. Calabria, near San Vito, Reggio Calabria, A. Jordan 395 and 595 (LY); on calcareous soil, Pisa, Pisani s.n., 5/1846 (LY).

SPAIN: Aragon, Fiscal, Bonley s.n., 6/1876 (LY); Champs ā Tobara, E. Bourgeau 557 (WAG); Pyrenees mts, Camprodon, in the fields, E. Bourgeau 675 (WAG); prov. Fresneda, Don Fadrique village, in fields, E. Reverchon 1173 (LY); prov. Castilia, in fields of Amézaga, Sennen and Elias s.n., 9/6/1906 (LY); fields near Palma, Sennen s.n., 15/5/1913 (LY); Campomedes in Aragon, F. Tremols s.n., 6/1887 (LY).

SWITZERLAND: Vallais, Hills of Champlan above Sion, in fields, L. Marret 330 (LY).
TURKEY: Prov. Maras, Fazarcik, between Narli and Karabiyikli, Davis and Hedge 27847 (B); Charnoy, near Givet, minutes from French border, Arm. Thielens s.n., 20/5/1866 (LY).
TURKMENISTAN: in cultivated fields near Ax-Tepe, D. Litwinow 604 (LY).

2. N. paniculata (L.) Desv. in J. Bot. App. 3: 162 (1814) var. **paniculata**
Basionym: *Myagrum paniculatum* L., Sp. Pl.1: 641 (1753). Type: Described from Europe, herb. Linn. 819/10 (holotype: LINN).
Homotypic synonyms: *Neslia paniculata* (L.) Desv. In J. Bot. App.3: 162 (1814) subsp. *paniculata* (Fisch., Meyer and Ave-Lall.) Maire & Willer in Maire, Fl. Afr. Nord 13: 201 (1967).
Closely allied to *Neslia paniculata* (L.) Desv. var. *apiculata.* The main difference between the two varieties is that in var. *paniculata* the fruit has no boss (umbo) after the style has been shed. This single difference let many authors separate this genus into two species. The geographical distribution is not distinct for the two taxa, and after investigating the available specimens, I disagree with them because one can find both varieties in the same area. The only difference between varieties is the boss or umbo of the fruit.

SPECIMENS EXAMINED:
CANADA: British Columbia, H. Shaw 178 (LY).
U S A: Howser lake, Selkirk, H. Shaw 723 (LY).
MOROCCO: Surroundings Hotel Alpina, Idnr, bare field, J. Dorgelo et al. 5219 (WAG).
TURKEY: Elbis, D. Gauba 1777 (B); Prov. Van, Bendimahi, in wheat field, Raus 4715 (B); Prov. Ankara, E. Walter 1307 (B).
AUSTRIA: Styria, in wheat near Judenburg village, K. Pilhatsch 747(LY).
BULGARIA: in wheat field near Cepelure village, S. Bulgaria, A. Jordan 12 (LY).
FRANCE: Pontaller (Doubs), Billot 273 (LY); Lyon, in the city, A. Jordan 187 (LY); Hanka Lahe, Mandchouria, Hugo Bohnhof 5, (LY); without location, Lesdain s.n., 8/1895 (LY); Seine and Oise, fields in Marcomsais, G. Rouy s.n., 30/7/1882 (LY); Aude, Sigean, in fields, Sennen s.n., 19/5/1903 (LY).
GERMANY: Schmargendorf, Beŕlin, G. Bolle s.n., 4/1850 (LY); prov. Sachsen, Cőnnern, A. Matthies s.n., 30/6/1901 (LY); Bavaria, Mittel Franken, near Pommelsbrunn, Jos. Meister 1006 (LY); Mecklenburg, fields near Krapelim, A. Toepffer 5737 (LY); near Werben, A. Toepffer 6368 (LY); Schwerin, fields near Godeon, A. Toepffer 7064 (LY).
SWITZERLAND: Holstein, near Saffking, Dbarton s.n., 6/1879 (LY).

6. Ochthodium DC.

Syst. Nat. II: 423 (1821)

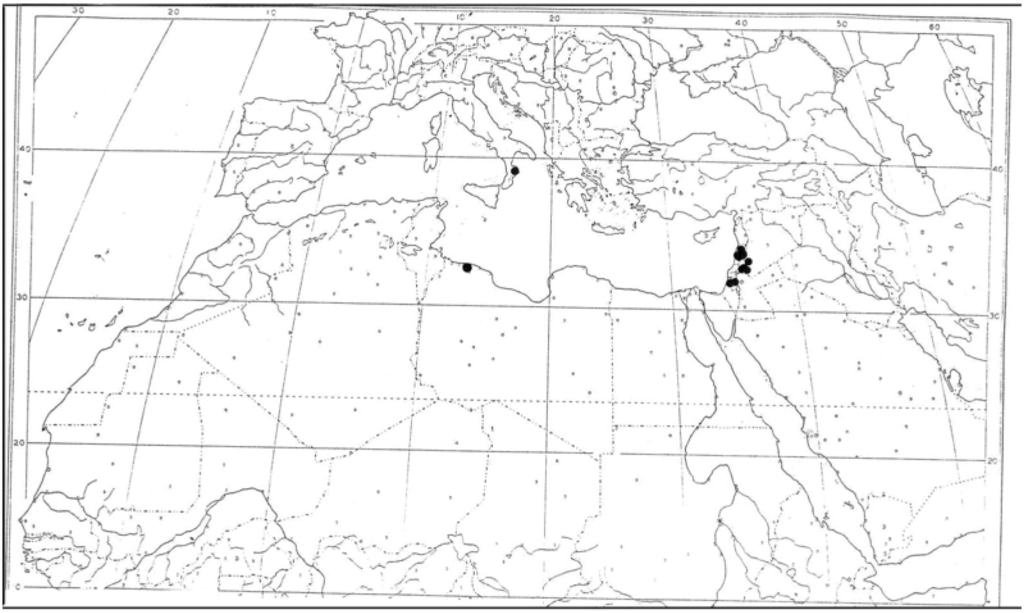
Annual herb, covered with sparsely simple and glandular hairs. Stem branched, erect or ascending. Lower leaves petiolated, oblong-lanceolate, lyrate or pinnatipartite, apex acute, margin dentate or crenate; upper leaves sessile or short-petioled, lanceolate to oblong-

lanceolate, undivided, dentate or crenate, rarely lyrate with few lateral lobes and a hastate terminal lobe. Inflorescences paniculate, elongating in fruit. Flowers small. Sepals spreading, more or less equal at base. Petals yellow, short-clawed, obovate to oblong-spathulate. Stamens 6; filaments free, edentate; anthers small, sagittate. Ovary 2-ovulate in two carpels; style short, pyramidal; stigma 2-lobed. Fruiting pedicels thick, stiff, erect or spreading. Fruit silicule, indehiscent, irregular ovoid, densely tuberculate, two locules with one seed each; valves silicle; septum thick. Seeds ovoid-oblong, brown; radicle incumbent.
Monotypic genus in the E. Mediterranean.

1. **Ochthodium aegyptiacum** (L.) DC., Syst. Nat.2: 423 (1821); Boiss., Fl. Orient.1: 369 (1867); Täckholm, Stud. Fl. Egypt, ed. 1: 343 (1956); Hedge in Fl. Turkey, vol.1: 347 (1965); Zohary, Fl. Pal.1: 257 (1966); Täckholm, Stud. Fl. Egypt, ed. 2: 178 (1974); El Hadidi & Fayed, Taeckholmia 15: 43 (1994-1995); Boulos, Fl. Egypt Checklist 40 (1995); Boulos, Fl. Egypt 1: 195 (1999).
Basionym: *Bunis aegyptiaca* L., Syst. Nat. ed. 12, 3: 231 (1768).
Type: In Egypt, herb. Linn. 847/11& 12 (holotype: LINN; isotype: L).
Icon: Zohary, Fl. Palestine 1, t. 374 (1966).
Annual herbs, 43-78cm, covered with sparsely simple and glandular hairs. Stem branched, erect or ascending with spreading branches. Lower leaves 2.5-7.5 x 0.7-5 cm, oblong-lanceolate, lyrate or pinnatipartite, petiolated 1-2 cm; upper leaves 1-5 x 0.2-3 cm, lanceolate or oblong-lanceolate, undivided, dentate or crenate, rarely lyrate, with few lateral lobes and a hastate terminal lobe, sessile or short petiolated up to 1.7 cm long. Flowering racemes dense, paniculate. Flowers small. Sepals 1.5-2 mm long, spreading, lanceolate. Petals 2-3 mm long, yellow, oblong-spathulate. Filaments free, 1.5-2 mm long; anthers small, oblong- sagittate, 0.5 x 0.3 mm. Ovary ovoid, 2-locules, 1 ovule in each locule; style short, pyramidal; stigma 2-lobed. Fruiting pedicels 3-8 mm long, thick, stiff, erect or spreading. Silicules 3-4 x 2-3.5 mm, indehiscent, irregular ovoid, densely tuberculate, 2 celled each cell containing one seed; septum thick. Seeds ovoid-oblong, brown, 2.5-3 x 1.5-1.7 mm; radicle incumbent.
Fl. & fr.: February-May.
Habitat: waste places and sandy area.
Distribution: W. Syria, Palestine, Israel, Lebanon, Turkey, Italy and Egypt (Map 15).

SPECIMENS EXAMINED:

EGYPT: without location, Schultes s.n., (L, No.901.255-487); without location, Hb. Brescort (OXF & FHO); without location, Hb. Boissier s.n., (L).
LIBYA: Tripoli, Gandoger s.n., 25/4/1903 (LY).



Map 15: Distribution of *Ochthodium aegyptiacum*

INDONESIA: Nongkodjadjar, Mt. Tengger, M. Buysman 29113 (LY).
ISRAEL: in Galilee, T. Lowne s.n., April, 1863 (OXF & FHO); Kiryath Amavrim near Jerusalem, G. Samuelsson 698 (B)
LEBANON: Khalil kuchtuck, E. of Sidon, Gaillardot 15349, 734 (B, BM, BR, LY, OXF & FHO); in garden of Sidon town, Gaillardot s.n., (W); near Sidon, Gaillardot 1553a (W); Beirut, E. Peyrou 392 (L).
PALESTINE: Jerusalem: Mt, Scopus, Amdursky 129 (BM, BR, HUJ, L, WAG); Ain Hesban, J. E. Dinsmore 582 (L); Jerusalem, J. E. Dinsmore 8582 (L); in cultivated lands, H. Petry s.n., 12/4/1906 (LY).
SYRIA: Golan, near the ancient Synagogue of Qazrin, A. Danin et al. 44. 015 (B). ITALY: in the roadside of Guzel-Dere, near Messina (Sicily), Chaude area, B. Balansa 419 (BR, OXF & FHO, WAG).

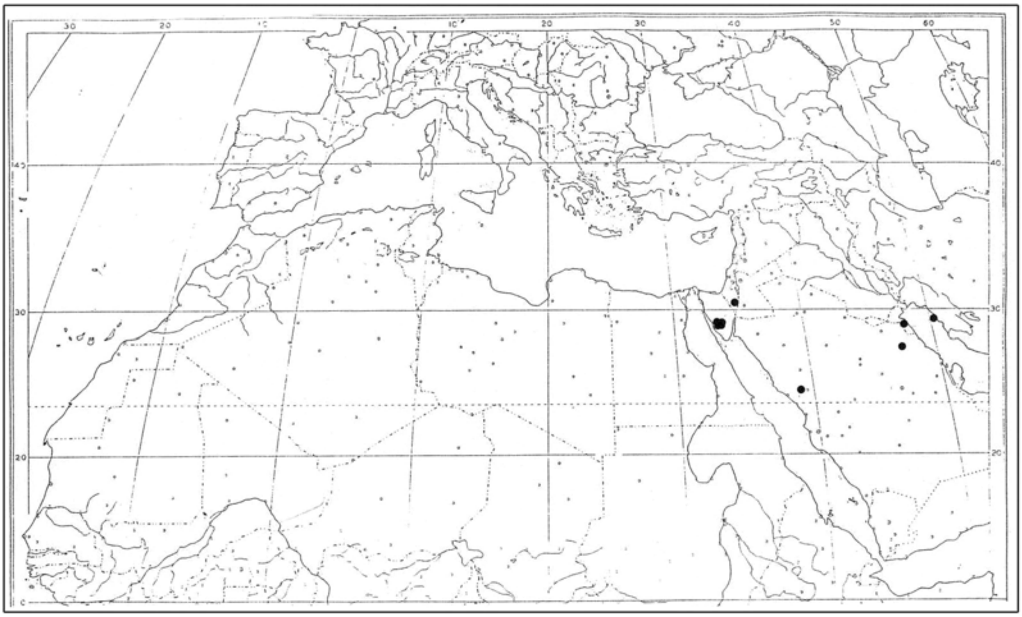
7. **Schimpera** Hochst. & Steud.

In Schimp., Pl. Arab. Exsicc. No.244 (1836); O.E. Schulz in Pflanzenfam. ed. 2, 17B: 474-475 (1936).

Annual herb, glabrous or a sparse indumentum of simple hairs. Stems decumbent or ascending, branched, yellowish-green. Leaves simple, runcinate-dentate or pinnatifid, obtuse or acute. Inflorescences dense, ebracteate, elongated in fruit. Flowers small. Sepals not saccate at the base, spreading, almost equal at base. Petals yellow, minute, slightly emarginate, sometimes longer than sepals. Stamens 6; filaments, free, narrow; anthers sagittate, obtuse. Stigma 2-lobed. Fruiting pedicels thickened, short. Fruits hard, indehiscent, silicule, ovoid,

tuberculate, appressed to the stem with a horizontal beak. Seeds compressed, brown; radicle incumbent.
Monotypic genus.

1. Schimpera arabica Hochst. & Steud. Ex. Endl., Pl. Arab. Exsicc. No. 244 (1836); Webb, Fl. Aeth. Aeg. 20 (1854); Boiss., Fl. Orient.1: 384 (1867); Muschler, R. Manual Fl. Egypt 430 (1912); Täckholm, Stud. Fl. Egypt ed. 1: 343 (1956); Zohary, Fl. Pal.1: 261 (1966); Hedge, in Fl. Iran, No.57/28.2: 126 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 178 (1974); Hedge & Lamond in Fl. Iraq, 4, 2: 936 (1980); Collenette, Illust. Flow. Pl. Saudi Arabia 206 (1985); El Hadidi & Fayed, Taeckholmia 15: 43 (1994-1995); Boulos, Fl. Egypt Checklist 40 (1995); Boulos, Fl. Egypt 1: 196 (1999).
Type: Arabia Petraea, Schimper 244. (holotype: OXF & FHO; isotype: L, W).
Heterotypic synonyms: *Schimpera persica* Boiss., Diagn. Ser., 1, 6: 18 (1845); Fl. Orient.1: 384 (1867).
Type: in Insula Karak Sinus Persici, Kotschy no.7 fl (isotype: NMGM, OXF & FHO, W); near Dalechi Persiae australis near to Fontes Petrolei No.1009 fr. (holotype: BM; isotype: L, WAG).
Icon: Täckholm, Stud. Fl. Egypt ed. 2, 179, t. 52A (1974).
Annual herb, 2-23 cm tall, sparsely pubescent with simple hairs. Stems branched in upper part or from base, erect or decumbent, becoming hollow, straw-like. Basal leaves 0.8-10.5 x 0.2-1.6 cm, numerous, rosulate, oblong-lanceolate, entire or dentate or runcinate, with 3-10 broadly triangular, acute or obtuse, dentate-crenate or entire lateral lobes, petiole 0.3-3 cm; cauline leaves sessile, 1-3 x 0.3-0.7 cm, oblong-lanceolate, sagittate-auriculate at base, entire or dentate. Inflorescences dense, ebracteate, elongated in fruit. Flowers small. Sepals 1-1.6 mm long, ovate, entire, obtuse. Petals 1.5-2.1 mm long, yellow, obovate, tapering into a short claw, slightly emarginate. Filaments 1-1.5 mm long, free, linear, broad at base; anthers 0.5-0.7 x 0.2-0.4 mm, sagittate. Stigma 2-lobed. Fruiting pedicels 2-4 mm long, rigid, thick, erect, appressed to stem. Fruit 5-8 mm (beak included), silicule, glabrous or papillose, lower part erect or spreading, strongly tuberculate; beak 3-5 mm, about two times as long as fruit proper, rigid, usually compressed, horizontal. Seeds 1.2-2.7 x 0.5-1.2 mm, compressed, oblong, brown; radicle incumbent.
Fl. & fr.: March-May.
Habitat: Sandy wadis and plains.
Vernacular names: Suffair (Iraq); Omm roos (Sinai); Sufra (Arabia, Kuwait).
Uses: eaten by camels, goats, sheep, etc.
Distribution: Middle East (Syria, Palestine, Jordan, Saudi Arabia, Kuwait, S. Iran, Iraq, Israel and Egypt) (Map 16).



Map 16: Distribution of *Schimpera arabica*

SPECIMENS EXAMINED:

EGYPT: **S**: Wadi el Rawla, Sinai, J. R. Shabetai s.n., 14/5/1937 (CAIM); S. Sinai, Upper Wadi Ga'arba, 60 km E of Abu Rudeis, N. Tadmor s.n., 27/5/1969 (HUJ); Sinai, Wilkinson s.n., 1834 (BM); Wadi Feiran, S. Sinai, Wadi bed, R. Meinertzhagen s.n., 1928 (BM); Wadi Feiran, S. Sinai, W. Barbey s.n., 8/2/1892 (B); Wadi Bafa, S. Sinai, W. Barbey 22 (B); Wadi Sidr, W. Barbey 34 (B); in Sinai, Aucher-Eloy s.n., (OXF & FHO)

IRAN: in palm garden of Khark Island, Persian gull, D. Kotschy 7 (BM, NMGM, OXF & FHO, W, WAG); Khasekestan, Ram Hormuz, Van Oosten 1312 (WAG).

ISRAEL: Negev, J. D. Angelis 518 (B, OXF & FHO, WAG); Negev, entrance of Tureiba, Feinbrun 34102 (HUJ).

KUWAIT: Managish road, Riad Halwagy 252 (CAI, WAG).

SAUDI ARABIA: As Summan, K. Batanouny s.n., 25/3/1988 (CAI); 15 km ENE Qaryat al-Ulya, J. Mandaville 1302 (BM).

3. Tribe Hesperideae O.E. Schulz

In Pflanzenfam. ed. 2, 17 B: 568 (1936).

Hairs simple, bifid, stellate or furcate. Sepals erect, saccate or not saccate at the base. Filaments without appendages, linear, free. Median honey glands present or absent. Stigma ± 2-lobed, capitate or decurrent lobes. Fruits a siliqua, dehiscent or indehiscent. Radicle incumbent, rarely accumbent.

8. Eremobium Boiss.

Fl. Orient.1: 156 (1867)

Annual or short-lived perennial herbs, covered with thinly canescent to tomentose stellate hairs. Stems ascending to prostrate, simple or branched from the base upwards. Leaves sessile, linear to oblong-linear, entire, rounded or obtuse at the apex. Flowers small, pedicellate. Sepals linear-oblong, thinly canescent to tomentose stellate hairs, the inner strongly saccate at the base. Petals violet to cream, linear-spathulate, longer than calyx. Stamens 6; filaments free, linear; anthers sagittate. Ovary contains numerous ovules; style short; stigma short, divergent. Fruiting pedicels slender, erect. Siliqua linear, terete, more or less compressed, dehiscent, hairy; valves with aslender median nerve; septum thin and hyaline. Seeds in one row in each locule, ellipsoid, brown to reddish, narrowly winged; radicle accumbent.
Monotypic genus.

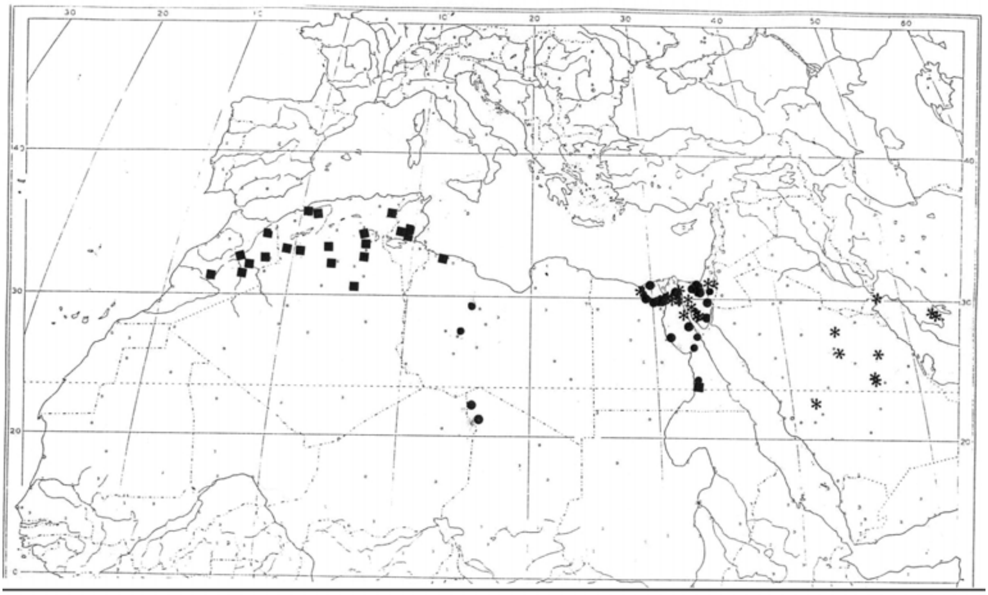
1. **Eremobium aegyptiacum** (Spreng.) Asch. & Schweinf. Ex Boiss., Fl. Orient. Suppl. 30 (1888); Täckholm, Stud. Fl. Egypt ed. 1: 344 (1956); Zohary, Fl. Pal. 1: 266 (1966); Rechinger, K., in Fl. Iran No.57/28.2: 266 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 187 (1974); Townsend, C., in Fl. Iraq, 4, 2: 1038 (1980); Collenette, Illust. Flow. Pl. Saudi Arabia ed. 2: 197 (1985); El Hadidi & Fayed, Taeckholmia 15: 44 (1994-1995); Boulos, Fl. Egypt Checklist 40 (1995); Boulos, Fl. Egypt 1: 196 (1999).
Basionym: *Malcolmia aegyptiaca* Spreng., Syst. Veg.2: 898 (1825). Type: in Egypt, Pyramids, Sieber (holotype: G; isotype: K).
Icon: Zohary, Fl. Pal.1, t 389 (1966).
Annual or short-lived perennial herbs, 10-40 cm, covered with thinly canescent to tomentose stellate hairs. Stems ascending to prostrate, simple or branched, grey-green. Leaves 0.5-2.5 x 0.2-0.4 cm, sessile to subsessile, linear to oblong, entire margin, obtuse apex, canescent with stellate hairs. Racemes at first short and dense, overtopped by young pods, much elongating in fruit. Flowers small, pedicellate 2-3 mm long. Sepals linear-oblong, 3-5 mm, outside thinly canescent to tomentose with stellate hairs; the inner ones strongly saccate at the base. Petals 4-8mm long, violet to cream, oblong-spathulate, narrowed from the base to relatively broad lamina, longer than sepals. Filaments 3-5 mm, linear; anthers 1-1.5 x 0.2-0.3 mm, sagittate. Fruiting pedicels 3-4 mm, slender, erect or slightly curved. Siliqua 1.2-6 x 0.1-0.2 cm, dehiscent, terete, more or less compressed, linear, staight or slightly curved, densely or thinly stellate hairs or glabrous, tapering into a short style. Seeds in one row in each locule, brownish or reddish or yellowish, smooth, oblong-ovate, 1-2 x 0.5-1.2 mm, more or less marginate-winged; radicle accumbent.
Fl. & fr.: February-June.

Habitat: Sandy soils.

Vernacular names: Arbeyaan, Sileys (Egypt); according to Schimper this plant is called Dsherat El-Bieta in Arabia.

Uses: it is eaten by camels, sheep and goats.

Distribution: Middle East (Palestine, Jordan, Israel, Saudi Arabia, Kuwait, S. Iran, Iraq), W. Pakistan and N. Africa (Morocco to Egypt) (Map 17).



Map 17: Distribution of *Eremobium aegyptiacum* subsp. *aegyptiacum* •, subsp. *lineare* ∗ and subsp. *longisiliquum* ▪

Three subspecies occur in Egypt.

Key to subspecies:

1a. Plant tall, spreading, 20-40 cm long; racemes dense; calyx quickly caducous; petals 5-8 mm long; fruits 2.5-6 x 0.1-0.15 cm, more than 8 seeds, slightly compressed, two times as broad as pedicel; seeds oblong, narrowly marginate……………………………………………….…**2**

1b. Plant dwarf, prostrate, 7-20 cm long; racemes loose; calyx frequently subpersistent; petals 6-10 mm long; fruits 1.2-2.2 x 0.15-0.2 cm, less than 8 seeds, compressed, 3 times as broad as pedicel, seeds suborbiculate to ovate, distinctly marginate ………………..subsp. **lineare**

2a. Plant spreading, annual or short-lived perennial, grey-green; fruits 2.5-4 x 0.1-0.12 cm…………………………….……………………………….………...subsp. **aegyptiacum**

2b. Plant spreading, sub-shrubby, woody branches at base, grey; fruits 3-6 x 0.1-0.15 cm………………………………………………...……………….subsp. **longisiliquum**

1. Subsp. **aegyptiacum**

Basionym: *Malcolmia aegyptiacum* Spreng. var. *aegyptiaca* Coss. In Comp. Fl. Atl. Vol. II: 134 (1883-1887). Type: In Egypt (Delile, Schweinfurth, Wiest) (holotype: G; isotype: BM, BR, K, L).

Heterotypic synonyms: *Eremobium pyramidium* (C. Oresl) Botsch., Novosti Sist. Vyss. Rast.1: 359 (1964).

Eremobium aegyptiacum var. *pyramidium* (C. Presl) Täckholm & Boulos, Publ. Cairo Univ. Herb. 5: 36 (1974).

Malcolmia pyramidium C. Presl, Abh. Konigl. Bohm. Ges. Wiss., ser.5, 3: 439 (1845).

Type: the lectotype was established in material deposited in the herbarium of the Botanical Institute of the Charles University Praha. (PRC). (not seen)

Icon: Collenette, Illust. Flow. Pl. Saudi Arabia, 197 (1985).

Plant grey-green, sometimes viscoid, long spreading, 20-40 cm. Leaves linear. Racemes dense. Calyx quickly caducous, rarely persistent in fruit. Petals 5-7 mm. Fruits 2.5-4 x 0.1-0.12 cm, slightly compressed, canescent with stellate hairs, two times as broad as pedicel, more than 8 seeds. Seeds oblong, 2.2 x 1.2 mm, yellow-brownish, narrowly marginate.

Distribution: Palestine, Saudi Arabia, Israel, Tschad, Arab Emirates, Libya and Egypt.

SPECIMENS EXAMINED:

EGYPT: **M**: Burg el Arab, A. Rhatlaf s.n., 7/4/1948 (CAI); Mariut, Burg el Arab, G. Täckholm s.n., 15/3/1928 (CAI); El-Arish in fields, N. Sinai, Täckholm s.n., 15/8/1951 (CAI); N. Sinai, 3-4 km, S. of Bir Lehfen, S. El Arish, G. Täckholm s.n., 21/3/1928 (CAI); El Arish-Rafah road, N. Sinai, Boulos s.n., 13/9/1965 (CAI); El Arish area beside the Airport, N. Sinai, K. Abdel Khalik 29 (SHG); between Bir Lehfen and El Kharruba village, El Hdidi & El Naggar s.n., 8/11/1983 (CAI); El Sheikh Zewid, K. Abdel Khalik 15 (SHG); Rafah, 16 km West of N. Sinai, Täckholm s.n., 15/8/1951 (CAI); 5 km. SW of Rafah, A. Shmida s.n., 17/2/1971 (HUJ).

Nv: Kilo 30, Ismailiya-Palestine road, Lupton s.n., 9/4/1946 (BM); 90 km from Alexandria, Cairo-Alexandria road, G. Shamza s.n., 21/3/1987 (CAI); Wadi El Farigh, Wadi Natroun, M. Zahran and W. Girgis s.n., 19/3/1968 (CAI); Cairo-Alexandria desert road, 90 km from Cairo, M. Hmam s.n., 2/4/1971 (CAI); Cairo-Alexandria desert road 70-100 km from Cairo, Ibrahim and Mahdi s.n., 29/12/1970 (CAI); Cairo-Alexandria desert road 5 km from pyramids, A. Abdel Fadeel s.n., 19/2/1952 (CAI); Cairo, Boissier s.n., 1903 (B); sandy Nile bank at Turra, south of Cairo, El Hadidi s.n., 10/4/1967 (CAI); Imbaba, Cairo, El Hadidi s.n., 8/11/1966 (CAI); Between the Giza pyramids and the village Kirdasa, G. Täckholm, s.n., 10/3/2000 (CAI); in the desert sand N. Giza pyramids, G. Täckholm s.n., 5/11/1926 (CAI); Pyramids region, Marticus s.n., (BR); Pyramids, Wilkinson 2 (BM); Pyramids, Wiest, A., s.n., 28/3/1835 (BM); in the area of Sakkara, pyramids, J. Bornmüller 10305 (BM); Cairo, in sand desert near pyramids, J. Bornmüller 10306 (LY); weed among Ricinus plant cultivated in desert sand N. Giza pyramids, G. Täckholm s.n., 5/11/1926 (CAI); Pyramids, near Abu Rawwash, Alexandria desert road Kilo 4-7, Boulos s.n., 26/12/1952 (CAI); Tahrir prov. along desert road, Täckholm et al. s.n., 28/5/1967 (CAI); Faiyum road 37 km from Cairo, Mahdi Sisi s.n., 15/2/1974 (CAI); Wadi Assiuti, Zahran and Girgis s.n., 4/4/1964 (CAI);

Di: Gebel Asfar, Sayed Montasir s.n., 9/3/1956 (CAI); East bank of Suez canal, Ismailiya, F. Lupton s.n., 8/4/1946 (BM); the road of Ismailiya-Suez, 20 km from Ismailiya, C. van Vliet 740 (L); Along the desert road of Cairo-Ismailiya, C. van Vliet 155 (L); Wadi El Mashabba, Midway between, G. el Maghara and G. el Halal, Boulos s.n., 24/4/1959 (CAI); 5 km before El Hassna, E. Shamso s.n., 3/4/1986 (CAI); 110 km from Newabea, El Hasana-Newabea road, Sinai, K. Abdel Khalik 1 (SHG). **R**: W. Sinai, Wadi Sudr, 5 km. S. of Ras Sudr, Danin et al. s.n., 6/3/1968 (HUJ); Hurghada, W Um Disi, A. H. Nasr s.n., 13/11/1935 (CAI); Red Sea Governorate, Gebel Abraqa, Wadi Abu Saa'fa, Peter Meininger 22 (WAG);

S: Dahab, Keller 236 (BM); South Sinai, 5 km before Feiran Oasis, Mohamed Gibali s.n., 30/3/1989 (CAI). **Da**: 55 km from Qena, Qena-Safaga desert road, K. Abdel Khalik 5 (SHG); Kom Ombo, desert Wadi Bizha, Gebel Ibn Messieh, in Wadi Sheit, Täckholm et al. s.n., 3/3/1961 (CAI).

LIBYA: 100 miles South of Bu Ngem, Guichard 79 (BM); Fezzan, Brack, Wadi Zigzah, D. Turner 82 (BM).

TSCHAD: NW Tiches Tibesti Sandächeam Enneri Bardague Tibesti and Borkou, Hildemar Scholz 157 (B); Tibesti and Borkou, Hildemar Scholz 158 (B).

ARAB EMIRATES: Al Ain area, El Ghonemy 79/5004 (NMGM).

ISRAEL: N. Negev, Beersheba to Revivim, Jaffe 27531 (HUJ).

2. Subsp. l**ineare** (Delile) Abdel Khalik, comb. et stat. nov.

Basionym: *Matthiola linearis* Delile in Laborde and Linant, Voy. Arab. Petr. 85 (1830).

Type: in Egypt (Schweinfurth) (holotype: B; isotype: L, G, BR,); in Arabia Petraea (Schimper, Boiss.) (holotype: B; isotype: WAG, L).

Heterotypic synonyms: *Eremobium lineare* (Delile) Asch. & Schweinf. ex Boiss., Fl. Orient. Suppl.30 (1888); Täckholm, Stud. Fl. Egypt ed. 1: 344 (1956).

Type: in sandy deserts: Egypt-Arabia, near pyramids (Wiest 541, Sieber!), Sinai (Bove ex 134; Auch. Ex.124, Boiss.) (holotype: B; isotype: BM, BR, L, WAG).

Eremobium diffusum (Decne) Botsch., Novosti Sist. Vyss. Rast.1: 359 (1964); Täckholm, Stud. Fl. Egypt ed. 2: 178 (1974). Type: in sandy deserts: Egypt-Arabia (Wiest 541, Sieber) (holotype: LE).

Homotypic synonym*: Malcolmia aegyptiaca* (Spreng.) Coss. var. *linearis* (Delile) Coss., Comp. Fl. Atlant. Vol.11: 134 (1883-1887).

Icon: Collenette, Illust. Flow. Pl. Saudi Arabia, 197 (1985).

Plant grey-green or green, sometimes viscoid, dwarf, prostrate, 7-20 cm long. Leaves oblong-linear to linear. Racemes loose. Calyx frequently subpersistent. Petals 6-10 mm. Fruits 1.2-2.5 x 0.15-0.23 cm, compressed, slightly stellate hairs or glabrous, 3 times as broad as pedicel. Seeds usually less than 8 seeds, suborbiculate to ovate, 2.1 x 1.6 mm, red-brownish, distinctly marginate.

Distribution: Saudi Arabia, Iran, Palestine, Israel, Jordan, Arab Emirates, Iraq, Kuwait, Egypt and Pakistan.

SPECIMENS EXAMINED:

EGYPT: **M**: Burg el Arab, Botany department excursion s.n., 4/4/1952 (CAI).

Nv: near Abu Rawash, El Hadidi s.n., 5/11/1952 (CAI); N. side of Giza pyramids, G. Täckholm s.n., 10/4/1926 (CAI); Giza, pyramids, Zrewiz s.n., 21/9/1910 (CAI); pyramids, Sieber s.n., (L); between Ramsis and Ismailia, A. Letoureux s.n., 19/2/1877 (LY); desert road to Ismailia, around Bir Abou-Sarom, W. Barbey 67 (LY).

Di: 5 km. S. of Ismailia, Bir Gafgafa road junction, Danin & Orshan s.n., 12/7/1967 (HUJ); in waste lands near Ismailia, Letourneux 7 (LY); Wadi El Nassuri, Wadi Anqabiya along Cairo-Suez road, El Hadidi s.n., 7/3/1956 (CAI); Suez, in the locality of Wadies Jaibe-el Gaurana and Sudor, O. Fielding s.n., 1869 (BM). **R**: Wadi Arabah, Schweinfurth s.n., 22/4/1887 (BM, BR). **S**: without location, Aucher 124 (BM, K, OXF & FHO); Wadi Bovour, Sinai desert, Bove s.n., Juin 1832 (BR); El Tor desert, Sinai, Bove s.n., Juin 1832 (L); between Wadi Sudr and Wadi Wardar, Kneucker s.n., 20/3/1904 (LY).

ARAB EMIRATES: Abu Dhabi Emirate, Al-Ain Hilton Hotel, Boulos & R. Al-Hasan 15728 (BR).

IRAN: Quest of Jaz Murian, Léonard 5734 (BR); between Dasht-e-Lut and Jaz Murian, Léonard 6310 (BR).

IRAQ: Basra, near Chilawa, 110km SSW Basra, K.H. Rechinger 8800 (B).

PAKISTAN: Kambar, Gabriel 514 (B).

ISRAEL: Wadi Araba, N. of Ain Ghadian, sandy soil, M. Zohary 429 (B, L, OXF & FHO); Negev, S of Beersheba, M. Zohary 27534 (HUJ).

SAUDI ARABIA: Riyadh, S Abedin and M.A. Al-Yahya 11577 (B); 170 km S of Khafji, M.I. Bajwa 207-75 (K); without location, Boissier s.n., 1846 (BR, K, L, WAG); Qasim, Dahagy 134211 (KSU); El-Jafi valley and El-Dahna, Migahid 13229 (KSU); Hauarae, Ras Hamam, Schimper 239 (BM, L, OXF & FHO); Riyadh, Thomas 10005 (KSU).

3. Subsp. **longisiliquum** (Coss.) Maire, Sahara central 105 (1933).

Basionym: *Malcolmia aegyptiaca* Spreng. var. *longisiliqua* Coss. Illustr. Fl. Atlant. 23, t. 16 (1882). Type: Cosson I.c. t. 16 (holotype: P not seen)

Homotypic synonym*: Eremobium longisiliquum* (Coss.) O.E. Schulz, Pflanzenfam. ed. 2,17 b: 571 (1936); Jafri, Fl. Libya, 23: 170, t. 53 (1977).

Distribution: Egypt, Libya, Tunisia, Algeria and Morocco.

Icon: Jafri, Fl. Libya 23, 171, t 53 (A-F) (1977).

This subspecies is similar to the previous subspecies but this plant has a sub-shrubby habit and longer siliqua. Jafri, in Fl. Libya (1977) distinguished this plant as *Eremobium longisiliquum* using the length of fruit and show sub-shrubby habit, after investigating the available material from N. Africa (Egypt to Morocco). I disagree with Jafri and agree with Maire to distinguish this plant at subspecies level because the shape of flower and leaves is the same as in the typical subspecies, the difference is in the length of fruit, the show of sub-shrubby habit and the geographical distribution of this subspecies.

SPECIMENS EXAMINED:

ALGERIA: prov. Oran, Aïn Sefra, Battandier 411 (BR, L); Hoggarm, Tassilider, E. Bolay s.n., 29/3/1971 (B); Biskra, Bousquet 392 (LY); Laghouat, in sands, L. Chevallier 134 a (LY); Ghardaïa, in sands, L. Chevallier 170 (LY); prov. Constantine: Mostagnea, sands near Biskra, E. Cosson s.n., 5/4/1858 (LY); Boudaûsa, Dukerley 18 (BR); S. Oran, Aïn-Sefra, in sand desert, A. Faure s.n., 25/4/1911 (BR); desert El Arfiane, between Biskra and Touggourt, L. Faurel

4811 (BR, L); Biskra, in sand dunes, G. Rouy s.n., 21/4/1892 (BR); plain, South Biskra, Ch. Schmitt 203 (LY); Touggourt, H. Scholz 7265 (B).
EGYPT: **Nv**: in sands near Aswan, Buruat s.n., 5/1895 (LY).
LIBYA: Tripoli, Bornmüller 574 (B).
MOROCCO: prov. Errachidia, Erfoud, 12 km N. Erfoud, Ch. Aurich & H. Förther s.n., 16/4/1987 (BR); 20 km NW Boudnib, near Beni Tadjite, H. Förther 6314 (BR); Tinouf (Ouarzazate), J. Bouharmont 21862 (BR); Ksar es Souk area, J. Lewalle 7122 (BR); prov. Errachidia, Tiujdad, J. Lewalle 13708 (BR); 19 km E Erfoud, near Merzouga, D. Podlech 52722 (BR).
TUNISIA: Mission Scientifique, M. Letourneux s.n., 1884 (BR); Gafsa, in uncultivated lands, J. Pitard 306 (BR, L); Gafsa, in desert, J. Pitard s.n., 3/4/1909 (L, LY); Medenine, C. Vanden Berghen s.n., 4/4/1980 (BR).

9. Erysimum L.

Sp. Pl. ed. 1: 660 (1753); Gen. Pl. ed.5: 296 (1754); O.E. Schulz in Pflanzenfam. ed. 2, 17B: 576-578 (1936).
Annual or perennial herbs, furnished with appressed medifixed hairs. Stem erect, simple or branched. Leaves oblong lanceolate to linear, entire to sinuate-dentate, the lower ones petiolate and upper ones sessile. Inflorescence racemose, ebracteate. Flowers pedicellate. Sepals erect, the inner one saccate at the base, and broader than the outer sepals. Petals yellow, clawed. Stamens 6; filaments linear, free, edentate; anthers sagittate, obtuse; stigma capitate or emarginate. Fruiting pedicels short, as thick as the fruit. Siliqua linear, spreading, dehiscent, terete, more or less compressed; valves with midrib. Seeds in one row in each cell, yellowish, brown, wingless, oblong; radicle incumbent.
About 100 species, chiefly in the Mediterranean region and SW Asia, ranging to central Asia; only one species in Egypt.

1. **Erysimum repandum** L., Demonstr. Pl. Hort. Upsal.17 (1753); Boiss., Fl. Orient.1: 189 (1867); Muschler, Manual Fl. Egypt 409 (1912); Cullen, in Fl. Turkey vol.1: 477 (1965); Zohary, Fl. Pal.1: 262 (1966); Rechinger, in Fl. Iran No.57/28.2: 304 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 176 (1974); Townsend, C. Fl. Iraq 4, 2: 1053 (1980); Tutin, T., Fl. Eur. ed. 2, 1: 335 (1993); El Hadidi & Fayed, Taeckholmia 15: 42 (1994-1995); Boulos, Fl. Egypt Checklist 39 (1995); Boulos, Fl. Egypt 1: 192 (1999).
Type: Described from plants grown in the Uppsala botanical garden, herb. Linn. 837/5 (holotype: LINN).
Heterotypic synonym: *Erysimum rigidum* DC., Syst. Nat.2: 505 (1821).
Type: in Oriente (Labillardiere) in herb. Delessert (holotype: P).

Icon: Boulos, Fl. Egypt 1, 189, t. 35 (11) (1999).

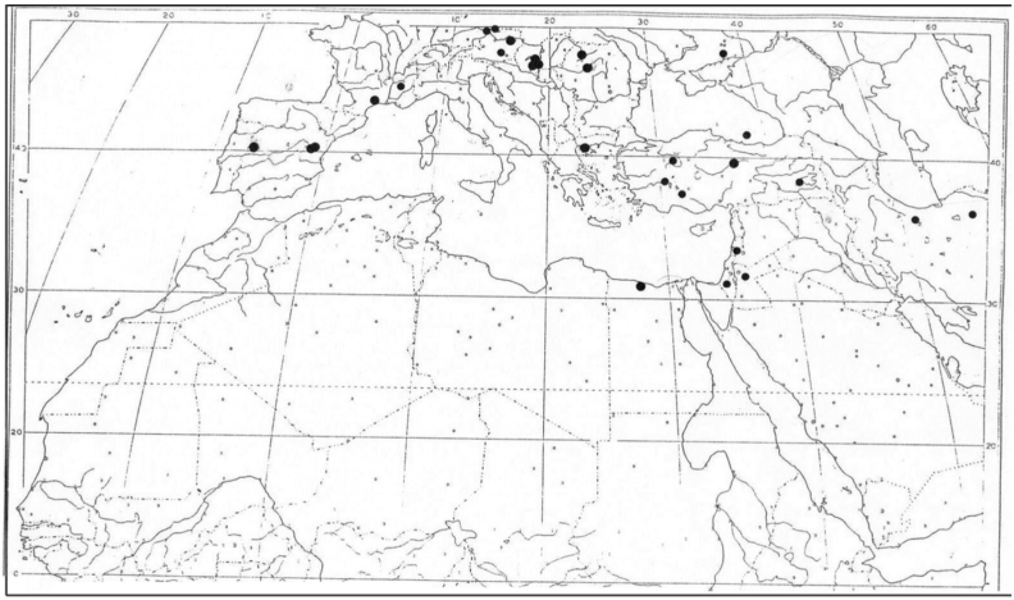
Annual herb, 11-30 cm, appressed pubescent, with an indumentum consisting of 2-fid and a few 3-fid hairs. Stems erect, simple or branched from the base. Lower leaves 1.6-5.5 x 0.2-0.7 cm, linear to narrow linear-oblong, repand-dentate, apex acute, hairy with 2-fid hairs, subsessile to petiolate 0.3-1.6 cm; upper leaves 1.5-3.5 x 0.2-0.6 cm, sessile, linear-lanceolate, entire to dentate, acute at the apex. Racemes dense, elongated in fruit. Flowers with short pedicels 2-3 mm. Sepals 4-5 mm, erect, slightly 2-saccate, with appressed medifixed and trifid hairs. Petals 6-8 mm, yellow, the lamina narrow oblong-spathulate, rounded or truncate apex, about half as long as the claw, covered with sparsely medifixed and trifid hairs from outside. Filaments 5-6 mm, linear; anthers sagittate, rounded at apex; style 2-3 mm; stigma slightly 2-lobed. Fruiting pedicels 2-3 mm, stout, widely divergent or spreading. Siliqua 1.8-6.5 x 0.1-0.15 cm, spreading, terete, slightly compressed, late dehiscent, with appressed medifixed and scattered trifid hairs especially near the style. Seeds in one row in each cell, oblong, wingless, slightly compressed, 1.6 x 0.7 mm, yellowish-brown; radicle incumbent.

Fl. & fr.: March-May.

Habitat: Calcareous ridges.

Uses: the seeds of this plant are antiscorbutic and have been used medicinally to relieve stomach ache and assuage fever (Townsend, C. & Guest, E. 1980).

Distribution: C. E. and S. Europe, Syria, Lebanon, Palestine, Jordan, Turkey, Iran, W. Pakistan, Afghanistan, C. Asia, N. W. India, America and N. Africa (Egypt to Morocco) (Map 18).



Map 18: Distribution of *Erysimum repandum*

SPECIMENS EXAMINED:

EGYPT: **M**: between Fuka and Matruh, M. Hassib s.n., 1933 (CAI).

U. S. A: Pasture, N. Kingston pike, near Farragut, First report for Tennessee, A. J. Sharp 13426 (BR).

ARMENIA: H. H. Calvert & J. Zohrab 1219 (OXF & FHO)

IRAN: Keredy (Karaj), weed in garden, D. Gauba 332 (B); E. Khorasan, near Rivash, A. Polatschek 51247 (B).

ISRAEL: Ammon, about 6 km. Before Ein Suella, Eig & Zohary 27604 (HUJ).

JORDAN: Al-Jubaiha, univ. Campus, Walid Jallad 267 (CAI).

LEBANON: Kefr Kuk, N of Hermon, 2/4/1881 (NMGM).

AUSTRIA: Vienna, in fields along paths J.V. Kovats 15 (WAG); in uncultivated lands near Vienna, M. Müller s.n., 14/5/1879 (LY); near Mösling, K. Richter s.n., 15/5/1890 (LY); Vienna, in fields nearby, Skofiton s.n., April-June (WAG).

CZECHIA: Bohemia near Marienbad, K. Laun s.n., 6/1926 (BR).

FRANCE: in SE part of France, Vauclues, 10 km SE of Apt., F.J. Breteler 12742 (WAG); in uncultivated lands near Vias, J. Kovāts 317 (LY).

GERMANY: Gőttingen, Grisebach s.n., (WAG); Baden, Karlsruhe near Mühlburg near the Kühlen Kruge, A. Kneucker 6 (LY).

GREECE: Thessalonici, Dimonie s.n., 4/1908 (LY).

HUNGARY: Ercsi, Sécombres, Ch. Magnier s.n., 4/1879 (LY); Budapest, in sand near Ercsi, A. Tauscher s.n., 20/4/1883 (LY); Ercsi (region of Alb), A. Tauscher 2766 & 3703 (LY).

NETHERLANDS: Amsterdam, Houthaven, s.n., 6/6/1908 (WAG).

ROMANIA: Transsylvania, in dry grass along road near Cojocna village, Csuros & Gergely 3246 (BR); Carei, Gas Clara, Pázmány s.n., 5/5/1961 (B).

SLOVENIA: Brno, in roadside, J. Podpera 730 (BR); prov. Valence, Segorbe, in uncultivated lands of Sierra, E. Reverchon 724 (LY); Moravia (central), Hustopece, in grasses near village Sakvice, F. Svestka 1022 (BR); S. Moravia region of Palava, dist. Mikulov, near village, V. Vasak s.n., 3/5/1973 (BR).

SPAIN: pov. Teruel: Royuela, in uncultivated lands, O. Debeaux 964 (LY); Royuela, in uncultivated lands, Magnier 3623 (LY); Montes Universales: fallow between Terrentes and Royuela, A. Polatschek s.n., 16/6/1977 (B); Prov. Teruel, near Royuela, E. Reverchon 4823 (B, LY).

TURKEY: Kerhoei, in cultivated felid, P. Ascherson 923 (BR); Lycia, Elmala in the hills, Bourgeau s.n., 17/6/1860 (B); W. Turkey, Eskisehir-Sagora, A. Scheibe 1253 (B); Antalya prov. near village Doyran, Mts Bey Dağlari, V. Vasak s.n., 30/4/1996 (BR); Burdur prov. Katranci Daği, (Mt) between Burdur and Bucak, V. Vasak s.n., 2/5/1996 (BR); Sivas, Wohak s.n., 1954 (B).

UKRAINE: Krim (Black sea), K. Talge 7 Dopoveer 16/5/1903 (WAG).

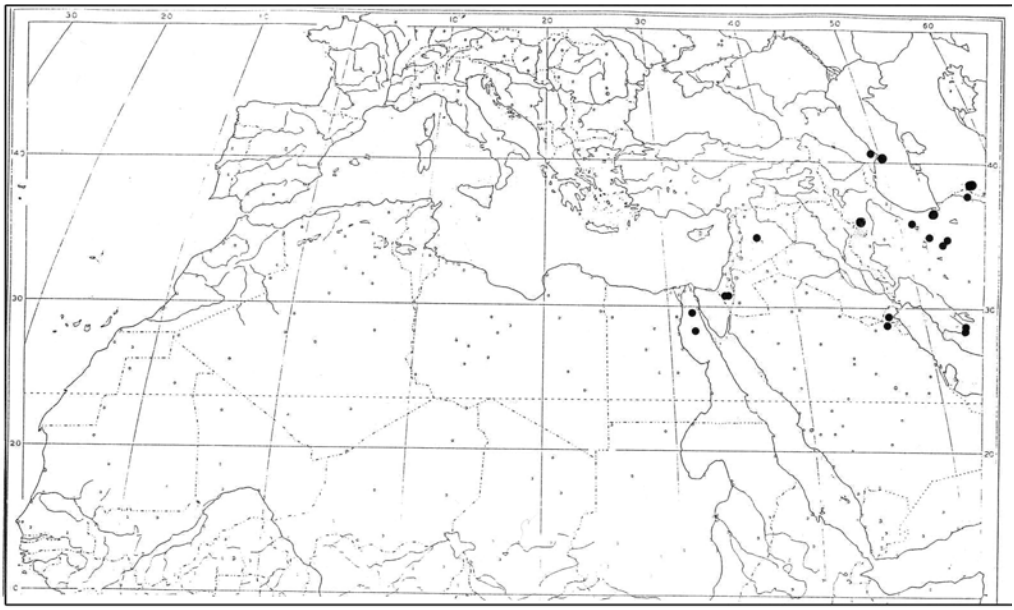
10. Leptaleum DC.

Syst. Veg. 2: 510 (1821); O.E. Schulz, in Pflanzenfam. ed. 2, 17 B: 568 (1936).

Dwarf annual herbs, glabrescent or sparingly simple hairs. Stem erect or prostrate, simple or branched from the base. Leaves linear or thread-shaped, undivided or pinnatisect with filiform lobes. Inflorescences short, racemose bracteate, few-flowered. Flowers axillary, solitary or pairs, pedicellated to subsessile. Sepals erect, linear, equal at the base, not saccate. Petals white, linear-oblanceolate, rounded apex. Stamens 4 or often reduced to 2 by abortion; anthers sagittate. Ovary contains many ovules; stigma lobes small and fused into a minute cone.

Fruiting pedicels short, thick. Fruit siliqua, linear, dorsally compressed, indehiscent, opening when moistened, obtuse and asymmetrical at the base, gradually tapering at apex; style almost none; valves reticulate-veined, 1-nerved. Seeds many, small, biseriate; radicle incumbent.
Monotypic genus.

1. **Leptaleum filifolium** (Willd.) DC., Syst. Nat.2: 511 (1821); Bentham & Hooker, Gen. Plant.81 (1862-1867); Boiss., Fl. Orient.1: 243 (1867); Täckholm, Stud. Fl. Egypt ed. 1: 346 (1956); Zohary, Fl. Pal.1: 270 (1966); Rechinger in Fl. Iran No.57/28.2: 251 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 183 (1974); Townsend, in Fl. Iraq vol.4, 2: 1027 (1980); Tutin, Fl. Eur. Ed. 2, vol.1: 339 (1993); El Hadidi & Fayed, Taeckholmia 15: 45 (1994-1995); Boulos, Fl. Egypt Checklist 42 (1995); Boulos, Fl. Egypt 1: 202 (1999).
Basionym: *Sisymbrium filifolium* Willd., Sp. Pl. ed.4, 3: 495 (1800). Type: in Siberia near Kumam river (Pallos) (holotype: G).
Heterotypic synonyms: *Leptaleum pygmaeum* DC., Reg. Veg. Syst. Nat.2: 511 (1821).
Type: in Persia (Michaux). (not seen).
Leptaleum longisiliquosum Freyn & Sint., Bull. Herb. Boiss.3: 692 (1893).
Type: Transcaspica; Aschabad, in grass covered sand hills on the Mekrowa, Freyn 53 b (holotype: B).
Icon: Zohary, Fl. Pal.1, t. 394 (1966).
Dwarf compact annual herbs, 3-8 cm, glabrous or sparingly simple hairs. Stem slender, erect or prostrate, simple or branched from the base. Leaves 0.6-4.8 x 0.1 cm, linear or thread like, undivided or pinnatisect with long filiform lobes, 3-5 filiform segments, petiolate 0.5-1.1 cm. Flowers long, axillary, solitary or in pairs, pedicels 1-2 mm. Sepals 4-5 mm, linear, not saccate. Petals 8-9 mm, white, linear-oblanceolate, apex rounded. Stamens 4 or 2; Filaments 7-8 mm, linear; anthers sagittate, 1-1.2 x 0.25 mm; stigma lobes small and connected into a minute cone. Fruiting pedicels 3-5 mm, thick. Fruits siliques 1-2 x 0.15-0.2 cm, linear, compressed, obtuse and asymmetrical at base, gradually tapering at apex, glabrous or with scattered simple hairs; valves reticulately veined with a distinct central nerve. Seeds in two rows in each locule, oblong-ovoid, yellowish-brown, smooth, 0.6-0.7 x 0.4-0.5 mm; radicle incumbent.
Fl. & fr.: March-May.
Habitat: sandy and stony wadis, sand hills.
Vernacular names: Huwaira (Kuwait), Qeseysah (Egypt).
Uses: Dickson (1955) says it is eaten for its hot peppery taste by the Badawina in Kuwait.
Distribution: Egypt, Syria, Palestine, Israel, Jordan, Arabia, Kuwait, S. Russia, Caucasus, Iran, W. Pakistan, Afghanistan, C. Asia and W. Mongolia (Map 19).



Map 19: Distribution of *Leptaleum filifolium*

SPECIMENS EXAMINED:

EGYPT: **Dg**: Wadi Chafura, north Galala, Schweinfurth s.n., 12-14/5/1887 (BR); Wadi Ghisli, south Galala, 1000 m, Schweinfurth s.n., 7-10/5/1887 (BM).

AFGHANISTAN: Griffth 1393 (L); Sologiske Skmifler, Volk 1413 (B).

AZERBAIJAN: Baku, in shrubby area of Songoria between rivers Tschulak and Ai, Karelin and Kiriloff 1242 (BR); Baku, L. C. Treviranus s.n., 1936 (LY).

IRAN: Teheran, in uncultivated area near Ray, Bornmüller 2/38 (BR, L); Krasnowodsk, in sand mountain area, J. Freyn 12 A (L); south Iran, in dry area near Dalechi, Kotschy 185.838 (WAG); south Iran, near Ruins of Persepolis, Kotschy 185 (WAG); Central prov. Road Teheran-Semnan, between Aivaneki and Garmsar, 21 km from Garmsar, J. Lambinon 76/5 (BR); Central prov. Road Teheran-Semnan, between Aivaneki and Garmsar, 13 km from Garmsar, J. Lambinon 76/24 (BR); south Teheran, Léonard 5277 (BR); Keredy, A. Parsa 243 (BR)

ISRAEL: Borot Loz, Negev highlands in stony slopes, A. Danin 14089 (BR); Negev highlands, Nahal Loz & Borot Loz, A. Danin et al. 20.010 (B); C. Negev, Hamakhtesh Hagadol, A. Shmida 32750 (HUJ).

KUWAIT: 57 km west of Atraf, sandy soil, M. I. Bajwa 48-76 (BR, CAI).

RUSSIA-SIBERIA: Stephan s.n., (B).

SAUDI ARABIA: 2 km S of the Saudi-Kuwait border, Mandaville 1637 (BM).

SYRIA: Deir el Zor- Palmyra, km 110, P. Bamps 9099 (BR); Maaloula, Bouharmont 27296 (BR).

TURKMENISTAN: Transcaspica, Ashkhabad, in sandy hills, near Mekrowa, J. Freyn 53 a, b (B); Ashkhabad, on Nephton mountain, J. Freyn 53C (L, LY).

11. **Malcolmia** R. Br.

In Ait., Hort. Kew. Ed. 2, 4: 121 (1812); O.E. Schulz, in Pflanzenfam. ed. 2, 17B: 468-570 (1936); P. W. Ball, Feddes Rep. 68: 179-186 (1963); Dvorak, F. & Konarikova, V., Feddes Rep. 81: 387-416 (1970); Stork, L., Svensk Bot. Tidsk., 65: 283-292 (1971); Stork, L., Svensk Bot. Tidsk. 66: 417-433 (1972); Stork, L., Opera Bot. 33: 1-118 (1972); Dovrak, F. & Konarikova, V., Feddes Rep. 83: 265-273 (1972), Feddes Rep. 84: 315-326 (1973).
Annual herbs, erect, simple or branched stem, covered with simple and branched hairs. Leaves simple, alternate, entire or dentate or pinnatifid, oblanceolate to elliptical, the radicle often petiolate, the upper ones mostly sessile. Flowers shortly pedicelled. Sepals erect, the inner pair strongly saccate at the base, broader than the outer pair. Petals white, pink or violet, often much longer than sepals, linear to narrow oblanceolate. Stamens 6; filaments linear, free; anthers oblong or ovoid, obtuse; style short, thin; stigma conical with decurrent lobes or capitate. Fruiting pedicels often short and thick or thin in fruit, subascending or spreading. Siliques linear ± cylindrical or subcylindrical, firm, 2-locular, dehiscent, hairy or glabrous; valves sometimes rigid with a distinct midrib; septum membranous to submembranous, not veined. Seeds small, in one row in each cell, ovoid or oblong, brown; radicle incumbent.

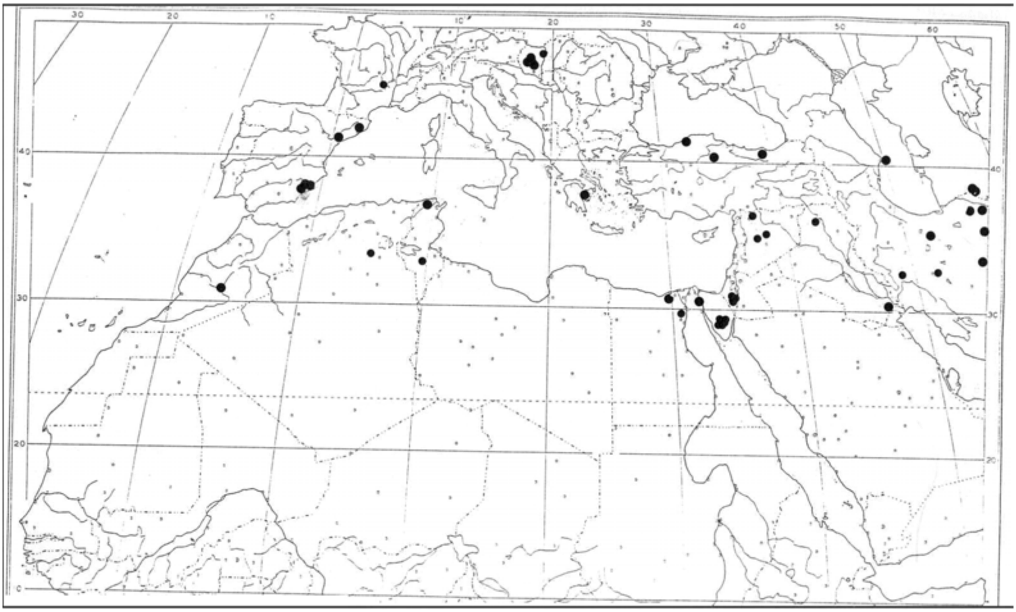
About 30 species chiefly in the Asian and Mediterranean region, three species in Egypt.
Key to the species:
1a. Leaves almost all in a basal rosette, pinnatifid or lyrate or pinnatipartite; Fruits glabrous…………………... ……………………..…………………..……**3. M. pygmaea**
1b. Leaves also along stems and fruits pubescent………..…………..…………………...…….**2**
2a. Flowers 3-4 mm; fruits 1-2.5 cm, pubescent with stellate hairs……………..…...**2. M. nana**
2b. Flowers 6-8 mm; fruits 1.5-7 cm, densely hispid with simple, branched and stellate hairs……… ……………………….…...…………………………….….….1**. M. africana**

1. **Malcolmia africana** (L.) R. Br., in Ait. Hort. Kew. Ed. 2, 4: 121 (1812); Bentham & Hooker, Gen. Pl. 1: 77 (1862); Boiss., Fl. Orient. 1: 221 (1867); Täckholm, Stud. Fl. Egypt ed. 1: 344 (1956); Cullen, in Fl. Turkey vol.1: 460 (1965); Zohary, Fl. Pal. 1: 265 (1966); Rechinger, K., in Fl. Iran, No.57/28.2: 257 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 180 (1974); Jafri, Fl. Libya 23: 169 (1977); Tutin, T. G., Fl. Eur. Ed. 2, vol. 1: 338 (19930; El Hadidi & Fayed, Taeckholmia 15: 41 (1994-1995); Boulos, Fl. Egypt Checklist 39 (1995); Boulos, Fl. Egypt vol.1: 190 (1999).
Basionym: *Hesperis africana* L., Sp. Pl., ed. 1: 663 (1753). Type: African rocket, Cult. From Algeria, herb. Linn. 841/5 (holotype: LINN; isotype: L, B).

Homotypic synonyms: *Strigosella africana* (L.) Botsch. In Bot. Zhurn. 57: 1038 (1972); Townsend, C. C., in Fl. Iraq vol. 4, 2: 1032 (1980).
Heterotypic synonym: *Malcolmia calycina* Sennen, Diagn. Pl. Espagne Maroc 178 (1936). Type: Maroc, Alluvions du Muluya (Ulad-Settut), Sennen & Mauricio 8667 (not seen).
Icon: Jafri, Fl. Libya 23, 168, t 52 (A-H) (1977).
Annual herbs, 8-26 cm, erect to suberect, pubescent with scattered simple, stellate or (2-4) branched hairs. Stem simple or branched. Basal leaves 1.2-8.2 x 0.4-1.8 cm, obovate to oblong, tapering into a petiole, 0.2-2.1 cm long, margin entire to sinuate-dentate, apex acute or obtuse; upper leaves 0.8-2.2 x 0.3-1 cm, oblong to oblanceolate, tapering into a short petiole or sessile, margin dentate to crenate, apex acute to obtuse. Flowers small, short pedicels 0.5-1.5 mm. Sepals 4-5 x 1 mm, erect, linear, inner ones saccate at base, slightly wider than outer ones. Petals 6-8 x 1-2 mm, violet to whitish, with distinct claw and blade spathulate, entire. Filaments 4-5 mm, free; anthers 1-1.5 x 0.6-0.75 mm, sagittate. Fruiting pedicels 1-4 mm long, spreading, thickened, as thick as fruit. Siliqua 1.5-7 x 0.1-0.15 cm, straight or curved, more or less tetragonous, densely hispid, tapering into a pointed, 0.5-1 mm long stigma; valves rigid with a distinct midrib; septum membranous. Seeds in one row in each cell, 1.2-1.7 x 0.5-0.8 mm, oblong to ovoid, browinish; radicle incumbent.
Fl. & fr.: March-May.
Habitat: Stony wadis and moist places in desert.
Vernacular names: Kashena, Khuzaima (Iraq), Bakushak, Chambar, Khatol (Pakistan).
Uses: it is eaten by sheep and camels.
Distribution: S. Europe, Syria, Palestine, Israel, Lebanon, Saudi Arabia, Kuwait, Turkey, Caucasus, Iran, Iraq, W. Pakistan, Afghanistan, C. Asia, W. Siberia, Tibet, India, N. China and N Africa (Egypt to Morocco) (Map 20).

SPECIMENS EXAMINED:

ALGERIA: gravel quarries, Biskra, B. Balansa 904 (WAG).
EGYPT: **M**: Mamora, 34 km from Rabat, Abdel Aziz s.n., 21/5/1962 (CAI).
Nv: Between Giza pyramids and village Kirdasa, G. Täckholm s.n., 10/11/1926 (CAI).
S: Deir Arbain, G. Täckholm s.n., 8/4/1927 (CAIM); the garden of Deir el Rahba at the entrance of Wadi el Arbain, Täckholm et al. s.n., 25/4/1961 (CAI); M. Catherine, S. Sinai, W. Schimper 233 (L, OXF & FHO); St. Catherine at Rahba garden, El Hadidi & El Naggar s.n., 8/5/1988 (CAI); M. Catherine, S. Sinai, grown in botanical garden, Shmida & Arbel 2005 (B); Wadi Roteg, St. Catherine, Nachlat E Sheich, A. Arbel & Shmida s.n., 21/4/1975 (HUJ); Gebel Deir El Banat, St. Catherine, El Hadidi & El Naggar s.n., 25/4/1983 (CAI); the garden of the small monastery situated to the left of the road before entrance of St. Catherine, Sinai, Täckholm et al. s.n., 25/4/1961 (CAI); Wadi el Arbain, S. Sinai, El Hadidi s.n., 12/5/1956 (CAI); Deir el Rahba at the entrance of Wadi el Arbain, S. Sinai, K. Abdel Khalik 2 (SHG); Deir el Rahba at the entrance of Wadi el Arbain, S. Sinai, K. Abdel Khalik 13 (SHG). **Di**: Ismailia, rare plant, Muschler s.n., 4/1906 (LY).

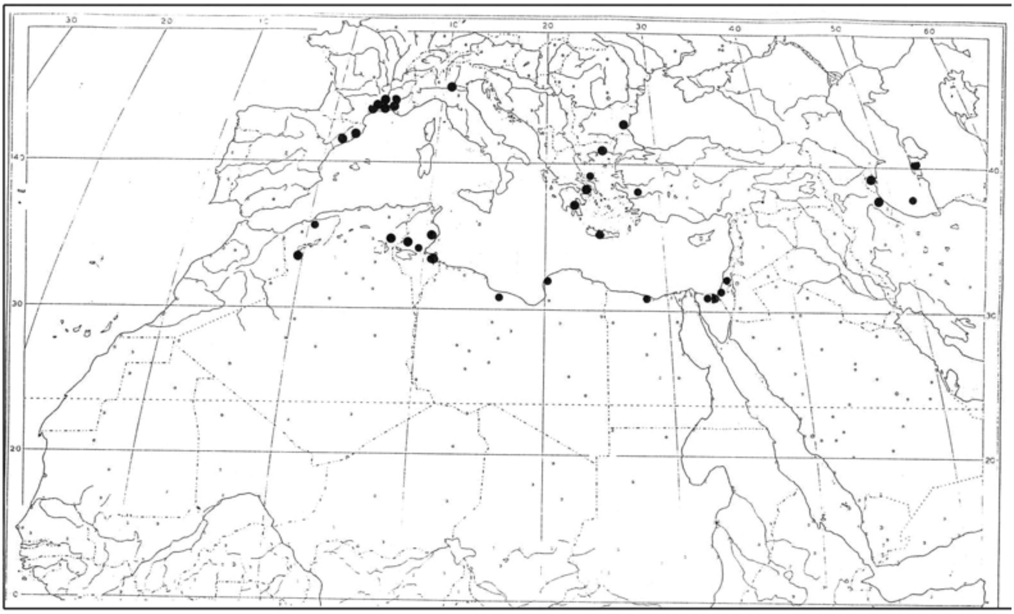


Map 20: Distribution of *Malcolmia africana*

MOROCCO: prov. Ouarzazate: Ouarzazate to Marrakech, E. Bayōn et al. 5525 (B).
TUNISIA: Matmata, in sand, C. J. Pitard 305 (LY, WAG); in uncultivated lands, Kébira, J. Pitard 756 (LY).
AFGHANISTAN: Kabul, Kamdeler 279 (B); prov. Logar, Logar Toler, 40 km S of Kabul, D. Podlech 3106 (B).
AZERBAIJAN: Baku, Recker s.n., 1880 (LY).
INDIA: Punjab, Thomson s.n., (L)
IRAQ: Sinjar, in Mosul-Liwa, N. Polunin et al. 45 (B, WAG); Basra, Rechinger 8498 (B).
IRAN: Ispahan, Aucher-Eloy 22 (OXF & FHO); near Schahrud, Bunge 47 (LY); prov. Tehran, between Tehran and Semnan, Rechinger 2764 (B); E. Khorasan, 70 km SW Torbate, Heydariyeh, Rechinger 51368 (B); E. Khorasan, in sands near mountain, 8 km NW Aliabad, Rechinger 51709 (B); N. Gorgan (Mohammad Reza Shah national park), N. Robate-e-Qareh Bil, Rechinger 52896 (B); E. Khorasan, in Ab Bakhsh, 48 km S. of Bonjnurd, Rechinger 53580 (B); prov. Khorasan, 23-25 km Qayen, Rechinger 56020 (B); Khuzistan, Rum Hormuz, M. van Oosten 1321 (WAG).
ISRAEL: Negev, Beersheva, roadsides, J. D, Angelis 515 (B, OXF & FHO, WAG); Negev Highlands, Mizpe Ramon, A. Danin et al. 18. 002 (B); Negev Highlands, Nahal Elot, slopes, cliffs and Wadis, A. Danin et al. 21. 038 (B); Negev Highlands, 8 km SW of Yerokham, Loessial soil and stony slopes, A. Danin et al. 24. 007 (B); Negev, Shivt ruins, Zohary 33148 (HUJ).
LEBANON: G. Druce s.n., 1925 (OXF & FHO).
SYRIA: Qalát Jáaber, J. Bouharmont 27351 (BR); near Aleppo, in ruderal place, Kotschy 48 (BM, WAG); Tadmur, ruins of Palmyra 41a, hill and ruin of Qala Ibn Maan, W. Licht s.n., 11/3/1979 (B).
TURKMENISTAN: in Ashkabad, J. Freyn 60 (LY); in waste lands in Ashkabad, Litwinow 545 (LY).
FRANCE: Hérault, in alfalfa plot with clay soil in Saimt-Geriyet-le-Bas, Billot 1411 (L, LY); Hérault, in Nissan, F. Sennen 2919 (LY); .
GREECE: in sands of Attica, near Chalerum, Aquit 1094 (LY).
HUNGARY: near Budam (Budapest), Basthing s.n., (L); Central Hungary, Smatelep near Ercsi, between grasses, Staub 2059 (B, L); Sinatelep, near Ercsi, edge of the road, A. J. Tauscher 7 and 1508 (LY).

SPAIN: in uncultivated lands, Murcia, E. Bourgeau 570 (LY); fields of Cartagena, E. Bourgeau 1065 (B); in sands near Murcia, Poeta and Rigo s.n., 5/1891 (LY); Catalonge, plain of Ebro ā Aldover, in sands, F. Sennen 784 (LY); border of Slobegat near Barcelona, F. Tremols s.n., 5/1878 (LY).
TURKEY: Gumushane in Oslamannis Bilimek, Anon s.n., ± 1880 (WAG); prov. Konya, between Erĕgli and Ulukisla, along road Konya-Adana, Hennipman et al. 997 (B); prov. Kars, Iğdir, Th. Raus 076 (B).

2. **Malcolmia nana** (DC.) Boiss., Fl. Orient.1: 222 (1867); El Hadidi & Fayed, Taeckholmia 15: 41 (1994-1995); Boulos, Fl. Egypt Checklist 38 (1995); Boulos, Fl. Egypt 1: 188 (1999).
Basionym: *Sisymbrium nanum* DC., Syst. Nat.2: 486 (1821).
Type: in coastal Anatolia (Tourn), maris Caspia near Baku and Lenkoran (Hoh), near Enzeli Persiae bor. (Buhse). (not seen).
Homotypic synonym: *Maresia nana* (DC.) Batt. In Batt. & Trab., Fl. Algerie 1: 68 (1888).
Heterotypic synonym: *Malcolmia confusa* Boiss., Fl. Orient. 1: 221 (1867).
Type: in coastal sands Etoliae near Missolonghi (Nieder), Eginae (Spurn), Anatoliae near Samsun (Tchih Wiedem) (holotype: G), (not seen).
Icon: Boulos, Fl. Egypt 1, 189, t 35 (8) (1999).
Annual herbs, 7-17 cm, tomentose-canescent with short stellate hairs. Stems erect or prostrate, branched. Leaves 0.4-2 x 0.1-0.3 cm, oblong-ovate or linear-oblong, entire to sinuate-dentate, canescent, sessile to subsessile. Inflorescence racemes, corymbose. Flowers small, petiolate 1.5-3 mm long. Sepals 1.7-2 mm long, slightly saccate at the base, canescent from outside. Petals 3-4 x 1-1.2 mm, pink-violet, spathulate to oblong-obovate. Filaments 2-3 mm, linear, dilated at the base; anthers 0.3-0.4 x 0.2 mm, ovoid to oblong; style short, 0.5-1.5 mm long; stigma capitate or 2-lobed. Fruiting pedicels 2-5 mm long, erect, thickened. Siliques 1-2.5 x 0.1 cm, erect to spreading, terete, pubescent; valves dehiscent, truncate at base, 1-nerved. Seeds in one row in each locule, 0.6-0.8 x 0.3-0.4 mm, oblong-ellipsoidal, yellowish to greenish; radicle incumbent.
Fl. & fr.: February-March.
Habitat: in sand of coastal lands.
Uses: it is eaten by sheep and camels.
Distribution: S. Europe, Syria, Jordan, Palestine, Israel, Turkey, Afghanistan and N. Africa (Egypt to Morocco) (Map 21).



Map 21: Distribution of *Malcolmia nana*

SPECIMENS EXAMINED:

ALGERIA: Mostaganem, in sandy soils, B. Balansa 155 (K); 5 km north Negrine, Leippert s.n., 28/3/1969 (B); prov. Oran, in sandy place near Castle Aïn-Ben-Khelil, A. Warion 10 (LY).

EGYPT: **M**: El-Garawla, 25 km E of Mersa Matruh, Täckholm s.n., 1/4/1972 (CAI); El-Arish, el Sheikh Zewied, K. Abdel Khalik 14 (SHG); El Arish, Zohary s.n., 1/5/1925 (HUJ); El Arish-Rafah road, 23 km from El Arish, K. Abdel Khalik 28 (SHG); 30 km E of El Arish, D. Podlech 49945 (BR).

LIBYA: Benghasi, G. Ruhmer 13 (B, BR); Tripolitania, Lepcis Magna, dry sandy ground near the Roman amphitheatre, C. C. Townsend 66/35 (K).

TUNISIA: Gafsa, in cultivated fields, C. Pitard 307 (WAG); Sfax, in cultis, C. Pitard 15 (WAG); Midoum, Djerba, Vanden Berghen s.n., 10/4/1978 (BR); Gafsa, in running sands, J. Robert s.n., 8/5/1886 (LY); Mezraia, Djerba, Vanden Berghen s.n., 28/3/2978 (BR); Rhizene, Djerba, Vanden Berghen 232 (BR); Tadjdit, Djerba, Vanden Berghen 257 (BR).

AZERBAIJAN: in sands beside Sea shore in Olchovka near Lenkoran, A. Grossheim 566 (K); Talish, Hohenacker s.n., 1830 (LY).

IRAN: sandy shore scattered and widespread, Bowles Scholarship Bot. Exp.791 (K); Mahmoudabad (Mazandaran), in sands, P. Furse 5053 (K); north and west Iran, near sea, M. Jacobs 6177 (L); prov. Gilan, near to Caspian sea E Bandar-e Pahlavi, Rechinger 39595 (B).

ISRAEL: Tel-Aviv, in sands, G. Samuelsson 758 (B); Tel-Aviv, sands, M. Zohary & N. Feinbrun 49 (B, K).

PALESTINE: Philistean plain, Holon, Fragman 33265 (HUJ); Gaza, collected by the American colony, Jerusalem 1455 (K).

BULGARIA: Black sea coast, on the maritime sands near Ropotamo river, Kuzmanov 81000 (B).

FRANCE: in sandy beach of Leucate, near Narbonne (Aude), G. Gautier s.n., 15/5/1882 (LY); Hérault, beach of Roquehaute, near Vias, J. Hérail 465 (LY); in sandy beach of Roquehaute (Hérault), Ch. Magnier 2999 (LY); in sandy beach of Portiragws (Hérault), R. Neyra 2306 (LY); Aude, beach of Leucate, A. Respaud 465 bis (LY); in sands of Agde (Hérault), A. Théveneau 3008 (LY).

GREECE: Attica, in sand beach of Phaleri, de Heldirech 820 (LY); Amoudhi near Ayios Yeoryios, on sand dunes, R. D. Meikle 2078 (K); prov. Athens: Attica, in sandy beach, T. Pichler s.n., 6/1876 Y); 1 km NW of Fanari, Raus & Schiers 16713 (B); Kreta, Eparchia Selīnou, E Sarakiniko, lateral valley of beach, Ralf Jahn 4 (B).

ITALY: Apulia, Gargano, in sand place of Circa Bodi, Porta and Rigo 542 (LY).

SPAIN: Catalunia: in sands of Castelldefels, H. Coste 1542 (B); sandy beach between Cambrils and Salou, Hno. Domingo 760 (LY); sand dunes on beach of Castelldefels, F. Sennen 1582 (LY).

TURKEY: Muğla, in Marmaria, bay E of Datea port, sand dunes, Davis 41346 (K).

3. **Malcolmia pygmaea** (Del.) Boiss., Fl. Orient.1: 222 (1867); Aschers. & Schweinf. Illust. Fl. Egypt 50: 38 (1887); Durand & Schinz, Consp. Fl. Afr.1, 2: 92 (1895); Sickenb. Contrib. Fl. Egypt 175 (1901); Muschler, Manual Fl. Egypt 1: 405 (1912); El Hadidi & Fayed, Taeckholmia 15: 41 (1994-1995); Boulos, Fl. Egypt Checklist 38 (1995); Boulos, Fl. Egypt 1: 188 (1999).

Basionym: *Hesperis pygmaea* Del., Fl. Egypt Illust.19: 596 (1813). Type: in Egypt, near Alexandria and Aboukir, Del. Auch. Exs. 130. (holotype: B)**;** near the sea beach in Karrak island (Kyexs. 4) (not seen).

Heterotypic synonyms: *Hesperis pygmaea* DC., Syst. Nat. 2: 455 (1821). Type: in Syria (Savigny); near Alexandria, Oliv. ex Delil. (holotype: B).

Homotypic synonym*: Maresia pygmaea* (DC.) O.E. Schulz in Engl. & Prantl, Pflanzenr. 86 (IV, 105): 210 (1924).

Icon: Täckholm, Stud. Fl. Egypt ed. 2, 173, t. 51 (A) (1974). As *Maresia pygmaea*.

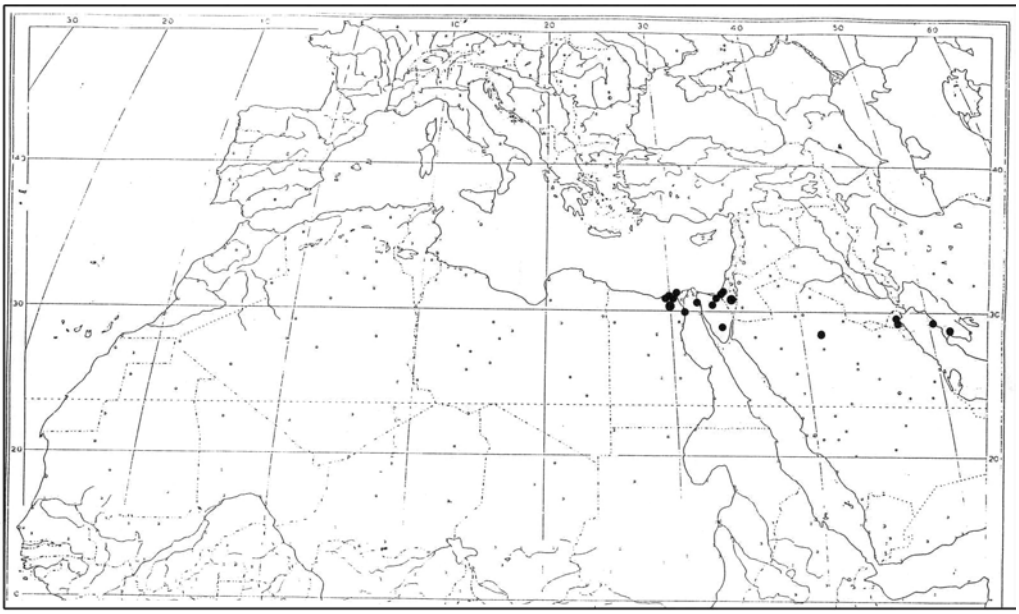
Annual herbs, 6-11 cm, minutely branched hairy or glabrous above. Stem erect or ascending, branched, leafless. Leaves 0.6-1.5 x 0.2-0.5 cm, in a rosette, obovate-oblong to spathulate, sinuate-toothed, pinnatifid with obtuse lobes, tomentose with minutely branched hairs, petiolate 0.5-1.5 cm. Flowers few, in racemes, tapering into the pedicels 0.4-1.2 cm. Sepals 3-4 mm, covering with minutely branched hairs from outside, erect. Petals 7-10 mm, violet, limb obovate-rounded or truncate; claw white. Filaments 5-6 mm, linear; anthers 0.6-0.7 x 0.3-0.4 mm, sagittate; style short 1-2 mm long; stigma 2-lobed or decurrent. Fruiting pedicels 1.1-1.5 cm long, erect or spreading, filiform or thick. Siliques 1.7-3.3 x 0.1 cm, straight or slightly curved, linear, dehiscent, glabrous; valves thiny, glabrous, 1-nerved; septum membranous. Seeds 0.7-0.8 x 0.5-0.6 mm, ovoid, yellow-brownish; radicle incumbent.

Fl. & fr.: March-April.

Habitat: sandy soils.

Vernacular name: Shigaara.

Distribution: Iran, Palestine, Israel, Syria, Arabia and Egypt (Map 22).



Map 22: Distribution of *Malcolmia pygmaea*

SPECIMENS EXAMINED:

EGYPT: **M**: 26 km, Sidi Krer, Alexandria-Matruh coastal road, K. Abdel Khalik 22 (SHG); Alexandria: M. Martins s.n., (BR); Bulkeley s.n., 13/3/1889 (B); P. Ascherson s.n., 13/3/1887 (B); R. Massie-Blomfield s.n., 1881 (NMGM); F. G. Walsingham 58 (K); Oliver s.n., (B); Mandara, B. G. Boland s.n., 2/3/1913 (CAIM); Mandara, M. Hefnawy s.n., 8/3/1929 (CAI); Abu Qir: Boulos s.n., 25/11/1959 (CAI); Aucher-Eloy s.n., (OXF & FHO); El Kantarah, El Arish, Laurent s.n., 1903 (BR); Bir Lehfen, S of El Arish, G. Täckholm, s.n., 21/3/1928 (CAI); Rafah, Persia, M. Drar s.n., 7/3/1937 (CAIM).

Nv: Alexandria-Cairo desert road 35 km from Alexandria, F. Saad s.n., 18/4/1959 (CAIM); Cairo, in Palmelis, Muschler s.n., 27/4/1910 (K). **Di**: Gebel Lehfn, J. R. Shabetai s.n., 17/8/1929 (CAIM); Wadi el-Mizeirie near G. el-Maghara, N Sinai, Boulos s.n., 24/4/1959 (CAI). **S**: Gebel Musa, Judith s.n., 23/4/1966 (CAI).

IRAN: North Iran, on the island Khārk, Bornmüller 57 (BM, BR, K, OXF & FHO); S. Iran, in sands near Buschir, Bornmüller 58 (B, K).

ISRAEL: Negev, NNW BeerSheba, Bernert s.n., 12/3/1982 (B); Negev, entrance Tureiba, Feinhrun 27694 (HUJ).

KUWAIT: Arafjan, Wuleson 14, 149 (K); Shaibah, 30 miles S of Kuwait, Wuleson 404 (K).

PALESTINE: sand dunes of Khan Junis, Boulos s.n., 14/1/1955 (CAI).

SAUDI ARABIA: Jubbah-An Nafud, J. S. Collenette 5707 (K).

4. Tribe Lunarieae O.E. Schulz

In Nat. Pflanzenfam. ed. 2, 17 B: 481 (1936).

Hairs usually absent, when present usually sparse and simple. Filaments free, without appendages. Fruit a silicule, flattened, dehiscent, broad; septum present or absent.

12. Ricotia L.

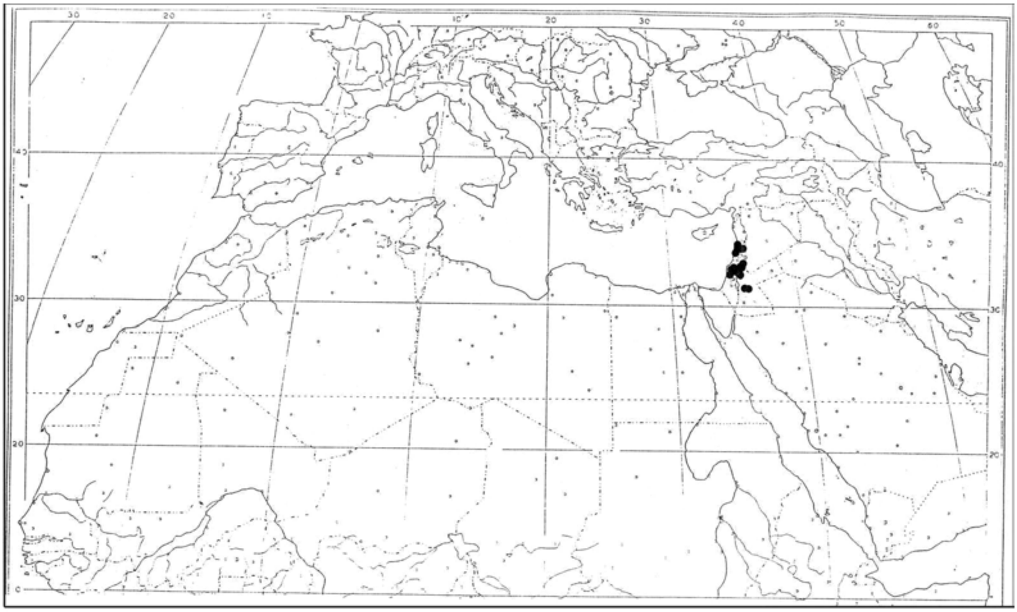
Sp. Pl. ed. 2: 912 (1763).

Annual or perennial herbs, glabrous or sparingly simple hairy. Stem procumbent, branching. Leaves petiolate, trifoliate or pinnate, entire. Inflorescence terminal or axillary, racemose. Flowers large, pedicellate. Sepals erect, 2-saccate. Petals pink or violet, clawed; limb emarginate or obcordate. Stamens 6; filaments free, edentate; anthers sagittate, acute; stigma capitate or 2-lobed. Fruiting pedicels deflexed. Fruit dehiscent, strongly flattened, lenticular to elliptical with a short apiculate style; valves flat, glabrous; septum delicate or absent. Seeds in one or two rows in each cell, compressed, orbicular, wingless; radicle accumbent.
9 species in the East Mediterranean region, one species in Egypt.

1. **Ricotia lunaria** (L.) DC., Syst. Nat. 2: 284 (1821); Boiss., Fl. Orient. 1: 254 (1867); Täckholm, Stud. Fl. Egypt ed. 1: 348 (1956); Zohary, Fl. Pal. 1: 282 (1966); Täckholm, Stud. Fl. Egypt ed. 2: 185 (1974); El Hadidi & Fayed, Taeckholmia 15: 46 (1994-1995); Boulos, Fl. Egypt Checklist 43 (1995); Boulos, Fl. Egypt 1: 205 (1999).
Basionym: *Cardamine lunaria* L., Sp. Pl. ed. 1: 656 (1753). Type: in Syria. (not seen).
Heterotypic synonym: *Ricotia aegyptiaca* L., Sp. Pl.2: 912 (1763). Type: in Egypt, herb. Linn. 833/1 (holotype: LINN; isotype: L).
Icon: Zohary, Fl. Pal.1: t.416 (1966).
Annual herbs 15-30 cm, glabrous or sparsely simple hairs. Stem procumbent, branching. Leaves trifoliate or pinnate, petiolate 0.5-3.6 cm; segments petiolate 0.2-1 cm, ovate or oblong, acute, dentate-crenate or entire. Inflorescence a raceme, few-flowered. Flowers large, pedicellate 0.4-1.9 cm. Sepals 4-8 mm, erect, saccate at the base. Petals with a 5-8 mm long claw and pink or white limb, 5-8 x 2-4 mm, obcordate to bifid. Filaments 4-7 mm, free, no teeth; anthers sagittate, acute, 2-2.5 x 0.3-0.4 mm; stigma capitate or 2-lobed. Fruiting pedicels 0.5-1.3 cm, curved or spreading. Fruits silicules, 0.6-3.7 x 0.3-1.4 cm, 2-celled becoming 1-celled when mature, strongly flattened, lenticular to elliptical with a short apiculate style; valves not veined, papery. Seeds brown, 2.5-8 x 2.2-7 mm, in one row, compressed, orbiculate, wingless; radicle accumbent.
Fl. & fr.: March-May.

Habitat: Rocky ground.

Distribution: Middle East (Syria, Palestine, Israel, Lebanon, Jordan and Egypt) (Map 23).



Map 23: Distribution of *Ricotia lunaria*

SPECIMENS EXAMINED:

EGYPT: Without location: 825 284 (BR); Hb. Prescot (OXF & FHO); Hb. Lyart (L); Willdenow collection (W); Portenschlager 1235 (W); Hb. Sehlmeyer, Spnogel s.n., 15/1/1819 (B).

ISRAEL: M. Israel, M. Boamums s.n., 8/12/1968 (L); Mt Carmel, Boissier s.n., April 1846 (L, LY); Haifa, on Mt. Carmel, J. Bornmüller 68 (BR, LY); Haifa, Mts. Carmel, Cothe 266 (L); Coast of Galilee, Rosh Hanniqra, J. Lorch 34049 (HUJ); Tel Abib, Mauh s.n., 1866 (OXF & FHO); Haifa, in Monte Carmel, H. Petry s.n., 9/4/1905 (B); Haifa, in Mt Carmel, H. Petry s.n., 12/4/1910 (B, LY); Haifa, in Mt Carmel, between rocks, G. Samuelsson 559 (B, K); Western upper Galilee, among rocks, M. Zohary 630 (B, BM, BR, L, OXF & FHO, WAG).

JORDAN: Magdala, J. E. Dinsmore 5343 (L); Magdala, B. T. Lowne s.n., April 1863 (OXF & FHO); Beit Lidon, Sabatiyek, herb. Postian 374 (BR); Al-Hamma, Walid Jallad 440 (CAI).

LEBANON: between the rocks, near the river of Aoulé, near Sidon, I. Blanche 1 (L, LY); Beyrout, G. Druce s.n., 1925 (OXF & FHO); calcareous rocks of Kamderoun, Sidon, C. Gaillardot s.n., 28/2/1813 (BR); Skanderun, near Sidon, C. Gaillardot s.n., March 1813 (B); Wadi Damier, stony slopes, Ghwaois 5374 (K); Shewlan, T. D. Maitlaud 94 (K).

PALESTINE: N Palestine, Kefr Kamma, 26/3/1884 (NMGM); Pimard 1846 (LY, OXF & FHO, WAG).

SYRIA: without location, M. Buysman 3118 (LY); Damascus, in a garden, unknown 1819 (W); Golan, Tel Abu Khanazir, A. Danin s.n., 26/4/1979 (WAG); Golan, Yahudiya forest, A. Danin et al. 45. 004 (B); Serg Karmel, A. Sterneck s.n., 4/4/1907 (LY).

5. Tribe Matthioleae O.E. Schulz

In Nat. Pflanzenfam. ed. 2, 17 B: 557 (1936).

Hairs simple, medifixed, stellate, branched or glandular. Sepals erect, the inner sepals saccate or not. Filaments free, linear, Without appendage or the inner winged towards the base. Median glands present or absent. Stigma usually with long decurrent lobe (horn-like), rarely ovoid. Fruit asiliqua, indehiscent or tardly dehiscent, hairy, horned or not. Radicle accumbent.

13. Diceratella Boiss.,

Diagn. Pl. Orient. Nov., Ser. 1, 5: 80 (1844); Jonsell, B., Bot. Notiser 131: 251-257 (1978) & Bot. Notiser 132 : 521-535 (1979).

Subshrubs, densely covered with branched and stellate hairs. Stems woody, grey to whitish, erect, branched. Leaves petiolate, ovate to elliptical, obtuse, attenuate at base, covered with stellate hairs. Racemes ebracteate, mostly with showy flowers, much elongated in fruit. Sepals not saccate with narrow hyaline margins. Petals white or lilac, mostly clawed, the lamina obtuse apex. Stamens 6, distinctly tetradynamous; filaments linear, free; anthers long, linear to subulate, acute to obtuse. Nectaries at each side of each lateral stamens. Fruiting pedicels as thick as fruits, erect, hairy. Fruit a siliqua, tardily dehiscent, linear, straight or slightly curved; style very short; stigma sessile, conoidal bifid; valves keeled or not, without horns, with 1 midrib, contains marked thickenings on the inner side; septum thick. Seeds in one row in each locule, compressed, brown, ovate to suborbicular, with narrow wing, mucilaginous; radicle accumbent.

7 species in NE tropical Africa, Arabia, Iran and Egypt; only one species in S. Egypt.

1. **Diceratella elliptica** (DC.) Jonsell, Bot. Notis.132: 526 (1979); Jonsell, in Fl. Trop. East Afr.60 (1982); El Hadidi & Fayed, Taeckholmia 15: 44 (1994-1995); Boulos, Fl. Egypt Checklist 41 (1995); Boulos, Fl. Egypt 1: 199 (1999).

Basionym: *Matthiola elliptica* DC., Syst. Nat.2: 167 (1821)

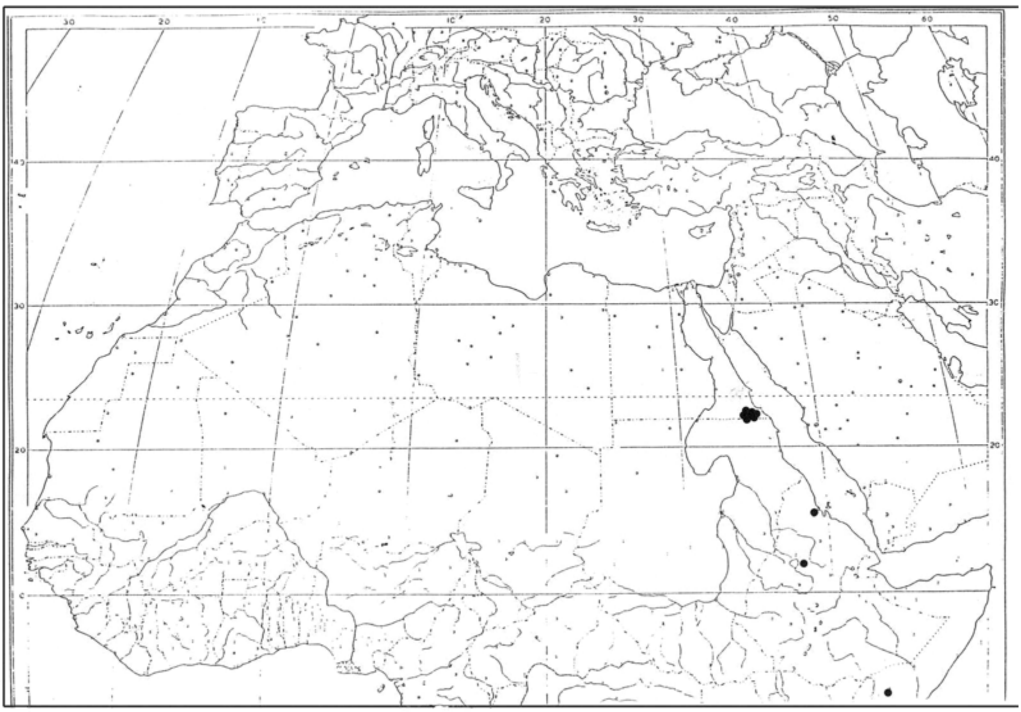
Type: In Abyssinia near the base of Mt. Taranta, Salt s.n., 1810 (holotype: BM).

Homotypic synonym: *Pirazzia elliptica* (DC.) Chiov., Nuov. Giorn. Bot. Ital., n. s., 26: 147 (1919).

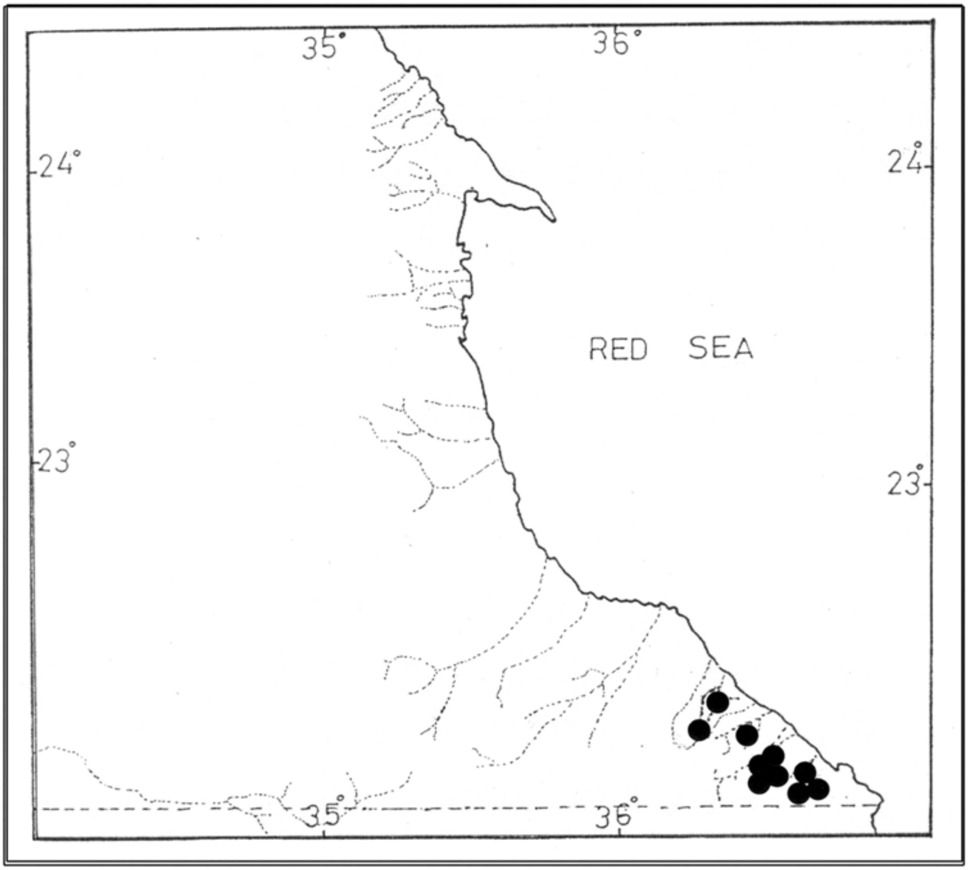
Icon: Täckholm, Stud. Fl. Egypt ed. 2: 182, t. 53 B (1974). As *Matthiola elliptica* DC.

Subshrubs, 50-75 cm hight, grey, canescent with simple and stellate hairs. Stems woody, rigid, whitish, erect or ascending, branched from base. Leaves 1.1-3.6 x 0.6-2.1 cm, petiolate 0.5-2.1 cm, crowded at base, elliptic to ovate, entire or slightly toothed margin, obtuse apex to attenuate at base, covered with stellate hairs. Racemes ebracteate, elongating in fruits. Flowers

pedicellate 3-5 mm. Sepals 1.7-1.8 cm long, linear, hairy. Petals 2.8-3 cm long, white to lilac, long claw and obovate lamina distinct, margin entire and apex rounded. Filaments 6-9 mm long, linear, free; anthers oblong-linear, 4 mm long. Fruiting pedicels 4-7 mm, as thick as fruit, erect, hairy. Fruits 2.5-6 x 0.1-0.2 cm, tardly dehiscent, linear, patent, straight or slightly curved, hairy; style short, thick; stigma ovoid, as thick as fruit, with divergent lobes; horns absent; valves with distinct 1-midrib, keeled, with transverse septa or internal projections from the lower side; septum thick. Seeds in one row in each locule, light brown, elliptic to suborbicular, 1-1.1 x 0.8-1 mm, compressed, with a very narrow wing; radicle accumbent.
Fl. & fr.: January-April.
Habitat: rocky slopes and wadis; 300-1000m.
Vernacular names: Bishari, Hamboak (Egypt).
Uses: grazed by camels and sheep.
Distribution: Sudan, Ethiopia, Somalia, Djibuti, Kenya and Egypt (Mt. Elba) (Map 24).



Map 24: Distribution of *Diceratella elliptica*



Map 25: Distribution of *Diceratella elliptica* in Egypt

SPECIMENS EXAMINED:

EGYPT: **Sa**: Gebel Elba: M. Hassib s.n., 25/1/1930 (CAI); Wadi el Shallal, K. Abdel Khalik 16 & 17 (SHG); Gebel Todgesh, J. R. Shabetai s.n., 27/3/1936 (CAIM); Täckholm, G., 27/1/1929 (CAIM); Wadi Yahameib, Täckholm et al. s.n., 22/1/1962 (CAI); Wadi Saremtai, Täckholm et al. s.n., 23/1/1962 (CAI); Wadi Siamtit, Täckholm et al. s.n., 23/1/1962 (CAI); Khor across Gebel Shallal, Täckholm et al. s.n., 24/1/1962 (CAI); Wadi el Shallal (Bir area), Täckholm et al. s.n., 24/1/1962 (CAI); Gebel Gogart, Täckholm et al. s.n., 7/2/1962 (CAI); Gebel Karam Elba, Täckholm et al. s.n., 7/2/1962 (CAI); Wadi Mera Kwan, Täckholm et al. s.n., 10/2/ 1962 (CAI); Wadi Rabdeit, Gebel Rabdeit, S. Elba, M. Drar s.n., 21/1/1933 (CAIM); Gebel Rabdeit, J. R. Shabetai s.n., 22/3/1933 (CAIM).

ETHIOPIA: base of Mt. Taranta, Salt s.n., 1810 (BM); Lgscha-Lgschas, Schimper 1194 (BR); Jlaichello Kokab, Au Mard O, acrowr 1600 m, Schweinfurth & Riva 1107 (BR).

KENYA: Mandera distr., 4 km on the Mandera-Ramu road, Red sandy soil, alt. 290 m, M. G. Gilbert & M. Thulin 1373 (BR, WAG).

14. **Matthiola** R. Br.,

In Ait., Hort. Kew. ed. 2, 4: 119 (1812).

Annual or perennial herbs, tomentose or canescent with simple, stellate, branched (dendroid or forked), and glandular hairs. Stems erect or ascending, branched, rigid or herby. Leaves simple, entire or dentate to pinnatifid, lanceolate, linear or oblanceolate, petiolated or sessile. Inflorescences racemose, ebracteate. Flowers usually large, sessile or pedicellated. Sepals erect, the inner one saccate. Petals white, purple, livid to cream, linear, oblong or obovate, clawed, margin entire to undulate, obtuse or retuse at the apex. Stamens 6; filaments free, the inner filaments winged towards the base; anthers linear to oblong. Lateral nectar glands annular or horse-shoe shaped (semilunar); middle glands absent. Fruiting pedicels often short ± thick, erect or ascending. Fruit a linear siliqua, many seeds, indehiscent or late dehiscent, straight or contort or slightly curved, hairy or glabrous, compressed to terete; style indistinct; stigma two decurrent lobes, each lobe horn like or ovoid; valves with a distinct midrib, not keeled, without transverse septa or internal projections from the lower side; septum thick, not veined. Seeds in one row in each locule, compressed, ovoid to oblong, brownish, narrowly winged; radicle accumbent.

About 55 species in Macaronesia, W. Europe, Mediterranean region; only 4 species in Egypt.

Key to the species:

1a. Perennials, woody at the base. Fruits with or without horned apex………………...……..…**2**

1b. Annuals, rigid at the base. Fruits with two-horned apex…..…………………..…………….**3**

2a. Plants 35-80 cm high. Leaves 0.8-8.5 x 0.2-1.1 cm, linear to lanceolate, entire. Petals 1.7-2 cm, livid. Fruiting pedicels 2-5 mm long. Apex of fruits without hornes …..**1. M. arabica**

2b. Plants 15-30 cm high. Leaves 1.5-4 x 0.1-0.3 cm, linear-oblong to narrow oblanceolate, entire to narrow toothed, rosettes. Petals 1.5-2 cm, yellowish to purple. Fruiting pedicels 1-1.5 mm long. Fruits with two horns 2.5-3 mm long or hornless…………...**2. M. fruticulosa**

3a. Petals 0.7-1.2 cm. Lateral horns 3-5 mm, straight to upcurved; with two small appendages beside the lateral horns…………………………………………….……………**4. M. parviflora**

3b. Petals 1.5-2.2 cm. Lateral horns 2-8 mm, horizontally to upcurved, or incurved; without appendages beside the lateral horns……………………………...….….**3. M. longipetala**

1. **Matthiola arabica** Boiss., Ann. Sci. Nat. Bot., ser. 2, 17: 49 (1842); Boiss., Fl. Orient. I: 152 (1867); Täckholm, Stud. Fl. Egypt ed. 1: 345 (1956); Zohary, Fl. Pal. I: 271 (1966); Täckholm, Stud. Fl. Egypt ed. 2: 180 (1974); El Hadidi & Fayed, Taeckholmia 15: 44 (1994-1995); Boulos, Fl. Egypt Checklist 41 (1995); Boulos, Fl. Egypt 1: 200 (1999).

Type: Sinai, Boissier 132 (Holotype: G; isotype: B, K)

Heterotypic synonym: *Matthiola tristis* R. Br., in Ait. Hort. Kew. ed. 2, 4: 120 (1812).

Type: Between hard rocks of Sinai mountains, W. Schimper 314, 26/5/1835 (holotype: BM, isotype: E).

Icon: Zohary, Fl. Pal.1, t. 395 (1966).

Perennial herbs, 35-80 cm high, canescent, densely covered with stellate, dendroid and glandular hairs. Stems erect or ascending, rigid, branched from the base, greyish-white, leafy. Leaves 0.8-8.5 x 0.2-1.1 cm, crowded at the base, linear to lanceolate, entire, acute or obtuse, canescent with stellate hairs, the lower petiolated 0.6-3.3 cm long; the cauline one sessile to subsessile. Racemes ebracteate. Flowers large, sessile or short pedicellate 1-2 mm. Sepals 9-10 mm long, linear-oblong, entire, obtuse, tomentose. Petals 1.7-2 cm long, white to livid, linear-oblong, entire to undulate, retuse at the apex. Filaments 4-6 mm, linear, free, the inner one broader than outer; anthers 2.5-3 mm, oblong. Fruiting pedicels 2-5 mm long, thick as fruit, hairy. Fruit a siliqua, 2-5.3 x 0.1-0.13 cm, spreading, straight or curved, hairy; style short, 1mm long, glabrous; stigma ovoid, with slightly 2-lobed, sometimes broader than fruit; horns absent; valves with 1-midrib, smooth from inside, rigid; septum thick. Seeds many in one row in each cell, brownish, oblong, 1.1-1.3 x 0.7-0.8 mm, narrow winged; radicle accumbent.

Fl. & fr.: March-May.

Vernacular names: Chomchom or Khomkhom, Homhom (in Sinai).

Habitat: stony places in deserts.

Uses: eaten by camels and sheep in Sinai.

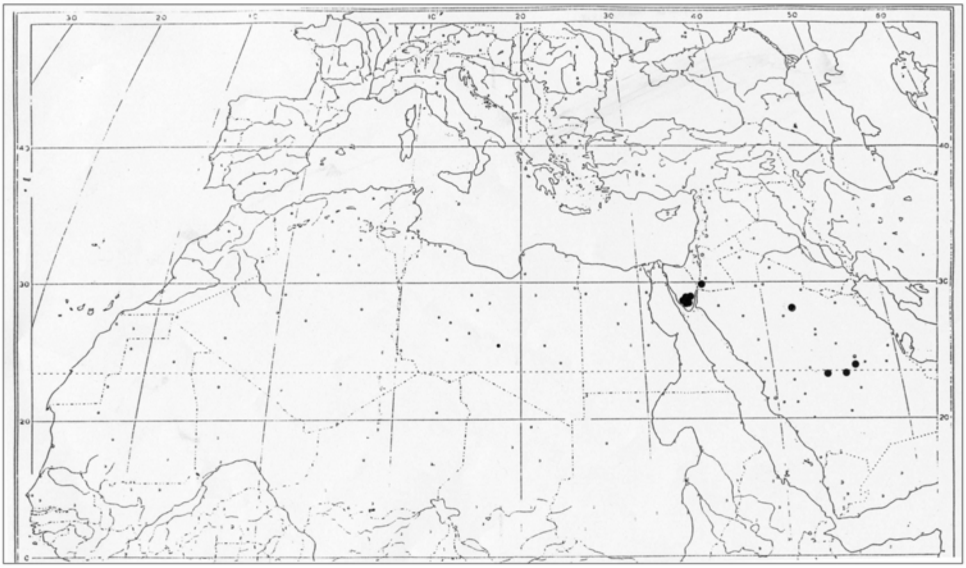
Distribution: Saudi Arabia, Palestine, Jordan and Egypt (Sinai) (Map 26).

SPECIMENS EXAMINED:

EGYPT: **S**: Sinai, Aucher 132 (B, K); Sinai, Herb. Du Mortier s.n., (BR); Sinai desert, N. Bove 133 (BR); Sinai desert, C. G. Ehrenberg 197 (L); Sinai mountainous region, M. Hassib s.n., April 1940 (CAI); Between hard stony of Mountains Sinai, W. Schimper 314 (BM); Sinai, Wadi Islaa, M. Hassib s.n., April 1940 (CAI); Gebel Musa, Mohamed Gibaly s.n., 31/3/1989 (CAI); top of Gebel Musa, S. Sinai, Täckholm et al. s.n., 24/4/1961 (CAI); the area up to 25 km NE of St. Catherine Monastery, S. Sinai, Darwish El Far s.n., 3/4/1955 (CAI); Mt. Sinai, St. Catherine Monastery, Hepper 8747 (K); near the Monastry of St. Catherine, Danin s.n., 24/4/1968 (HUJ); Wadi Catherine, S. Sinai, M. Abdallah & A. Khattab s.n., 20/4/1962 (CAIM); Wadi El Arbaien, Boissier s.n., March, 1846 (BR, L); Wadi El Arbaien, back of Gebel Catherine, S. Sinai, A. Abbas s.n., 2/4/1980 (CAIM); Wadi El Arbaien, S Sinai, K. Abdel Khalik 12 (SHG); Wadi El Arbaien, S Sinai, Abdei Raaof s.n., 15/10/1983 (CAI); St. Catherine, grown in the botanical garden on Mt. Scopus, No.2026 (B); in the vicinity of St. Catherine Monastery, S. Sinai, Boulos s.n., 10/4/1963 (CAI); Gebel el Deir outside the Monastery of St. Catherine, S Sinai, El Hadidi s.n., 10/5/1956 (CAI); in the garden of small Monastery to left the road leading to the St. Catherine, 10 min. walk from there, Täckholm et al. s.n., 10/5/1956 (CAI); Wadi Razana, S. Sinai, Abdel Raaof s.n., 10/4/1983 (CAI).

SAUDI ARABIA: Hail-Jubbah road, between Qullan-Qana, Collenette 5714 (K); Al-Cabd; Kal'a Sorar; Nefud, Hemhem, A. Musil s.n., 1909 (W).

JORDAN: Aqaba, 12 km N of Aqaba, along the road to Amman, Dawud Al Eisawi 2904 (B); 15 km NE of Aqaba, wadi Ithm, Zohary & Feinbrun 32903 (HUJ).



Map 26: Distribution of *Matthiola arabica*

2. **Matthiola fruticulosa** (L.) Maire in Jahand. & Maire, Cat. Pl. Maroc. 2: 311 (1932); Cullen, in Fl. Turkey vol.1: 449 (1965); Täckholm, Stud. Fl. Egypt ed. 2: 181 (1974); Jafri, Fl. Libya 23: 150 (1977); Tutin et al. Fl. Eur. ed. 2, vol.1: 341 (1993); El Hadidi & Fayed, Taeckholmia 15: 44 (1994-1995); Boulos, Fl. Egypt Checklist 44 (1995); Boulos, Fl. Egypt 1: 200 (1999).

Basionym: *Cheiranthus fruticulosus* L., Sp. Pl. ed. 1: 662 (1753).

Type: Described from Spain, Italy and Montpellier, herb. Linn. 839/13 and 14 (holotype: LINN).

Heterotypic synonyms: *Matthiola coronopifolia* DC., Syst. Nat. II: 173 (1821).

Type: in rocky or stony places near Monastry of Parco in Sicilia, near Panormum (Bocc.); in Mt. near Athens (Sibth.) (not seen).

Cheiranthus coronopifolia Sibthorp, in Fl. Graec. Prodr.2: 25 (1813). Type: in Mt. near Athens (4) (not seen).

Matthiola tristis Boiss., Fl. Orient. I: 153 (1753). Type: in Siccis totius Graeciae Abyzantio (Noë) (holotype: G).

Cheiranthus tristis L., Syst. Nat. ed. 10: 1134 (1759). Type: in Italy, herb. Linn.839/23 (holotype: LINN).

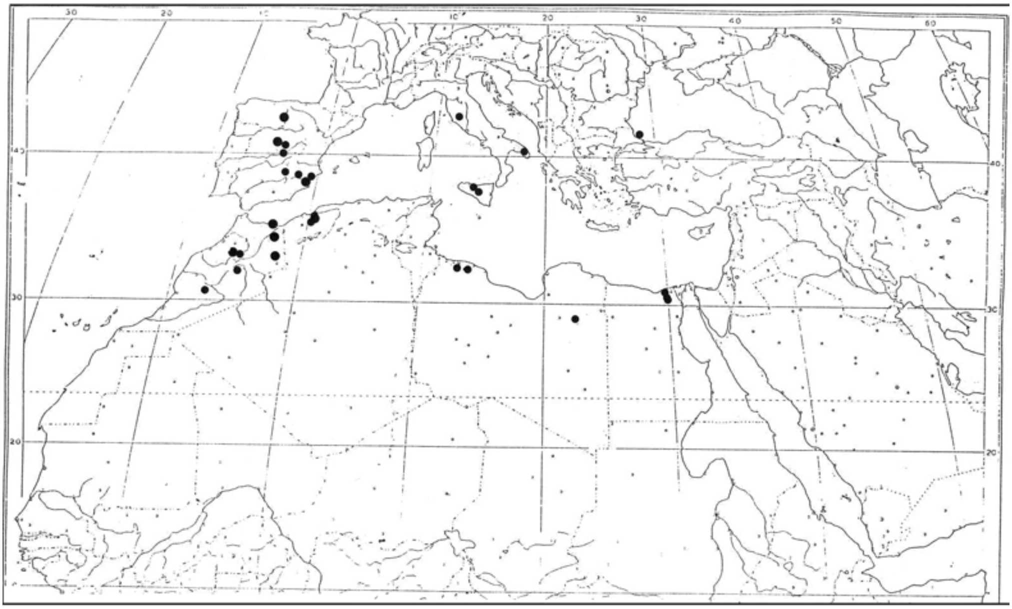
Icon: Jafri, Fl. Libya 23, 151, t.45 (A-D) (1977).

Perennial herbs 15-30 cm, woody at the base, covered with simple, 2-or 4-fid and stellate hairs. Stems branched from the base, erect or ascending. Leaves 1.5-4 x 0.1-0.3 cm, in rosettes, linear-oblong to narrowly oblanceolate, entire, rarely toothed, petiolate 1-2 cm to subsessile, hairy. Inflorescence racemose, elongating in fruit. Flowers subsessile to short-petioled, 1 mm long. Sepals 7-11 mm long, erect, lanceolate, hairy. Petals 1.5-2 cm, yellowish to purble, claw and limb distinct, margin entire to slightly undulate, obtuse at apex. Filaments 3-6 mm, free, linear; anthers 1.5-2.5 mm long, sagittate to oblong. Fruiting pedicels 1-1.5 mm long, hairy, as thick as fruit. Fruits 4-7 x 0.1-0.15 cm, tardily dehiscent, straight or curved upwards, torulose, spreading, covered with stellate hairs; stigmatic appendages (horns) straight or upcurved, 2.5-3 mm long or hornless; stigmatic head 1-1.5 mm, slightly divergent; valves hairy, with one nerved; septum submembranous. Seeds in one row in each locule, oblong, brown, winged, 2.2 x 1.2 mm; radicle accumbent.

Fl. & fr.: March-May.

Habitat: sandy soils

Distribution: S. Europe, Cyprus, Lebanon, Turkey and N. Africa (Egypt to Morocco) (Map 27).



Map 27: Distribution of *Matthiola fruticulosa*

SPECIMENS EXAMINED:

ALGERIA: Mostaganem, D'Alleizette 337 (B); Mostaganem, on the dry hills, Balansa 41 (WAG); sandy clay area in Chott el Rarbi, SW of the prov. of Oran, Kralik 239 (WAG) and 11563 (BM).

EGYPT: **M**: Alexandria, N. B. Ward 34 (K). **Nv**: growing in field to the right of the desert road Cairo-Alexandria a little S of Amria, Täckholm et al. s.n., 2/4/1961 (CAI); Cairo-Alexandria desert road S of Amria, Täckholm et al. s.n., 31/5/1961 (CAI); Cairo-Alexandria desert road, 180 km from Cairo, Täckholm et al. s.n., 16/4/1967 (CAI).

LIBYA: Jefren, K. M. Guichard Kg/Li 578 (BM); Cyrenaica, Wadi el-Atrun, R. Pampanini 3166 (BR); Dunes W of Tripoli, René du Parquet s.n., March 1867 (BM).
MOROCCO: prov. Oujda, Taourirt-Debdou, 14 km S Taourirt, Bayōn et al. s.n., 13/4/1987 (B); Plain about 15 km W of Midelt near of Oued Ansegmir, W. de Wilde & Dorgelo 2496 (WAG); 29 km WSW of Tazenakht, main road to Ouarzazate, near Kourkouda, S. Jury 14495 (BM); Mts. Atlas, Adaou-Atlarh, near town Tounfite, C. G. van Steenis 19399 (L); Middle Atlas, road p 20, between Sefrou and Boulmane, 9 km N Boulmane, Vogt 10331 & Oberprieler 4779 (B); prov. Figuig, road p 19 between Bouarfa and Oujda, 5 km N Tendrara, Vogt 10623 and Oberprieler 5071 (B); Mts of Beni Snassen, road from Beni Ammar to Taforalt, 2.5 km W Sidi Yahia Ben-Ahmed, Vogt 11270 & Oberprieler 5718 (B).
ITALY: in calcareous soil, Sicily, near Caltanisetta, Heldreich s.n., 17/4/1840 (WAG); in calcareos soil near S. Martano, Huet du Pavillon s.n., 2/4/1855 (WAG); in calcareas soil near Nebrodum, near Isnello, A. Huet du Pavillon s.n., 19/6/1855 (WAG); in calcareais soil, reg. Montiano, Ross 207 (WAG).
SPAIN: Prov. Zaragoza, between Munébrega and Calatayud, J. H. Boerboom 80023 (WAG); Valley of S. Juan de Alcaras, in the Ravines, E. Bourgeau 569 (WAG); sandy hills of Abaza, E. Bourgeau 1067 (WAG); Cerro de Aranjuez, E. Bourgeau 2096 (WAG); 5 km from Finestrat, W Border of Lemon orchard, C. C. Jongkind 774 (WAG).
TURKEY: Istanbul near sea, Noë 8 (BR).

3. **Matthiola longipetala** (Vent.) DC., Syst. Nat.2: 174 (1821); Cullen, in Fl. Turkey vol. 1: 449 (1965); Zohary, Fl. Pal. 1: 272 (1966); Rechinger, K. H., in Fl. Iran No.57/28.2: 239 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 181 (1974); Jafri, Fl. Libya 23: 153 (1977); Collenette, Illust. Flow. Pl. Saudi Arabia 203 (1985); Tutin, T. G., et al. Fl. Eur. ed. 2, vol. 1: 341 (1993); El Hadidi & Fayed, Taeckholmia 15: 44 (1994-1995); Boulos, Fl. Egypt Checklist 41 (1995); Boulos, Fl. Egypt 1: 201 (1999).
Basionym: *Cheiranthus longipetalus* Vent., Descr. Pl. Jord. Cels., t. 93 (1803).
Type: Iraq, Baghdad, Oliver & Bruguiére s. n. (holotype: B, isotype: L).
Heterotypic synonym: *Matthiola oxyceras* DC., Syst. Nat. 2: 173 (1821).
Syntypes: In desert sand near Damascus (Labillardiere); between Kermanshah and Amadan in Iran (Oliver) (holotype: K); between Aleppo and Mosul (Oliver) (holotype: K).
5 subspecies occur in Egypt.
Key to subspecies:

1a. Stem short (5-23 cm), prostrate or ascending; juvenile leaves in rosette; petals obovate, entire; fruits 3-5 x 0.15-0.22 cm; lateral horns 3-5 mm, straight to upcurved; seeds suborbicular…………... .. ……………………………………………………**2**. subsp. **hirta**
1b. Stem long (15-50 cm), erect or ascending; juvenile leaves not in rosetta; petals linear or oblong-obovate or oblong-spathulate, undulate or entire; fruits 3.5-6.5 x 0.1-0.2 cm; lateral horns 2-8 mm, horizontal or straight to upcurved or incurved; seeds ovoid or oblong…. …**2**
2a. Plant covered by stellate, branched and glandular hairs, glutinous; fruits straight or slightly curved, covered with glandular, branched and stellate hairs; horns 2-4 mm, hairy, acute….…………………………………………………………………**4**. subsp. **livida**

2b. Plant covered by stellate, branched and sometimes glandular hairs in the lower part; fruits straight or slightly curved or contorted, covered with stellate and branched hairs; horns 2-8 mm, hairy, spreading or strongly incurved…………………………………………………..…**3**

3a. Fruits straight or contorted; lateral horns 2-8 mm, horizontal or slightly recurved; petals 1.5-2.2 cm long; seeds oblong………….………………………………**5**. subsp. **longipetala**

3b. Fruits straight or slightly curved; lateral horns 2-8, horizontal or straight to incurved or upcurved; petals 1.2-1.7 cm long; seeds ovate or oblong…………………..……………**4**

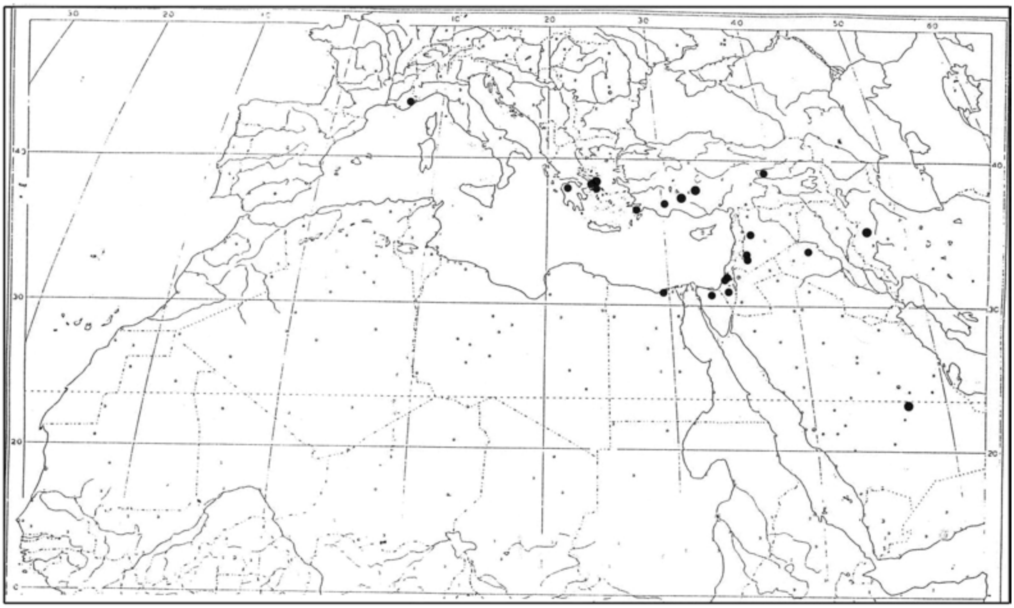
4a. Fruits 3-5 x 0.1-0.15 cm, easily deciduous, canescent with whitish hairs; lateral horns 2-4.5 mm long, variable from horizontal to upcurved or deflexed; valves with slightly basal appendages; petals obovate-oblong, margin entire to undulate; seeds ovate to slightly oblong…………………………………………………………………**3.** subsp. **kralikii**

4b. Fruits 3-6.5 x 0.1-0.15 cm, not deciduous, canescent with yellow-green hairs; lateral horns 4-8 mm long, straight or strongly incurved; valves without basal appendages; petals oblong-spathulate, entire margin; seeds oblong…………………………...**1**. subsp. **bicornis**

1. Subsp. **bicornis** (Sibth.) P.W. Ball, Feddes Repert. 68: 194 (1963); Cullen, in Fl. Turkey vol. 1: 450 (1965); Zohary, Fl. Pal. 1: 273 (1966); Täckholm, Stud. Fl. Egypt ed. 2: 181 (1974); El Hadidi & Fayed, Taeckholmia 15: 45 (1994-1995); Boulos, Fl. Egypt 1: 201 (1999).
Basionym: *Cheiranthus bicornis* Sibthorp, in Fl. Graec. Prodr. 2: 26 (1813).
Type: Greece, without location, Hb. Sibthorp s. n. (holotype: OXF & FHO).
Homotypic synonym: *Matthiola bicornis* (Sibthorp) DC., Syst. Nat. 2: 177 (1821).
Icon: Gustav Hegi, Illust. Fl. Central Europe, Vol. IV-I, Fig. 881 (N, O), 470 (1919).

Annual herbs, 15-35 cm, tomentose or pubescent with appressed stellate, branched or sparingly glandular hairs. Stems branched from the base, rarely leafy, procumbent. Leaves 2-8 x 0.3-1 cm, sessile or petiolate at the base 0.5-1.1 cm, crowded at base, linear-lanceolate, sinuate-dentate or entire, acute at apex, covered with stellate hairs. Inflorescence elongating in fruit. Flowers large, sessile. Sepals 8-9 mm, saccate at base, hairy, lanceolate. Petals 1.5-1.8 cm, pink to mauve, oblong-spathulate, entire, limb obtuse and claw yellow. Filaments 3-5 mm, free, linear; anthers 2.5-3 mm, sagittate-oblong. Fruiting pedicels 1-2 mm, hairy, as thick as fruit. Fruits 3-6.5 x 0.1-0.15 cm, straight or slightly curved, horizontally spreading, stiff, hairy with stellate and branched hairs, terete; stigma short, obtuse, divergent or slightly 2-lobed; horns of fruits 4-8 mm, straight or strongly incurved, hairy, acute, triangular; valves 1-nerved, hairy; septum submembranous to firm. Seeds in one row in each locule, brown, oblong, 1.5-1.8 x 0.7-1 mm, winged; radicle accumbent.
Fl. & fr.: March-May.
Habitat: sandy soils.
Vernacular names: Shigaara, Ghobbeisha (Egypt).

Distribution: Cyperus, Greece, France, Turkey, Syria, Israel, Palestine, Iraq, Saudi Arabia, Libya and Egypt (Map 28).



Map 28: Distribiution of *Matthiola longipetala* subsp. *bicornis*

SPECIMENS EXAMINED:

EGYPT: **M**: Alexandria-Matruh coastal road, near Burg el Arab, K. Abdel Khalik 24 (SHG). **Di**: Wadi el Arousiya, Gebel el Maghara, N Sinai, Boulos s.n., 28/4/1959 (CAI).

IRAN: prov. Kurdistan, between Sanandaj and Salavatabad, Rechinger 42822 (B).

IRAQ: between Ramadi and Rutba, 260 km to Ramadi, K. H. Rechinger 12643 (BR).

ISRAEL: Jerusalem, Judean Mts., A. Danin s.n., 16/4/1992 (B); Negev, Tel-Arad, Eig 32996 (HUJ); Negev, Wadi Masri, Zohary 33014 (HUJ).

PALESTINE: Gaza and Fehud, H. Amstel s.n., 11/3/1930 (B).

SAUDI ARABIA: Hilwah, near Al-Hawtah, Al-Farhan and Thomas 10332 (KSU).

SYRIA: Damascus, calcareous hill, between Messw and Raborie, Gaillardot 697 (B); near town of Damascus, Gaillardot 1526 (B); near Kāfāt, 15 km E of Hama, W. Licht s.n., 29/3/1979 (B).

FRANCE: Gorbio, Alpes maritimes, J. Weill 5961 (L).

GREECE: prov. Attica, growing among wheat, de Heldreich s.n., April 1847 (WAG); de Heldreich 118 (WAG); Attica, near Athens, de Heldreich 1109 (B); prov. Attica, Mégara, among rocks, M. Oosten s.n., 21/4/1959 (WAG); near Athens, in sand, T. G. Orphanides 157 (WAG); S Rhodos, SE of Asklepios. C. G. van Steenis 21420 (L).

TURKEY: Prov. Antalya, near the fall of the Düden-Köy at the top of the Cliffs, W. J. de Wilde et al. 412 (L); prov. Konya, between Eregli and Ulukisla, along the road Konya-Adana, W. J. de Wilde et al. 1019 (L); H. Ern 22 (B); Tassia, in sands near Saban Daği, C. Haussknecht 4379 (BR); Antalya, 270 km NW of Antalya, Nebrer, Kehl 17-18/15/II (B).

2. Subsp. **hirta** (Conti) Greuter and Burdet, Willdenowia 13 (1): 94 (1983); El Hadidi & Fayed, Taeckholmia 15: 45 (1994-1995); Boulos, Fl. Egypt Checklist 42 (1995); Boulos, Fl. Egypt 1: 201 (1999).

Basionym: *Matthiola pumilio* (Sibth.) subsp. *hirta* P. Conti in Mém. Herb. Boissier 18: 69 (1900). Type: in insula Rhodo, (Sibthorp) (holotype: OXF & FHO).

Homotypic synonym: *Matthiola longipetala* subsp. *pumilio* (Sibth. and Sm.) P. W. Ball in Fedde rep. 68: 194 (1964); Täckholm, Stud. Fl. Egypt ed. 2: 181 (1974); Jafri, Fl. Libya 23: 154 (1977).

Heterotypic synonyms: *Matthiola humilis* (Clarke) DC., Syst. Nat. 2: 177 (1821).

Cheiranthus humilis Clarke, Travels 2 (2): 42 (1814).

Type: In Egypt, near Rosetta, Clarke (holotype: BM).

Matthiola longipetala subsp. *aspera* (Boiss.) Täckholm & Boulos, in Publ. Cairo Univ. Herb.5: 35 (1974). Type: Israel, in hot desert of Juda between S Saba and Dead Sea.(holotype: G).

Icon: Jafri, Fl. Libya 23, 152, t. 46 (A-F) (1977). As *M. longipetala* subsp. *pumilio*.

Annual herbs 5-23 cm, covered with short and long birsty hairs, simple, 2-4 branched or glandular hairs especially in sepals. Stem short, often spreading or procumbent, branched from the base. Leaves 3-6 x 0.4-0.8 cm, rosette in juvenile stage, linear to lanceolate, petiolate 1.5-3 cm at the base to sessile in the upper one, pinnatifid to dentate or entire at the upper, tomentose with stellate hairs. Flowers sessile to subsessile. Sepals 5-8 mm, lanceolate, covered with simple, branched and glandular hairs from outside. Petals 1.5-1.8 cm, distinct into limb purple, obovate, obtuse or slightly emarginate apex, entire margin and yellow claw. Filaments 3-5 mm, free, linear; anthers 2-2.5 mm, sagittate. Fruiting pedicels 1 mm long, hairy. Fruits 3-5 x 0.15-0.22 cm, stiff, straight, erect or spreading, covered with stellate hairs; lateral horns 3-5 mm, straight to upcurved; terminal horn slightly shorter than lateral horns, 1-1.5 mm long; valves stiff, 1-nerve; septum submembranous. Seeds in one row in each locule, sub-orbicular, yellow-brownish, 1-1.3 x 0.9-1 mm, narrow winged; radicle accumbent.

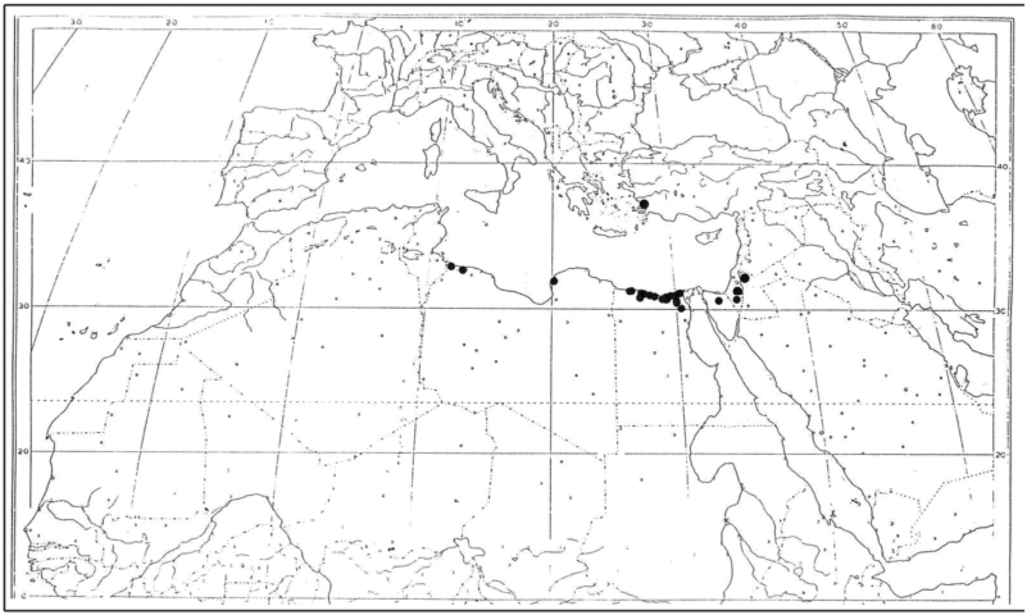
Fl. & fr.: March-May.

Habitat: sandy plains and wadi bed.

Vernacular names: Shigaara, Ghobbeisha (Egypt).

Uses: eaten by camels and sheep.

Distribution: Mediterranean region of Europe and N. Africa, Eastwards to Arabia (Map 29).



Map 29: Distribution of *Matthiola longipetala* subsp. *hirta*

SPECIMENS EXAMINED:

EGYPT: **M**: Barley fields 95 km, East of Sallum, Täckholm et al. s.n., 26/5/1963 (CAI); Wadi Garawla near Matruh, Amal Amin s.n., 24/4/1973 (CAI); on the coastal road 46 km before Matruh, Täckholm s.n., 17/2/1965 (CAI); El Garawla 25 km East Mersa Matruh, Täckholm s.n., 1/4/1972 (CAI); Between El Kersa and Ras el Hilal, Boulos s.n., 26/4/1973 (CAI); Ras el Hekma, Täckholm et al. s.n., 2/6/1964 (CAI); el Daba, William Girgis s.n., 16/4/1972 (CAI); SW of Alamein, G. Murray s.n., 1928 (BM); on the way between Burg el Arab to Alamein, Täckholm s.n., 17/2/1965 (BR, CAI); between Burg el Arab and el Hammam, Tackhom and El Hadidi s.n., 20/3/1975 (CAI); Burg el Arab, sandy soil, A. Khattab s.n., 7/4/1948 (CAI); near Burg el Arab, K. Abdel Khalik 23 (SHG); Ikingi Mariut, G. Täckholm s.n., 22/1/1928 (CAI); in the fields around Ikingi Mariut, Täckholm s.n., 7/4/1967 (CAI); Mariut, Bot. Dep. Excursion s.n., Spring 1956 (CAI); Mariut, W. Barbey 49 (B); Amria, West of Alexandria, Boulos s.n., 26/3/1954 (CAI); Amria, near Alexandria, A. J. Wilmott 390322 (BM); Alexandria, C. G. Ehrenberg s.n., 1820-1826 (L); Alexandria, Muschler s.n., 14/4/1903 (B); Alexandria, Parquet s.n., 9/4/1872 and 7/5/1872 (BM); Alexandria, Mariut, J. Bornmüller 10308 (BM); Alexandria, Kralik s.n., 9/3/1847 (BM); Montazeh, Alexandria, Morcos Schenuda 1522 (BR); between Alexandria and Mamorah, Parquet s.n., 7/5/1872 (BM); Mamorah, Parquet s.n., 2/4/1872 (BM); near Mamorah, Parquet s.n., 15/4/1872 (BM); Abu Qir, Hassib s.n., 9/3/1945 (BM); Abu Qir, G. Täckholm s.n., 26/3/1927 (CAI). **Nv**: on the agricultural road Alexandria-Cairo, 10 km S of Alexandria, M. Zahran s.n., 8/11/1977 (CAI); Cairo Alexandria desert road, South of Amria, Täckholm et al. s.n., 31/5/1962 (CAI); Wadi Natrun, pure desert, R. Meinertzhagen s.n., 1928 (BM). **Di**: E. Sinai, Wadi Gedeirat, R. Meinertzhagen s.n., 1928 (BM). **S**: Without location, R. Meinertzhagen s.n., 1928 (BM).

LIBYA: Sabrata, Boulos 1518 (CAI); road Agedabia-Mersa el Bregha, Léonard 5085 (BR); Benghazi, G. Ruhmer 21883 (B).

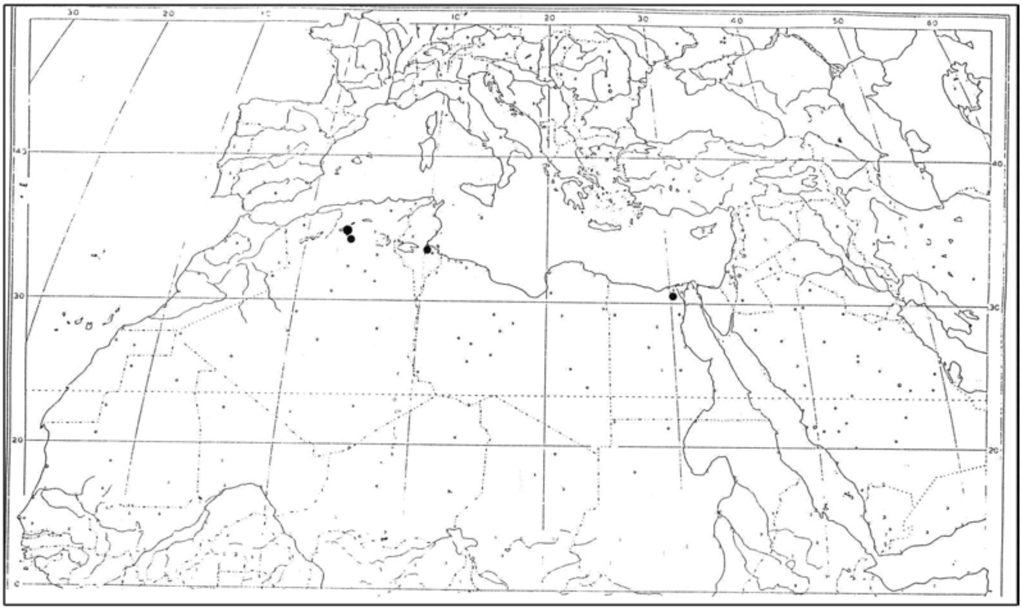
ISRAEL: Dead Sea valley, near Ormats Solar pounds, 2 km N of the Dead Sea northern coast, A. Danin et al. 0.7.008 (B); Negev, about 6 km N of Dimona, Zohary 27706 (HUJ).

JORDAN: lower Jordan valley, 1 km NE of Pzael, 18 km N of Jericho, A. Danin et al. 09.005 (B).

GREECE: Rhōdos island, 1 km W Pefki, Ralf Jahn s.n., 9/5/1995 (B).

3. Subsp. **kralikii** (Pomel) Maire, Fl. Afr. Nord 14: 20-25 (1977).
Basionym: *Matthiola kralikii* Pomel, Nouv. Mat. Fl. Atl. 374 (1874).
Type: S of Tunisia, Sfax and Gabes, Kralik s. n. (isotype: GOET, LE, LY, MANCH).
Homotypic synonyms: *Matthiola oxyceras* (Pomel) var. *basiceras* Coss., Comp. Fl. Atl. 2: 104 (1883-1887).
Lonchophora kralikii (Pomel) Jafri, Fl. Libya 23: 163, Fig. 50 (1977).
Icon: Jafri, Fl. Libya 23: 164, t. 50 (1977). As *Lonchophora kralikii.*
Annual herbs, 15-40 cm long, pubescent with appressed whitish stellate, branched hairs, sometimes covered with glandular hairs in the lower part. Stem branched, erect or ascending. Leaves 1-4.5 x 0.3-0.7 cm, oblong-lanceolate, sinuate-toothed or entire, petiolate 0.5-2 cm at base to sessile at upper ones. Flowers sessile. Sepals 5-8 mm, saccate at the base, linear, acute, hairy. Petals 1.2-1.7 cm, yellowish to purple, obovate-oblong to spathulate, margin entire to undulate. Filaments 3-4 mm, free, linear; anthers 2.5-3 mm, oblong. Fruiting pedicels less than 1 mm. Fruits 3-5 x 0.1-0.15 cm, spreading, ascending, straight or slightly curved, torulose or subtorulose, canescent with whitish stellate and branched hairs, easily deciduous; stigma erect to suberect 1-2 mm long, 2-lobed, obtuse; lateral horns 2-4.5 mm long, variable from horizontaly to upcurved or deflexed, hairy; valves 1-nerved, with slightly basal appendages, pubescent; septum submembranous. Seeds in one row in each locule, ovate to slightly oblong, 1-1.1 x 0.7-0.8 mm, yellow-brownish; radicle accumbent.
Fl. & fr.: March-May.
Habitat: Sandy soils.
Vernacular names: Shigaara, Gobbeisha (Egypt).
Uses: grazed by animals.
Distribution: N. Africa (Egypt to Morocco) (Map 30).

SPECIMENS EXAMINED:
ALGERIA: Takersane, near the forest office of Takersane, about 45 km SW from Djelfa, A. Dubuis 15084 (B, BR).
EGYPT: **Nv**: Cairo-Alexandria desert road, 100 km from Alexandria, K. Abdel Khalik 7 (SHG).
TUNISIA: 13 km S of Gabes, (deep rooting field weed), Leippert 7027 (B).



Map 30: Distribution of *Matthiola longipetala* subsp. *kralikii*

4. Subsp. **livida** (Delile) Maire, Fl. Afr. Nd. 14: 23 (1977); El Hadidi & Fayed, Taeckholmia 15: 45 (1994-1995); Boulos, Fl. Egypt Checklist 42 (1995); Boulos, Fl Egypt vol. 1: 201 (1999).

Basionym: *Cheiranthus lividus* Delile, Descr. Egypte, Hist. Nat. 67 (1814).

Type: in Egypt desert, near Cairo; near Pagum Caid-Bey (Delile 1) (holotype: B).

Homotypic synonym: *Matthiloa livida* (Delile) DC., Syst. Nat. 2: 177 (1821).

Heterotypic synonym: *Matthiola glutinosa* Jafri, Fl. Libya 23: 155, t. 47 (1977).

Type: Libya, 240 km from Sebha, along Hun highway, dry flat with loam on top, S. I. Ali 1427, 31/3/ 1973 (holotype: ULT).

Icon: Zohary, Fl. Pal. 1, t. 400 (1966).

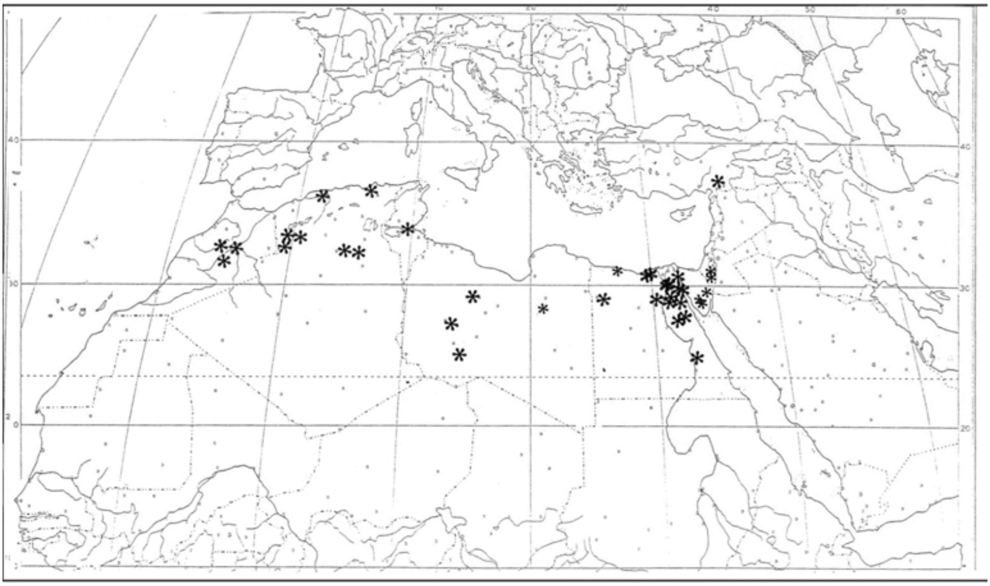
Annual herbs, 15-50 cm tall, canescent with glandular, stellate and branched hairs, glutinous, yellow-green. Stem branched, erect. Leaves 2-7 x 0.5-1 cm, linear to lanceolate, obtuse or acute apex, entire or sinuate-dentate margin, petiolate 1-3 cm at the base to sessile at cauline ones, covered with stellate and glandular hairs. Flowers sessile to short pedicellate 1 mm long. Sepals 7-9 mm, linear, canescent with stellate, glandular hairs, scarious margin. Petals 1.4-1.8 cm, livid, cream to mauve, linear-oblanceolate with undulate or entire margin. Filaments 3-5 mm, free, linear; anthers 2-2.5 mm, oblong. Fruiting pedicels 1-1.5 mm, hairy. Fruits 3.5-6.5 x 0.1-0.2 cm, erect-spreading, straight or slightly curved, canescent with branched, stellate and glandular hairs; horns 2-4 mm, horizontal to slightly curved, hairy, acute; stigma head 1-1.5 mm, obtuse or subacute, slightly divergent; valves, hairy, 1-nerved; septum stiff to submembranous. Seeds in one row in each cell, oblong, brown, 0.8-1 x 0.4- 0.6 mm, narrow winged; radicle accumbent.

Fl. & fr.: March-May.

Habitat: sandy soils, stony wadis and plains.

Vernacular names: Shigaara, Shimshim, Ghobbeisha, Sleeh, Naegeisi, Shudjara (Egypt).

Distribution: Saudi Arabia, Palestine, Israel and N Africa (Egypt to Morocco) (Map 31).



Map 31: Distribution of *Matthiola longipetala* subsp. *livida*

SPECIMENS EXAMINED:

ALGERIA: prov. S Oran, from Mograr Tahtani to Djemien bonu Resq, Bonnet & Maury s.n., 16/4/1888 (LY); El Ateuf, in sands, near Ghardaia, L. Chevallier 272 (B, WAG); Sidi-Yahia, in sand area, L. Chevallier 538 (WAG); Quargla, in sands, Chevallier s.n., 1899 (B); Aïn Sefra, SW of prov. Oran, Cosson s.n., 7/5/1856 (LY); Ouargla extreme S. of Alger Dept., Doumort s.n., 5/1892 (LY); Oasis-Steppe desert a Hassi-el Hadj Ahmed, NW of El-Hadjira, A. Dubuis & Faurel 5498 (L); Prov. Oran, sand dunes in Chellala Dahrania, Kralik 238 (WAG).

EGYPT: **M**: Mersa Matruh, M. Darar s.n., 24/5/1935 (CAIM); Hammam, M. Darar s.n., 22/4/1929 (CAIM); Mariut, M. Darar s.n., 8/12/1929 (CAIM); near Alexandria, Kotschy 6726 (BM). **Nv**: Lower Egypt, A. Wiest 532 (BM); Cairo, in desert, near Abbasia, Bornmüller 10314 (BM); Cairo, in desert, Kralik 48 (LY); Cairo, near Abbasia, A. Keller 320 (BM); near Cairo, A. Keller 411 (BM); desert SE of Heliopolis, M.R.S. Boeljé-van Rwyven 7 (L); Faiyum, G. Täckholm s.n., 11/1/1928 (CAI); Faiyum, Nile Faiyum, A. Khattab s.n., 24/3/1959 (CAIM); 12 km E of Edfu, Täckholm et al. s.n., 10/2/1961 (CAI). **Dl**: 45 km on the road to Siwa-Um el Saghier, El Hadidi s.n., 17/4/1968 (CAI); Siwa-Matruh desert road, G. Fahmy s.n., 15/4/1968 (CAI).

Di: Cairo-Ismailiya desert road, 23 km before Ismailiya, K. Abdel Khalik 27 (SHG); Cairo-Suez road, Boulos s.n., 24/3/1972 (CAI); Suez road, km 34, M. Imam s.n., 17/2/1957 (CAI); Wadi Liblab, Bot. Dep. excursion s.n., 3/3/1951 (CAI); East bank of Suez canal, Ismailiya, F. Lupton s.n., 8/4/1946 (BM); Suez, in the locality of Wadis Jaibe el

Hawara and Sudor, E. Fielding s.n., 1869 (BM); Suez, H. Walter 45 (B); 5 km W of Wasit, Danin et al. s.n., 27/3/1968 (HUJ). **R**: Coastal plain, 60 km South of Suez, M. Kassas s.n., 25/2/1964 (CAI). **Dg**: Wadi Abar, gebel Ataqa, Suez, Amal Amin s.n., 15/2/1956 (CAI); Wadi Fool, N. of Suez road, Täckholm et al. s.n., 8/12/1954 (CAI); Wadi Amloug, 60 km South of Suez, M. Kassas s.n., (CAI); Wadi Garawi, Helwan desert, Täckholm s.n., 4/4/1960 (CAI); Wadi Hof near Helwan, Gamal Rateb s.n., 3/3/1950 (CAI); Wadi Segal, N. Galala, M. Imam s.n., 9/2/1956 (CAI); Wadi Askwar, S. Galala, J. R. Shabetai s.n., 15/4/1945 (CAIM); Wadi Ghisli, S. Galala, W. Egypt, Schweinfurth s.n., 7-10/5/1887 (BM). **S**: Wadi Feiran, S. Sinai, M. Abdallah & A. Khattab s.n., 22/4/1962 (CAIM); Gebel Catherine, S. Sinai, M. Abdallah & A. Khattab s.n., 27/4/1962 (CAIM).

LIBYA: Tripoli, S. Gebel Es Soda, Gabriel s.n., 8/1/1972 (B); SW, 50-60 km NNW Hon, Gabriel s.n., 28/1/1972 (B); Cyrenaika, N, of Gebel Harudsh, H. Scholz 70154 (B); Fezzan, Brack, Wadi Zigzah, D. Turner 25/82 (BM).

MOROCCO: Prov. Er-Rachidia: 20 km NW of Boudnib, H. Förther 6294 (BR); Tafilalt, 12 km SE Erfoud, D. Podlech 50885 (BR); Charis, road p 32, between Er-Rachidia and Goulmima, R. Vogt 11693 & Ch. Oberprieer 6141 (B).

TUNISIA: in sandy desert of Beni-Sïd, near Gabes, Kralik 159 (LY).

ISRAEL: N. Negev, west of BeerSheba, Zohary & Grizi 628 (B); Negev highland, 6 km SW of Dimona, near the nature reserve, A. Danin et al. 22.039 (B).

TURKEY: prov. Gaziantep, Gasiantep on SW slopes of Dükük Baba, Davis & Hedge 27823 (B).

5. Subsp. **longipetala**

Basionym: *Cheiranthus longipetalus* Vent., Descr. Pl. Jord. Cels. T. 93 (1803).

Type: Iraq, Baghdad, Oliver & Bruguiere s.n., (holotype: B, isotype: L).

Icon: Zohary, Fl. Pal. 1, t. 399 (1966).

Annual herbs, 20-45 cm, pubescent with stellate and 2-4 fids in different length hairs. Stem branched from the base, erect to suberect. Leaves 1.5-7 x 0.2-0.6 cm, crowded at the base, linear, linear-lanceolate, entire or sinuate-dentate, hairy, short petiolate 4-10 mm at the base to sessile in the upper part. Flowers sessile or subsessile. Sepals 7-10 mm long, linear-oblong, covered with branched and glandular hairs. Petals 1.5-2.2 cm long, purple to pink, distinct into limb linear to oblanceolate, undulate or entire margin and claw is purple to yellowish. Filaments 5-7 mm long, linear, free; anthers 2-3 mm, oblong-sagittate, obtuse. Fruiting pedicels 1 mm long, hairy. Fruits 3-6 x 0.1-0.15 cm, hairy, straight or contort, stiff, erect or spreading; lateral horns 2-8 mm, horizontal or slightly recurved; terminal horn 1-1.5 mm, slightly 2-lobed, hairy; valves slightly 1-nerved or not; septum submembranous. Seeds in one row in each locule, oblong-ovoid, brown-yellowish, 1-1.2 x 0.7-0.8 mm, slightly winged; radicle accumbent.

Two varieties occur in Egypt:

1. var. **contorta** Zohary, Fl. Pal. 1: 273 (1966).

Fruits thin 3-5 x 0.1 cm, contorted or recurved, tomentose; lateral horns 2-4 mm; valves with nerves.

2. var. **longipetala**

Fruits straight 3-6 x 0.1-0.15 cm, tomentose; lateral horns 3-8 mm; valves without nerves.

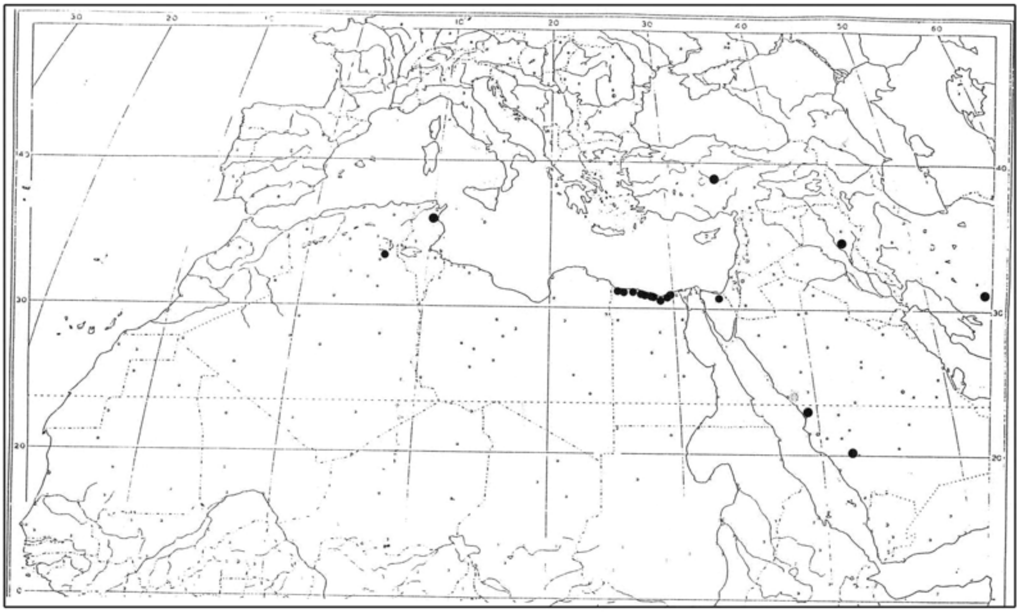
Fl. & fr.: March-May.

Habitat: sandy and stony desert.

Vernacular names: Shigaara, Gobbeish (Egypt).

Uses: this plant is grazed by camels and sheep.

Distribution: S. Europe, Saudi Arabia, W. Asia, S. Russia, Turkey, Palestine, Israel, Jordan, Syria, Iran, Iraq and N. Africa (Egypt to Morocco) (Map 32).



Map 32: Distribution of *Matthiola longipetala* subsp. *longipetala*

SPECIMENS EXAMINED:

ALGERIA: in sand dunes South of Guemar, in Oued Kie Wadi, Kralik 14 (B).

EGYPT: **M**: Sallum, 5 km from frontier, Täckholm et al. s.n., 24/5/1963 (CAI); Matruh-El Sallum road, El Rasool village, E. Sallum, A.G. Fahmy 965 (CAI); Wadi el Habs between Matruh and Agiba, Täckholm et al. s.n., 23/3/1974 (CAI); Mersa Matruh, dry wadi bed, R. Meinertzhagen s.n., Jan.1928 (BM); 28 km before Matruh, Alexandria-Matruh road, K. Abdel Khalik 25 (SHG); Matruh-Alexandria road at 185 km W of Alexandria, A.G. Fahmy s.n., 30/1/1987 (CAI); on the coastal road 46 km before Matruh, Täckholm et al. s.n., 3/5/1966 (CAI); 105 km before Matruh, Alexandria-Matruh coastal road, K. Abdel Khalik 8 (SHG); Ras el Hekma, Migahid & Shafey s.n., 25/5/1954 (CAI); Burg el Arab to Alamein, Tackholm & Boulos s.n., 1/6/1964 (CAI); Burg el Arab, El Hadidi s.n., 22/3/1956 (CAI); Burg el Arab, Ibrahim & Mahdi Sisi s.n., 29/3/1973 (CAI); Maamora, E. Alexandria, M. Hefnawy s.n., 14/3/1928 (CAI). **Di**: El Arish, Eig s.n., 2/5/1925 (HUJ); El Arish, beside Airport, K. Abdel Khalik 30 (SHG). **S**: Without location, R. Meinertzhagen, Jan.1928 (BM).

TUNISIA: Brache, sandy soil, SW Kairvan, Leippert 7232 (B).

IRAQ: Baghdad, between Tigris river and Gebel Hamrin, Samarra, Rechinger 9598 (B).

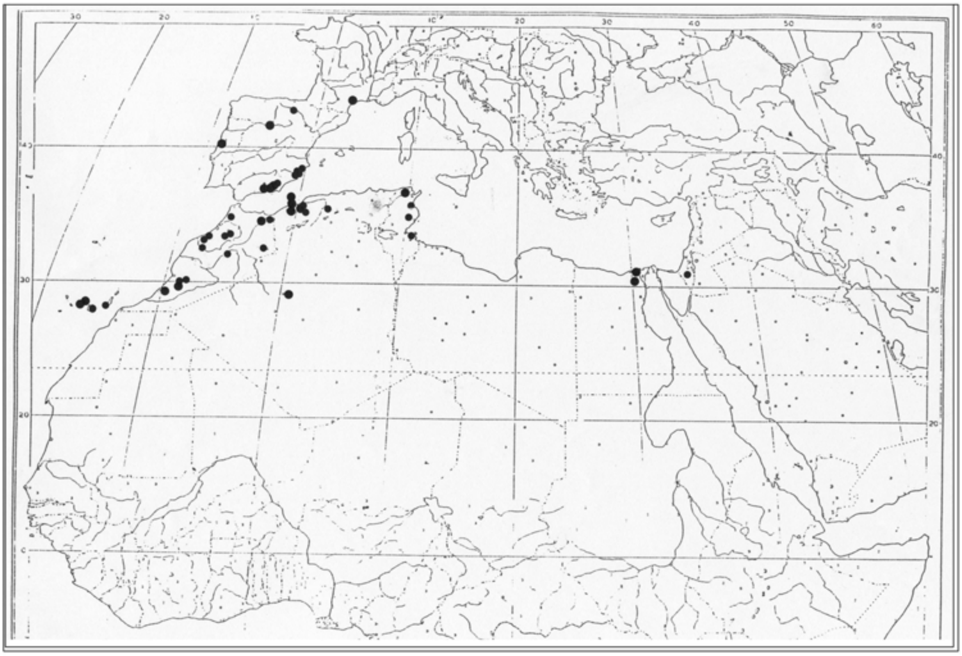
SAUDI ARABIA: Al-Baha, Al-Farhan 758 (KSU); Al-Harra, S. Chaudhary & El-Sheikh 1641 (KSU).

TURKEY: prov. Ankara, 139 km from Ankara to Sertiorear, Walter 1352 (B).

4. **Matthiola parviflora** (Schousboe) R. Br. in Ait. Hort. Kew., ed. 2, 4: 121 (1812); Zohary, Fl. Pal. 1: 272 (1966); Täckholm, Stud. Fl. Egypt ed. 2: 181 (1974); Jafri, Fl. Libya 23: 161 (1977); Tutin, T.G. et al., Fl. Eur. ed. 2, vol. 1: 341 (1993); El Hadidi & Fayed, Taeckholmia 15: 44 (1994-1995); Boulos, Fl. Egypt Checklist 41 (1995); Boulos, Fl. Egypt 1: 200 (1999).
Basionym: *Cheiranthus parviflora* Schousboe in Kongel. Danske Vidensk.-Selsk. Skr.1: 195 (1800). Type: Described from Morocco (holotype: BM).
Icon: Jafri, Fl. Libya 23, 162, t. 49 (A-F) (1977).
Annual herbs 15-25 cm, whitish-green, tomentose with stellate and branched hairs. Stems erect, branches spread at the base. Lower leaves 2-6 x 0.4-0.8 cm, crowded at the base, petiolate 4-11 mm long, oblanceolate, sinuate-dentate or pinnatifid, the lobes acute, hairy with stellate and branched hairs; cauline leaves similar the lower one but sessile. Racemes short, elongated in fruit. Flowers sessile. Sepals 5-7 mm, lanceolate. Petals 7-12 mm, pink to purple, obovate-oblong or spathulate. Filaments 4-7 mm long, free, linear; anthers 1-1.5 mm, sagittate. Fruiting pedicels 1 mm long as thick as fruit. Fruits 3-6 x 0.15 cm, erect or spreading, linear-terete, straight or slightly curved, pubescent with more or less branched hairs; with lateral horns 3-5 mm long, much longer than stigma, straight or upcurved, acute, hairy; with two small appendages beside the lateral horns; stigma slightly 2-lobed; valves with 1-midrib, not keeled, straight, hairy; septum pitted, thick. Seeds in one row per cell, brown, ovoid-oblong, 1.2-1.5 x 1-1.2 mm, narrowly winged; radicle accumbent.
Fl. & fr.: March-May.
Habitat: sand plains, fields, uncultivated land.
Uses: eaten by camels and sheep.
Distribution: S Spain, Canary Islands, Palestine and N. Africa (Egypt to Morocco) (Map 33).

SPECIMENS EXAMINED:

ALGERIA: Santa Cruz, Alleizette s.n., April 1904 (BR); Oran, dry areas, Alleizette 3686 (B); Mostaganem, in uncultivated land, B. Balansa 83 (WAG); prov. Oran, in sands, Bové s.n., 4/1839 (LY); prov. Oran: Gambetta, Doumergue s.n., 14/3/1886 (LY); Jolygome, Doumergue s.n., 20/3/1887 and 28/5/1890 (LY); Mostaganem, Doumergue s.n., 13/4/1903 (LY); Gambetta, A. Faure s.n., 26/4/1906 (LY); Santa-Cruz, A. Faure s.n., 16/2/1913 (B); Oran, Mussat s.n., 4/10/1902 (LY); Terriet el Had, WFR Suringar s.n., 20/4-7/5/1881 (L).
EGYPT: **M**: Maruit, Burg el Arab, G. Täckholm s.n., 15/3/1928 (CAI). **Nv**: Wadi Natroun, North part, El Hadidi s.n., 11/3/1968 (CAI).
MOROCCO: Ida Ouchemlal Mts Amaluz and tidli Ighichan, Cosson s.n., 1876 (LY); SW of Oued Massa, between Agadir and Tiznit, Davis 53315 (BM); in Oudjda, A. Faure s.n., 21/4/1933 (BR); Tiznit, road to Tafraout km 30, J. Lewalle 7511 (BR); Bou Isakern, J. Lewalle 7670 (BR); Oued Zem, J. Lewalle 9178 (BR); Marrakech, J. Lewalle 9270 (BR); Tezerwalt, J. Lewalle 9760 (BR); Rommani, J. Lewalle 10125 (BR); Bemchid Seltat, J. Lewalle 10324 (BR); Rabat, Oued Abrech, J. Lewalle 10954 and 12335 (BR); Kheniget, J. Lewalle 11903 (BR); Tazrourt, J. Lewalle 12516 (BR); Kheniget, J. Lewalle 12941, &13419 (BR); Mts of Ben-Sassen, between Mechra-Homadi, Vogt 11127 and Oberprieler 5575 (B); road between Ait-Bahia and Tafraoute, 15.7 km SE Ait-Bahia, Vogt 11745, & Oberprieler 6193 (B).



Map 33: Distribution of *Matthiola parviflora*

TUNISIA: Sousse, in wasteland, J. Pitard 14 (L, LY, WAG); Gafsa, in cultivated land, J. Pitard 303 (L, LY, WAG); Matmata, Kébira, J. Pitard 755 (LY); near Myaram, Thebas, Zeitum, Schlte s.n., (L).
ISRAEL: Central Negev, Segal 303619 (HUJ).
PORTUGAL: in island of Maiorica, in sand beach, Tremols s.n., 9/1893 (LY) .
SPAIN: Baléares, bords of Portopi near Palma, Bianor 1576 (LY); Almeria, between rocks along coast, B.K. Boom 11624 (L); farm in Cartagena, E. Bourgeau 571 (LY, WAG); Tenerife, near beach of Guimariense, E. Bourgeau 701 (LY); in sandy farm in Cartagena, E. Bourgeau 1066 (WAG); in fields of Amusco, Bourgeau 1568 a (B); Mt. of Taco, near Buemavesta, O. Burchard 45 (LY); Alicante, Altea, along rail road of Altea to the south, Excursion to Spain 82-6, 13/4/1982 (L); in Framada dry spot between Cacteta and near Almeria, Huter & Rigo 763 (LY); Lorca, Sierras, along side the farm, Jeronimo 4910 (L); Gran Canaria, Barranco Seco, G. Kunkel 8583 (WAG); Cerca Temisas, G. Kunkel 9057 (WAG); Fuerteventura, Puerto Lajas in beach sand, J. Pitard 25 (L, LY); 3 km SW of Alicante, in corn field, W.J. Reinders 3024 (L); prov. Almeria, in Halfa steppe, H. Scholz & Hiepko 591 (B).

15. **Morettia** DC.

Syst. Nat. 2: 426 (1821); Stork & Wuest, Bol. Soc. Brot. Ser. 2, 53: 241-273 (1980).

Annual to perennial herbs, canescent with stellate, branched hairs. Stems prostrate or procumbent, branched from the base, lignified with age. Leaves petiolate or sessile to subsessile, lanceolate to ovate or obovate, the margin entire or dentate, acute to obtuse at the apex. Racemes bracteate, elongating in fruits. Flowers axillary or terminal in racemes, pedicels short. Sepals erect, not saccate at the base, equal at base, hairy. Petals with a narrow claw and oval or obovate lamina, margin entire, pinkish, white or yellow. Stamens 6; filaments free, without appendages; anthers ovate, acute to obtuse. Fruiting pedicels thick, hairy, erect ± appressed to the axis. Fruit a siliqua, terete to tetragonous, hairy, straight or curved above, tardily dehiscent; style short or long, cylindrical; stigma 2-lobed, persistent; valves straight or curved, hairy, 1-nerved, rigid; septum membranous. Seeds in one row in each cell, ovate to rounded, brown; radicle accumbent.

Distribution: mainly Saharo-Sindian with a slight extension into Mediterranean belt and in the South Arabian province of the Sudano-Zambezian region.

Four species in N. Africa to Arabia; three species in Egypt.

Key to the species:

1a. Plant ascending, yellow-green; leaves up to 3 x 1.2 cm; sepals 5-6 mm long, persistent in fruit; fruits 2-3 mm wide at base…………………….…………………………3**. M. philaeana**

1b. Plant ascending or prostrate, grey or white; leaves up to 2 x 1 cm; sepals 2.5-5 mm long, deciduous in fruit; fruits 1-2 mm wide at base…………………..………………...……...…**2**

2a. Leaves petiolate, entire; flowers small (petals 4-5 mm long); fruits strongly curved, not appressed to the stem; fruits 1 mm wide at base……………………………**2. M. parviflora**

2b. Leaves sessile to subsessile, entire to dentate; flowers large (petals 6-8 mm long); fruits straight or slightly curved, appressed to the stem; fruits 1-2 mm wide……..**1. M. canescens**

1. **Morettia canescens** Boiss., Diagn. Pl. Orient. Sér. 1, 2 (8): 17 (1849); Boiss., Fl. Orient.1: 145 (1867); Täckholm, Stud. Fl. Egypt ed. 1: 344 (1956); Ozenda, Fl. Saharo Septen. Cent. 268 (1958); Zohary, Fl. Pal. 1: 274 (1966); Täckholm, Stud. Fl. Egypt ed. 2: 180 (1974); Migahid & Hammouda, Flow. Pl. Saudi Arabia 65 (1974); Maire, Fl. Afr. Nord 14: 41 (1977); Collenette, Illust. Flow. Pl. Saudi Arabia 203 (1985); El Hadidi & Fayed, Taeckholmia 15: 44 (1994-1995); Boulos, Fl. Egypt Checklist 41 (1995); Boulos, Fl. Egypt 1: 197 (1999). Type: Nakkeb, Saudi Arabia, Schimper 341 (holotype: B, isotype: BM, E, L, OXF & FHO).

Heterotypic synonyms: *Morettia philaeana* Boiss., in Ann. Sci. Nat. 60 (1842).

Type: Mts. Sinai, Aucher-Eloy 136 (holotype: BM; isotype: OXF & FHO).

Morettia philaeana Boiss.: Jafri, Fl. Libya 23: 122 (1977) (Fig. 38 A, B, E3, E4 seem to represent *M. canescens*).

Homotypic synonym: *Morettia nakkebiana* Hochst. In Sched. Pl. Arab. Petr. Schimper, ed. 2 (1843). Type: Nakkeb, Saudi Arabia, Schimper 341 (holotype: BM; isotype: OXF & FHO).

Icon: Zohary, Fl. Palestine 1, t. 402 (1966).

Perennial herbs, 10-35 cm, canescent with appressed stellate hairs, grey colour. Stem prostrate, much branched, slender. Leaves 0.5-1.2 x 0.3-0.7 cm, lanceolate or oblong-elliptica, acute at apex, entire or small dentate at the margin, with appressed stellate hairs, sessile to short-petiolate 1-3 mm. Flowers small, pedicellate 1-2 mm, hairy. Sepals 4-5 mm, deciduous, oblong to linear-oblong. Petals 6-8 mm long, white to pale pink, spathulate, distinctly into claw and lamina, the apex rounded to slightly emarginate, entire margin. Filaments 1.5-3 mm, linear, free; anthers 1.5-2 mm long, linear-oblong. Fruiting pedicels 2-4 mm, hairy, erect, appressed to axis. Fruits 0.6-1.4 x 0.1-0.2 cm, appressed to branches, straight, torulose, cylindrical, upper part tapering, late dehiscent, covered with stellate hairs; style 0.5-1 mm, thin, glabrous, slender; stigma with 2 divergent lobes, rather thick; valves torulose, with 3-visible nerves; septum membranous. Seeds in one row in each cell, brownish, ovoid, flat, 1-1.3 x 0.9-1.1 mm; radicle accumbent.

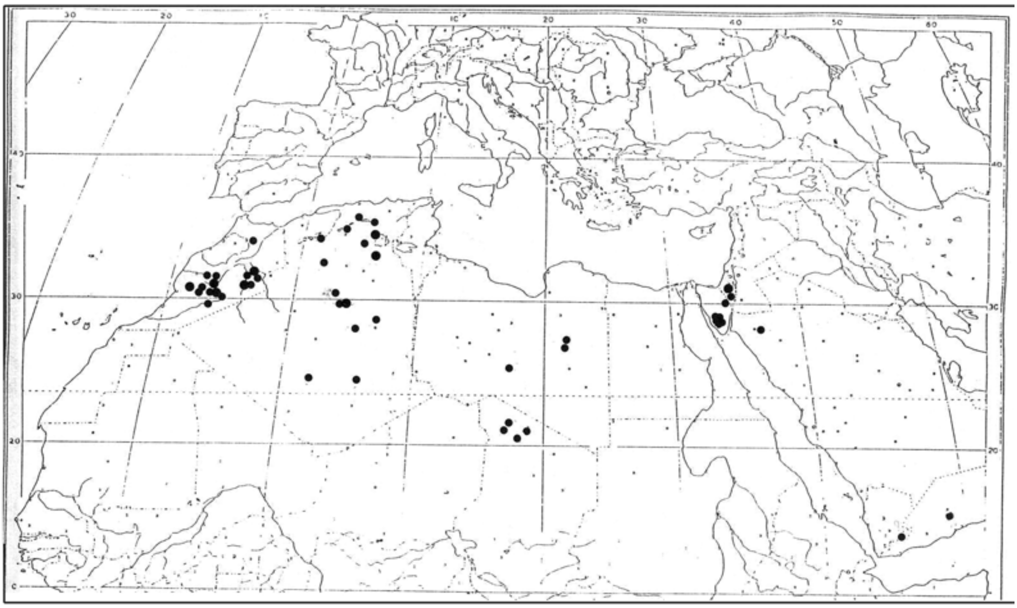
Fl. & fr.: February-April.

Habitat: Stony wadis and sandy plains.

Vernacular name: Rabeshe (Saudi Arabia).

Uses: reported as the main fodder of goats in the central Sahara and it is eaten by camels and sheep in Egypt.

Distribution: Saudi Arabia, Palestine, Israel, Tchad and N. Africa (Egypt to Morocco) (Map 34).



Map 34: Distribution of *Morettia canescens*

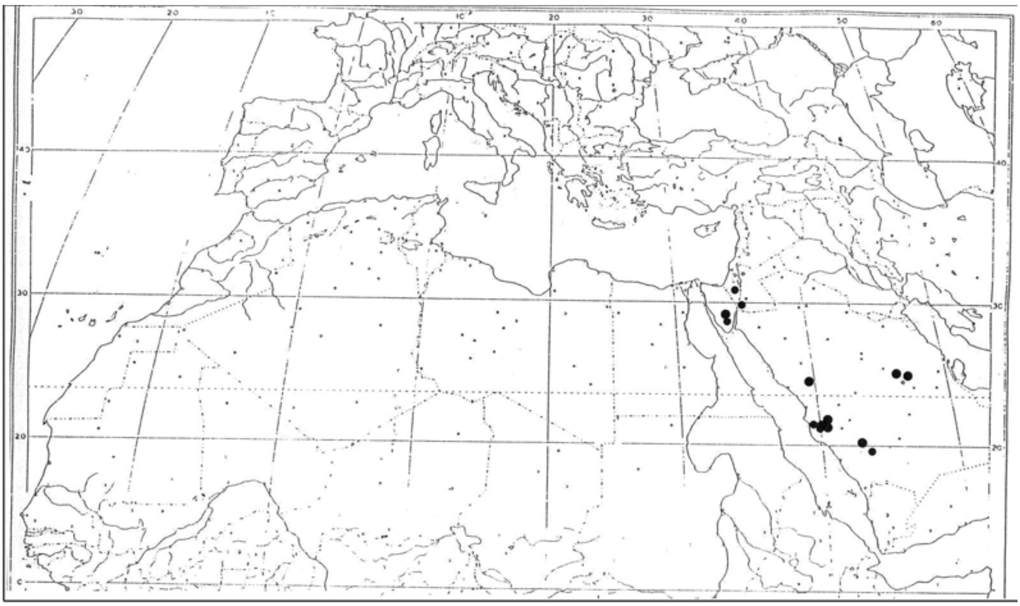
SPECIMENS EXAMINED:

ALGERIA: Montaine Atar, J. G. Adaw 18793 (WAG); Circ. Ain-Sefra, near to road, in gravel, near El Hadjadj, L. Chevallier 273 (B, LY, WAG); between Saret and Sahal el-Ser, in gravel, L. Chevallier 539 (K, LY, WAG); S. Escarpment Tadmait plateau, T. F. Clipp 134(K); around of Beni-Ounif, in sandy desert area, A. Faure s.n., 23/4/1938

(BR); Dep. Oasis, steppe desert, 75 km West of Dzioua on the road of Ksar el-Hirane, L. Faurel 5497 (BR); 50 km W of Ohanet, on the way to Hassi Bel Guebbour, P. Goetghebeur 3043 (B, BR, WAG); way Ain Salah to El-Golea, 220 km N on Ain Salah, P. Goetghebeur 3088 (B, BR, WAG); stony, clay-sandy area of plain between Ain Sefra and Tyout, SW of the prov. Oran, Kralik 241 (K, LY, WAG); Tassili, near Ajjer, M. Luikenga s.n., 21/12/1977 (B); Sidi Rached, Mussat s.n., April, 1889 (LY); Chegga, Mussat s.n., 20/4/1889 (LY); Wilaya Ouargla, plateau el Tinrhert, 70 km N. in Amenas, D. Podlech 32948 (WAG); Wilaya Ouargla, Tassili, N. Ajjer, 5 km S. of Guelta Dider, D. Podlech 33049 (CAI); Wilaya Tamanrasset, Hoggar-Massif, 5 km NE of Ideles, D. Podlech 33185 (CAI, WAG).
EGYPT: **Di**: El-Kuntilla, NC Sinai, M. Drar s.n., 1/5/1939 (CAIM). **S**: Sinai; A. Kaiser 590 (W); Trauernfeld s.n., 1855 (W); Wadi Feiran: M. Drar s.n., 3/5/1939 (CAIM); El Naggar s.n., 15/4/1998 (SHG); K. Abdel Khalik 10 (SHG); R. Meinertzhagen 3700 (BM); Wadi Tamara, W. Feiran, J. R. Shabetai s.n., 15/4/1937 (CAIM); Wadi El Sheikh, M. Drar s.n., 8/5/1939 (CAIM); Wadi Barak and Wadi Sebweh, C. H. Hart s.n., Febr.1884 (BM); outside the small Feiran Monastry W. Feiran, Täckholm et al. s.n., 10/5/1956 (CAI); Oasis of Wadi Feiran, near convent and garden banks of Wadi, Zohary s.n., 7/5/1940 (HUJ).
LIBYA: Umm Ashedida, K. M. Guichard KG/Lib. /105 (BM); Fessan: W side of Serir Tibesti, S. Wau el Kebir on the high plateau, Scholz 70080 (B); Cyrenaika Mts E. of Thamad Bu Hashishah, Scholz 70119 (B); N. of Cyrenaika, Serir Kalancho, SW Gialo, Scholz s.n., 31/12/1970 (B).
MOROCCO: W. de Kourkouda (Ouarzazate), Bouharmont 21842 (BR); Oulad Atmane (Ouarzazate), Bouharmont 21854 (BR); prov. Ouarzazate: valley below Bou Azzer mine, on mine tailings, Brooks et al. 23 (NMGM); Ouarzazate, Skoura, Castroviejo et al. 4807 (B); Ksar es Souk, N. of Errachidia, J. Fedz et al. 7059 (B); Zagora, Agdz, Hans-Joachim M 28 (B); Agdz, Ouarzazate, J. Lewalle 9295 (BR); El-Kelse, Ouarzazate, J. Lewalle 9410 (BR); about 9 km on the road from Ouarzazate to Zagora, J. Lewalle 10756 (L); Errachidia, J. Lewalle 11434 (BR); Tata, 30 km from Abbe, J. Lewalle 11607 (BR); Tata, J. Lewalle 11621 and 13798 (BR); Er Foud, prov. Errachidia, J. Lewalle 13675 (BR); Touf, prov. Errachidia, J. Lewalle 13705 (BR); prov. Errachidia, 20 km E. of Beni Tajjite, D. Podlech 51038 (BR); prov. Errachidia, 19 km E of Junction to Erfoud, Vogt 10456, Oberprieler 4904 (B).
TCHAD: Tarso Voon: West side ca 2200 m, H. Scholz 154 (B); Tarso Tousside: S rim of Trou au Natron 2200m, H. Scholz 155 (B); South of Bardai in Enneri Oudingueur on the dirt road Bardi to Zouar 1200 m, H. Scholz 156 (B); Tarso Tousside: South side of Trou au Natron 2200 m, H. Scholz 187 (B).
ISRAEL: S of Negev, Nahal Paran junction with Ramon-Eilat road, A. Danin et al. 27. 006 (B); Central Negev, Hameishar Hammada, Wadi bed, Zohary & Orshan 27727 (HUJ).
SAUDI ARABIA: North Hijaz, near deep pools NW of Shigsi village, off the Samamirn-Tabuk road in sand, Collenette 919 (K); Hauar, Ras Hamam, Schimper 239 (W); Nakkeb in area of rocks, W. Schimper 341 (B, BM, E, L, OXF & FHO).

2. **Morettia parviflora** Boiss., Ann. Sci. Nat. Bot. Ser. 2, 17: 60 (1842); Boiss., Fl. Orient. 1: 146 (1967); Zohary, Fl. Pal. 1: 275 (1966); Collenette, Illust. Flow. Pl. Saudi Arabia 204 (1985); Boulos, Fl. Egypt Checklist 41 (1995); Boulos, Fl. Egypt 1: 199 (1999). Type: Oman, in the desert of Mascate, Aucher-Eloy 4076 (holotype: BM, isotype: W).
Homotypic Synonyms: *Morettia canescens* Boiss. var. *parviflora* (Boiss.) Täckholm, Stud. Fl. Egypt ed. 2: 180 (1974); Maire, Fl. Afr. Nord 14: 44 (1977).
Icon: Collenette, Illust. Flow. Pl. Saudi Arabia 204 (1985).
Perennial herbs, 15-25 cm, white, tomentose covered with stellate and branched (dendroid) hairs. Stems prostrate or ascending, branched. Leaves 0.5-2 x 0.3-1 cm, petiolate 3-10 mm, ovate-elliptical, entire, acute, covered with stellate hairs. Flowers small, pedicellate 1-3 mm.

Sepals 2.5-3 mm, oblong, deciduous, not saccate at base, hairy. Petals 4-5 mm, white, subexserted, not clawed, oblong-spathulate, entire, obtuse at apex. Filaments 2-3 mm, free, without appendages; anthers 1-1.5 mm, sagittate, curved when dry. Fruiting pedicels 2-4 mm, as thick as fruits. Fruits 1-2 x 0.1 cm, thin, not appressed to axis, strongly curved, gradually tapering above, covered with stellate and dendroid hairs; style 1-1.5 mm long, hairy, thinner than fruit; stigma two lobes, slightly divergent, lobes triangular, thick; valves torulose, 1-nerved; septum membranous. Seeds many in one row in each locule, light brown, flat, ovoid, 1-1.2 x 0.8-1 mm; radicle accumbent.
Fl. & fr.: March-May.
Habitat: stony and sandy wadis.
Distribution: Saudi Arabia, Israel, Palestine, Jordan, Oman, Emirats Arabes and Egypt (Sinai) (Map 35).



Map 35: Distribution of *Morettia parviflora*

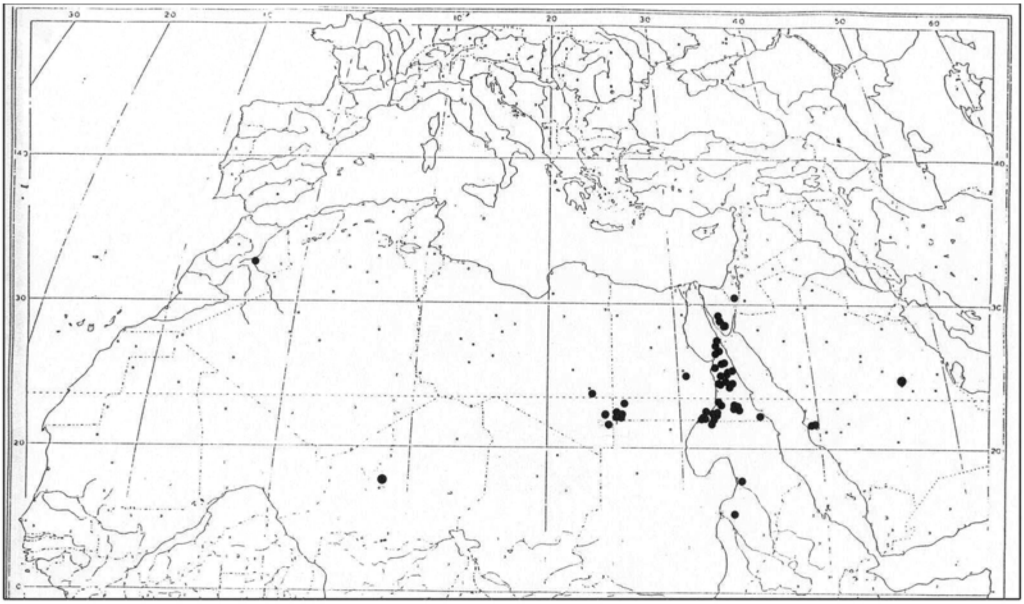
SPECIMENS EXAMINED:

EGYPT: **S**: S. Sinai, Bir Iqna, 20 km. N of Feiran, N. Tadmor s.n., 25/5/1969 (HUJ); area up to 25 km NE of St. Catherine Monastry, S. Sinai, Darwish Al Far s.n., March-April (CAI).
ARAB EMIRATS: Al Ain (Abu Dhabi), J. Bouharmont 21609 (BR).
ISRAEL: S. Negev, Northern end of the Eilat Massive, J. Lipkin 33324 (HUJ).
JORDAN: Aqaba, 12 km N of Aqaba, along the road to Amman, Dawud Al-Eisawi & Abed-Alla 2882 (B).

OMAN: Wadi Mistal, Ghubrah Bowl, 15 km from Rustaqrd, S. A. Ghazanfar 1753 (BR); in rocky or stony places, near Mascate, Bornmüller 49 (OXF & FHO, W); Batinah, Muscat area, Wadi Mutrah, H. Kürschner 99-53 (B).
SAUDI ARABIA: Al-Taif: Al-Shafa summit, 40 km W of Al-Taif, A.A. Fayed 1108 (B); Mecca: Mecca-Taif highway, about 20 km from Mecca, A.A. Fayed 1237 (B); Mountains of Gedda, Fischer 117 (W); Ar-Riyadh, 20 km NW Riyadd near Diriyah, W. Frey et al. 6569 (KSU); Wadi Harjab, rocky hillsides, D. Hillcoat 1698412(BR); El-Rabda, El-Madinah El-Munowera, Migahid & El-Sheikh 13530 (KSU); El-Der'eieh and Hanifa Wadi, Migahid 13533 (KSU); 2 km E Afif, Migahid & El-Sheikh 14091 (KSU); El-Ruwaida, Taif road to Riyadh, Migahid & El-Sheikh 14093 (KSU); without location, G. Schweinfurth 10 (B).

3. M. philaeana (Delile) DC., Syst. Nat. 2: 427(1821); Boiss., Fl. Orient. 1: 145 (1867); Oliver, Fl. Trop. Afr. Vol. 1: 61 (1868); Muschler, Mannual Fl. Egypt 403 (1912); Täckholm, Stud. Fl. Egypt ed. 1: 344 (1956); Zohary, Fl. Pal.1: 274 (1966); Täckholm, Stud. Fl. Egypt ed. 2: 180 (1974); Migahid & Hammmouda, Fl. Saudi Arabia 66 (1974); Jafri, Fl. Libya 23: 122 (1977); El Hadidi & Fayed, Taeckholmia 15: 44 (1994-1995); Boulos, Fl. Egypt Checklist 41 (1995); Boulos, Fl. Egypt 1: 199 (1999).
Basionym: *Sinapis philaeana* Delile, Fl. Aeg. Illust. 99, t. 33, fig. 3 (1813).
Type: Egypt, in Nubia, near Phile island, Delile s. n. (holotype: B; isotype: BR, LY, OXF & FHO).
Heterotypic synonym: *Morettia asperrima* Boiss., in Ann. Sci. Nat. Bot., Ser. 2, 17: 60 (1842).
Type: Mascate, N.4102 (holotype: B, isotype: E).
Icon: Zohary, Fl. Pal. 1, t. 401 (1966).
Perennial herbs, 20-50 cm long, yellow-green, tomentose with scabrous, brittle, stellate hairs, adhering to skin. Stem ascending, thick, much branched. Leaves 1-3 x 0.4-1.2 cm, petiolate 1-6 mm long, lanceolate to oblong-elliptic, margin teethed or entire, acute to rounded at apex, hairy. Racemes bracteate, elongating in fruits. Flowers large, pedicellate 1-2 mm. Sepals 5-6 mm long, hairy, oblong to lanceolate, not saccate at base, persistent in fruit. Petals 7-11 mm long, white, spathulate, clawed. Filaments 3-4 mm, linear, free; anthers 2.5-3 mm long, oblong-linear, acute to obtuse. Fruiting pedicels 2-3 mm, hairy, erect, appressed to axis. Fruits 1.4-2 x 0.2-0.3 cm, slightly curved, tomentose, thicker at the base than at the apex, tardily dehiscent, rigid; style thick, slender, glabrous, 1-1.5 mm long; stigma two lobes, divergent, thick; valves thick, torulose, 1-nerved, rigid; septum membranous. Seeds in one row in each locule, pale brown, ovoid, 1.5-1.7 x 1.3-1.5 mm; radicle accumbent.
Fl. & fr.: Februari-April.
Habitat: sandy and stony wadis and plains, muddy and moist ground especially by the Nile banks in upper Nubia.
Vernacular names: Saggar, tooshi (Egypt).
Uses: eaten by camels.

Distribution: N. Africa (Egypt to Morocco), Palestine, Israel, Saudi Arabia, Jordan, Sudan, Mali, Niger and Somalia (Map 36).



Map 36: Distribution of *Morettia philaeana*

SPECIMENS EXAMINED:

EGYPT: **S**: Without location, Seiber s.n., 1826 (B, BR, W); and 1834 (BM, L); Wadi Feiran, S. Sinai, Schweinfurth s.n., 1885 (BM, BR); desert el Tor, Bove 141 (BR); Wadi Bavour, N. Bove 141 (BR); Sinai Mountains region, M. Hassib s.n., April 1940 (CAI). **R**: S. Sinai, near Sharm el-Sheikh, Danin & Shmida s.n., 8/3/1968 (HUJ); Wadi Khoda, Red Sea coast, Täckholm et al. s.n., 12/2/1961 (CAI); Hurghada: Wadi Um Disi, H. Nasr s.n., 13/1/1935 (CAI); Wadi Abhad, Täckholm et al. s.n., 6/9/1960 (CAI); Mersa Allam, A. El Gazzar s.n., 13/1/1977 (CAI). **O**: Kharga, Baris, Täckholm & Kassas s.n., 8/2/1952 (CAI). **Da**: Eastern desert, Schweinfurth 208 (W); 35 km from Qena at the road Qena-Safaga, K. Abdel Khalik & A. Kamal 3 (SHG); 55 km from Qena at the road Qena-Safaga, K. Abdel Khalik & A. Kamal 4 (SHG); near Bir Simbar, near Qena, in the desert road between Qena-Qusseir, Schweinfurth 1339 (W); 25 km from Keft at the road Qusseir-Keft, K. Abdel Khalik & A. Kamal 6 (SHG); Keft-Kosseir road, Wadi el Beda, Wadi el Sheikh Abdel Al, H. Runkemitz s.n., 17/4/1933 (CAI); Gebel Dawi, on the Qusseir-Keft road, Täckholm et al. s.n., 9/2/1961 (CAI); along the road between Edfu to Mersa Alam, Wannenmacher s.n., 2/3/1981 (W); 12 km E of Edfu, Täckholm et al. s.n., 10/2/1961 (CAI); 60 km E. along the way to Mersa Alam, Boulos s.n., 7/10/1956 (CAI); 90 km E of Edfu along the road to Mersa Alam, Täckholm et al. s.n., 10/2/1961 (CAI); 105 km E of Edfu, Täckholm et al. s.n., 10/2/1961 (CAI); 110 km E of Edfu, Täckholm et al. s.n., 10/2/1961 (CAI); 116 km E of Edfu, Täckholm et al. s.n., 10/2/1961 (CAI); Wadi Kashab, Kom Ombo, Täckholm et al. s.n., 6/2/1964 (CAI); Wadi Sheet, 6.5 km E of Kom Ombo, Täckholm et al. s.n., 3/31961 (CAI); Wadi Sheet, 16 km E of Kom Ombo, Täckholm et al. s.n., 3/31961 (CAI); Wadi Kharreit, 64 km E of Kom Ombo, Täckholm et al. s.n., 4/3/1961 (CAI); Wadi Sheet, 75 km E of Kom Ombo, Täckholm et al. s.n., 3/31961 (CAI); Eastern desert, Wadi Kharreit, 80 km E of Daraw, NE of Aswan, Boulos 14414 (BR); Wadi el-Allagi, Wadi Targami, M. Abdalla and F. Saád s.n., 19/3/1962 (CAIM); Wadi Dehmit, Bir Um Hibal, Osborn Dale & Ibrahim Helmy s.n., 30/3/1966 (CAI); Bir Atrash area, Osborn Dale & Ibrahim Helmy s.n., 21/11/1965 (CAI); N Taghar: between Umm Qareiyat and Wadi Nasari, F. Saád 1208 (WAG); in the transitional zone between the desert and cultivation, Abdallah 1540 (WAG); Umm Halawa, at the Northern part of Wadi Haimur, Abdallah 1480 (WAG); Wadi or South of Abu Simbil, Abdallah 1638 (WAG).

Nn: Allagi village, Osborm Dale & Ibrahim Helmy s.n., 22/3/1966 (CAI); Abu Simbel, El Hadidi s.n., 5/3/1975 (CAI); in desert near Phylae island, Schimper s.n., 1819 (BM); Gebel Adda, 5 km SE of Abu Simbel, at the mouth of Wadi, Wilbur s.n., 25/3/1966 (CAI); Wadi Umm Qareiyat, Abu Simbel, Täckholm et al. s.n., 23/11/1963 (CAI); near Wadi Halfa, in Nile sand along the River, Letourneux 220 (LY, W); Wadi Khor Musa, in Wadi Halfa, Kasy s.n., 27/2/1962 (W); Lower Nubia, Wadi Tora, Prince Paul of Württemberg s.n., (W). **Dn**: Gilf Kebir, Wadi Hamra, Léonard 5068 (BR). **Uw**: Gebel Uweinat: Karkur Tahl, Léonard 4846 (BR); Eastern part, Léonard 4866 (BR); Wadi Coloquintes, Léonard 4787 (BR); Karkur Hamid, Léonard 5047 (BR). **Sa**: Gebel Elba, Wadi Aak, Täckholm et al. s.n., 27/2/1962 (CAI).

LIBYA: Mountain Uweinat area, border between Libya and Sudan, Léonard 3742 (BR); Dunes between Gebel Uweinat and Archenu, Léonard 4761 (BR); 45 km NW of Salma Kabir, North Kufram Mt., Wadi bed, J. E. Jany 61 (B).

MOROCCO: Tussem, between Ksar es Souk and Meski, L. van Hecke 2350 (WAG).

NIGER: Air, Wadi Tessenagat, 30 km SE El Meki, E. Schulz s.n., 26/3/1980 (B).

SUDAN: NW of UmDurman, K. Jackson 2318 (B); Murrat, in great desert, prov. Berber, Kotschy 363 (B, OXF & FHO, WAG); near Kurusku, G.F. Scott 3413 (BM).

ISRAEL: Arava Valley, Zohary 33350 (HUJ).

SAUDI ARABIA: Ammasiyah, Riyadh, Al-Ferhan and Thomas 10165 (KSU); Mt Jiddah, Fischer 117 (L); E of Jiddah, Kruijt 53 (L).

16. Notoceras R. Br.

in Ait. Hort. Kew. ed. 2, 4: 117 (1812); O.E. Schulz in Pflanzenfam, ed. 2, 17B: 559-560 (1936).

Annual herbs, covered with appressed medifixed hairs. Stems procumbent or prostrate, with spreading and stiffly branched. Leaves oblong-lanceolate, entire, petiolate to sessile, hairy. Racemes many flowered. Flowers small, pedicellate. Sepals not saccate at the base, erect. Petals white, spathulate, scarcely exceeding than sepals. Stamens 6; filaments, linear, free; anthers sagittate, small. Fruiting pedicels short and thick, hairy. Fruits tardily dehiscent, rigid, linear-oblong, tetragonous siliqua, with 2 apical horns, appressed to the axis; style short and slender, not exceeding the horns; stigma capitate; valves with adistinct midrib, rigid, pitted inside, each one with an apical horn; septum membranous, not veined. Seeds in one row in each locule, ovoid, brownish, wingless; radicle accumbent.

A monotypic genus.

1. **Notoceras bicorne** (Ait.) Caruel. Fl. Toscan. 536 (1860); Amo, Fl. Fan. Penins. Iber. 6: 536 (1873); Aschers. & Schwein., Illust. Fl. Egypt 2: 39 (1887); Muschler, Manual Fl. Egypt 403 (1912); Täckholm, Stud. Fl. Egypt ed. 1: 346 (1956); Ozenda, Fl. Sah. Sept. Cent. 266 (1958);

Zohary, Fl. Pal. 1: 275 (1966); Maire, Fl. Afr. Nord 13: 361 (1967); Rechinger, Fl. Iran 57/28.2: 223 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 181 (1974); Jafri, Fl. Libya 23: 144 (1977); Townsend, c.c., in Fl. Iraq 4, 2: 1018 (1980); Collenette, Illust. Flow. Pl. Saudi Arabia 205 (1985); Tutin, T.G., et al. Fl. Europ. ed. 2, vol. 1: 341 (1993); El Hadidi & Fayed, Taeckholmia 15: 45 (1994-1995); Boulos, Fl. Egypt Checklist 42 (1995); Boulos, Fl. Egypt 1: 202 (1999).

Basionym: *Erysimum bicorne* Aiton, Hort. Kew., ed. 1, 2: 394 (1789).

Type: Canary Islands, Masson 1778 (holotype: BM).

Homotypic synonym: *Notoceras canariensis* R. Br., in Aiton, Hort. Kew., ed. 2, 4: 117 (1812).

Heterotypic synonyms: *Notoceras hispanicum* DC., Syst. Nat.2: 204 (1821).

Type: Ruderal places in calcareous sands, Orcelis Murciae and Granatensis regni, Spain (Lagasca 1) (holotype: W; isotype: BM, LY).

Notoceras canariensis (R. Br.) Boiss., Fl. Orient. 1: 314 (1867).

Type: in desert of Saudi Arabia (Schimper 345, Auch. Eloy 118, Boiss.); Mascate (Auch. Eloy 4169) (holotype: B).

Icon: Jafri, Fl. Libya 23, 145, t. 44 (A-D) (1977).

Annual herbs, 8-25 cm, covered with appressed bipartite hairs. Stem procumbent or spreading, much branched from the base, branches spreading or horizontal. Leaves 0.8-2.5 x 0.2-0.4 cm, oblong-lanceolate, entire, acute at apex to attenuate and petiolate at base 0.3-1.1 cm or sessile in the upper. Racemes dense, elongating in fruit. Flowers small, pedicellate 1-1.5 mm long. Sepals 1-1.5 mm, hirsute with membranous margin, erect, oblong, not saccate at the inner ones. Petals 1.5-2 mm, as long as or slightly longar than sepals, yellow to dull white, oblong to narrowly spathulate. Filaments 1 mm long, linear; anthers 0.5 mm, sagittate. Fruiting pedicels 1.5-2 mm, thick, hairy, appressed to axis. Fruits 5-7 x 2 mm, erect, appressed to the axis, tetragonous, rigid, oblong, late dehiscent, covered with bifid hairs; style short, persistent, 1 mm long; stigma capitate; valves rigid, with 1-nerved, horned at apex; the horn measure 1-1.5 mm long, hairy, pitted inside; septum membranous. Seeds 3-4 in each locule, pale brown, compressed, rounded, wingless, 1-1.5 x 0.9-1.3 mm; radicle accumbent.

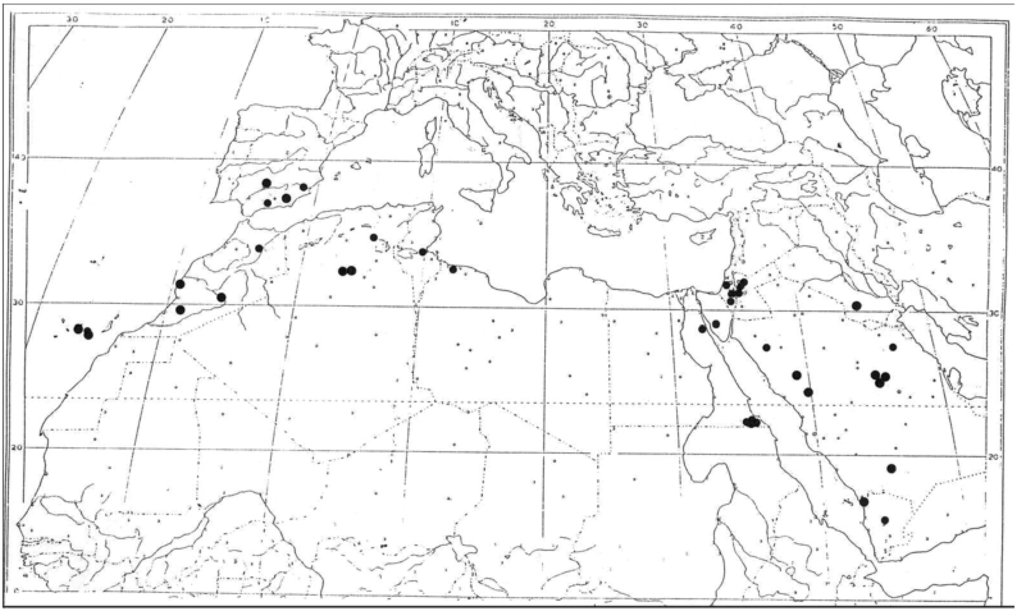
Fl. & fr.: February-April.

Habitat: sandy and stony deserts.

Vernacular names: Hassar (Iraq), Hammaad (Egypt).

Uses: Grazed by camels, Dickson (1955) suggests that it is a pasture plant.

Distribution: SW Europe (S. Spain), N. Africa (Egypt to Morocco), Syria, Palestine, Jordan, Israel, Saudi Arabia, Kuwait, Oman, Iraq, Iran, W. Pakistan, Yemen, Afghanistan, and Canary Islands (Map 37).



Map 37: Distribution of *Notoceras bicorne*

SPECIMENS EXAMINED:

ALGERIA: Biskra: on the stony hills, Balansa 891 (WAG); Ghardaia: in sand and ruderal areas around Palm garden, Chevallier 136a, (WAG); El Ateuf, in sands, near Ghardaia, L. Chevallier s.n., 14/2/1902 (B).

EGYPT: **S**: Sinai, Wadi Bavour, N. Bove 136 (BR); S.Sinai, Wadi Mukattab, 10 km S of Sheikh Nafai, Danin et al. s.n., 6/3/1968 (HUJ). **R**: Wadi Araba, Red Sea coast, Täckholm & Boulos s.n., 9/2/1966 (CAI). **Sa**: Gebel Elba: Saddle between Gebel Astriba and Gebel Makin, Täckholm et al. 1052 (CAI); Wadi Darawina, M. Hassib s.n., 29/11/1933 (CAI); Wadi Yehamib, M. Hassib s.n., 30/11/1933 (CAI); Wadi Maawaw, S. Elba, Täckholm et al. s.n., 28/11/1962 (CAI).

LIBYA: 20 miles S of Sidi Gelani, K. M. Cuichard 619 (BM).

MOROCCO: Taza: 52 km from Taza, 13 km to Guercif., Gavin Stark 814 (NMGM); Zagora, Agdz, Hans-Joachim M 31 (B); Atlas mountains, Gebel Amsitten, Harald Lindberg 2422 (B); between Ait-Bahia and Tafraoute, 16 km SE Ait-Bahia, Vogt 11744 & Oberprieler 6192 (B).

TUNISIA: Gafsa, in rocky place, J. Pitard 320 (WAG).

IRAQ: S desert, near As-Salman, Rechinger 9330 (B).

ISRAEL: S. Negev, 2 km N of Mizpe Har Chizkiyahu, Hammada edges, M. Chaouat 33921 (HUJ); Dead Sea Valley, near Mizpe Dragot, 15 km N of En Gedi slops and small cliffs of dolomite and wadis, A. Danin et al. 06. 032 (B); Judean desert, near Talath-ed-Damm, Feinbrun & Amdursky s.n., 19/4/1933 (B).

JORDAN: Jericho, in desert, J. Bornmüller 117 (BR); lower Jordan valley, 1 km NE of Pzael, 18 km N of Jericho, salty or leached calcareous soil, A. Danin et al. 09. 025 (B); Moab, Holy Hand, W.A. Hayne 76 (OXF & FHO).

PAKISTAN: Peshawar, Attock, Rechinger 30407 (B).

SAUDI ARABIA: Ammeriyeh, Riyadh, Al-Farhan & Thomas 10162 (KSU); As Summan, K. Batanouny 158 (CAI); El Medineh E. Alawali, Hedjaz, A. Khattab 1414 (CAIM); Horimela valley, Migahid 13572 (KSU); El-Mansouriah, Migahid 13573 (KSU); Shomrokh, SW Arabia, Migahid & El-Sheikh 13575 (KSU); El-Rabda, El-Madinah El-

Munowera, Migahid & El-Sheikh 13579 (KSU); Unaiza, Bidagi, Ain Eljowa, Buraida and Rima valley, Migahid & Sabri 13578 (KSU); Mts of Wadi Hebran, W. Schimper 345 (B).
YEMEN: Wadi Dhar, near Sanaa, J. R. Woody 175.134 (BM).
SPAIN: Santa Ursula, Asplund 105 (B); dry coast at Santa Fé, 4 hours from Almeria, E. Bourgeau 1056 (WAG); Tenerifa: Guimar, in cultivated sandy lands, Bourgeau 1246 (B, WAG); dry coast between Murcia and Orihuela, E. Bourgeau 1567 (WAG); Murcia, La Hoya, Jeronimo 7308 (B); Grana Canaria, Barranco of Aldea, N. Kilian & U. Willerding 2401 (B); without location, Masson 1778 (BM); Tenerife, Guimar, J. Pitard 29 (B); prov. Almeria, between Gergal and Venta, B. Valdes et al. 225/88 (B).

6. Tribe: Sisymbrieae DC.

Syst. Nat. 2: 150, 438 (1821).

Hairs simple, glandular, branched or absent. Sepals erect to spreading. Filaments without appendages, linear, free. Median honey glands present and forming a closed ring around the base of filaments. Stigma capitate or bilobed. Fruit dehiscent or indehiscent, compressed or not, asiliqua, glabrous or hirsute. Radicle incumbent.

Key to subtribes

1a. Plant never covered with glandular hairs. Leaves simple, lyrate-pinnatifid…..…………..….**2**
1b. Plants always covered with glandular hairs. Leaves 2-3 pinnatisect……...**3. Descurainiinae**
2a. Wet seeds not slimy (not mucilaginous), plant cover simple, branched or glabrous………..**3**
2b. Wet seeds slimy (mucilaginous), simple hairs absent…….…………....**1. Arabidopsidinae**
3a. Nectar glands merged, lateral glands at the basis of the short filaments single and ± ring shaped; plants covered with simple, vasculate hairs or glabrous, never branched ………………………………………………………………………………**4.Sisymbriinae**
3b. Nectar glands not merged, lateral glands at the basis of the short filaments always as a pair; plants covered with simple, bifid and branched hairs…………………….……..**2. Brayinae**

1. Subtribe: Arabidopsidinae O.E. Schulz,

Pflanzenr. 86 (IV, 105): 256 (1924).

17. Crucihimalaya Al-Shehbaz, O'Kane and Price,

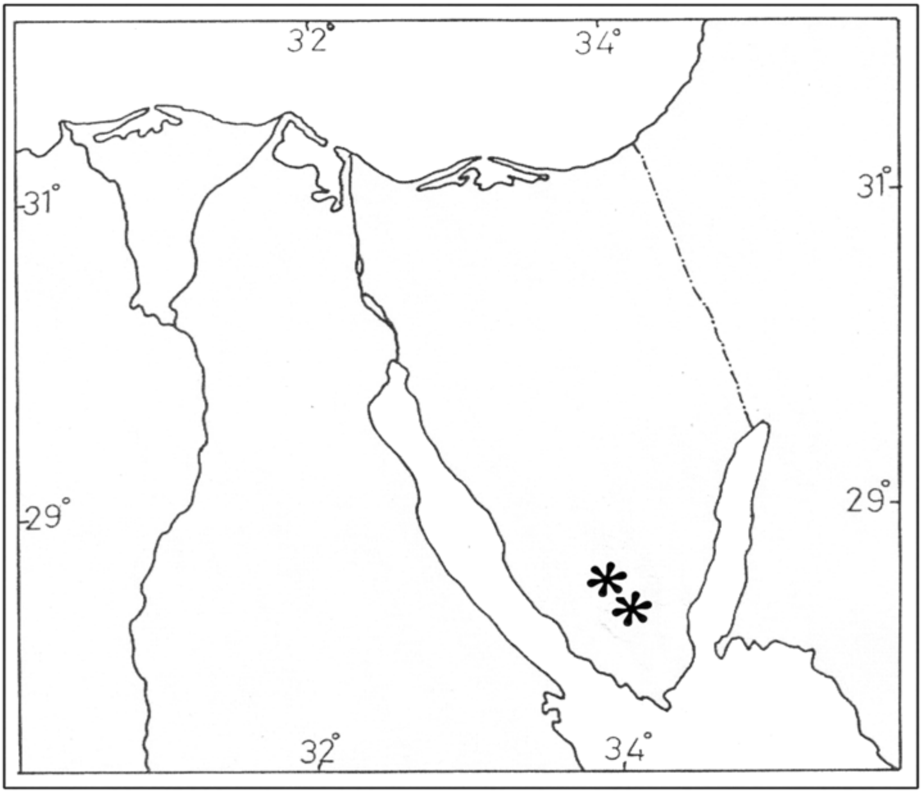
Novon 9: 298 (1999).

Annual herbs. Trichomes stalked, 2-multifids, mixed with few stellate hairs. Stem erect or ascending, simple or branched. Basal leaves petiolate, few in a rosette, mealy, oblong-spathulate, lyrate-pinnatifid, 3-5 lateral lobes; terminal lobe obovate, obtuse, entire; cauline leaves linear-lanceolate, sessile, cunate into a petiole-like base, entire or dentate. Racemes much elongating in fruit, bracteate or not. Flowers minute, pedicellate. Sepals oblong, erect, hairy, caducous, base of inner pair not saccate. Petals muve, spathulate. Filaments free, without

appendages; anther sagittate, obtuse at apex; style distinct; stigma capitate. Fruiting pedicles, hairy, slender, thin, spreading or ascending. Fruit dehiscent, linear, terete, glabrous, spreading; valves with adistinct midvein, glabrous; septum complete, membranous. Seeds uniseriate, wingless, oblong, yellow-brownish; radicle incumbent.
Nine species distributed in Asia and Egypt; only one species in Egypt.

1. **Crucihimalaya kneuckeri** (Bornm.) Al-Shehbaz, O'Kane and Price, Novon 9: 302 (1999).
Basionym: *Sisymbrium kneuckeri* Bornm., Allg. Bot. Z. Syst. 9: 45 (1903).
Type: in Catherine mountains, S of Sinai, Bornmüller s.n., 5/4/1902 (holotype: JE; isotype: B)
Homotypic synonyms: *Arabidopsis kneuckeri* (Bornm.) O.E. Schulz, in Pflanzenr.86 (IV, 105): 277 (1924); Täckholm, Stud. Fl. Egypt ed. 2: 176 (1974); Collenette, Illust. Flow. Pl. Saudi Arabia 193 (1985).
Icon: Collenette, Illust. Flow. Pl. Saudi Arabia 193 (1985) As *Arabidopsis kneuckeri.*
Annual herbs, 15-23 cm. Trichomes stalked, 2-multifids, mixed with few stellate hairs. Stem erect or ascending, simple or branched. Basal leaves 1.5-3 x 0.4-0.5 cm, petiolate 0.3-0.5 cm, few in a rosette, mealy, oblong-spathulate, lyrate-pinnatifid, 3-5 lateral lobes; terminal lobe obovate, obtuse, entire; cauline leaves 0.8-1.2 cm, linear-lanceolate, sessile or cunate into apetiole like base, entire or dentate. Racemes much elongating in fruit, bracteate or not. Flowers minute, pedicellate 2-4 mm. Sepals 1-1.5 mm, oblong, erect, hairy, caducous, base of inner pair not saccate. Petals 2-3 mm, mauve, spathulate. Filaments 1.5-2 mm, free, without appendages; anther 0.5 x 0.25 mm, sagittate, obtuse at apex; style about 0.5-1 mm long; stigma capitate. Fruiting pedicles 4-10 mm, hairy, slender, thin, spreading or ascending. Fruit 3-4.5 x 0.05 cm, dehiscent, linear, terete, glabrous, spreading; valves with adistinct midvein, glabrous; septum membranous. Seeds uniseriate, wingless, oblong, yellow-brownish; radicle incumbent.
Fl. & fr.: March-April.
Habitat: granitic rocks and sandy areas.
Distribution: Egypt and Saudi Arabia (Map 38)

SPECIMENS EXAMINED:
EGYPT: **S**: E slopes of Gebel Catherine, 1900-2250 m, Podlech 49785 (CAI); S. Sinai, env. of St. Catherine, Wadi Abu Heyman, red granite, bolders, A. Shmida s.n., 31/4/1967 (HUJ).



Map 38: Distribution of *Crucihimalaya kneuckeri*

18. **Olimarabidopsis** Al-Shehbaz, O'Kane and Price,

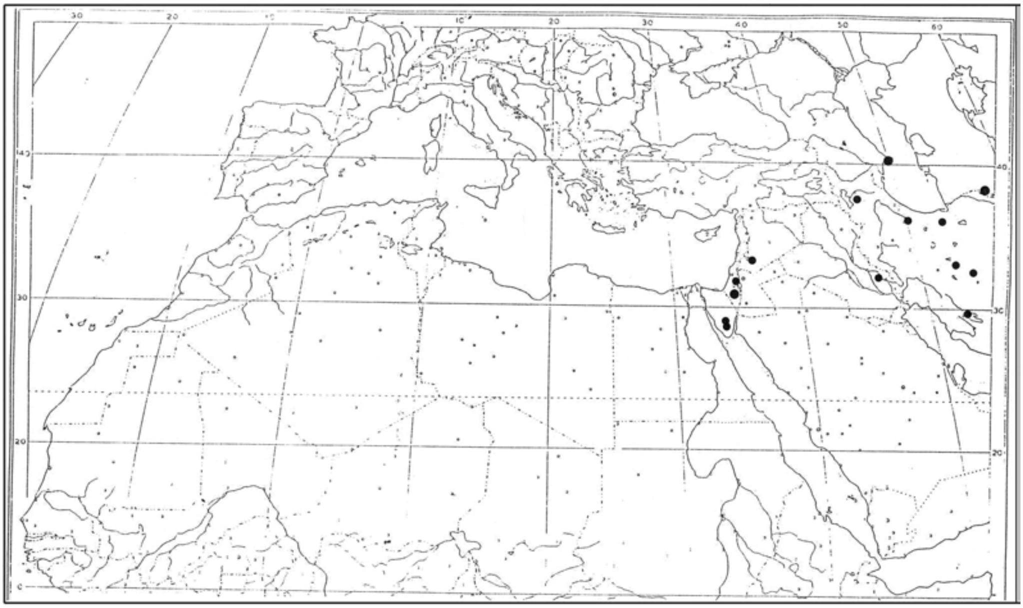
Novon 9: 296-307 (1999).

Annual herbs, covered with 2-4 fid hairs, short-stalked or sessile hairs. Stems simple or branched, erect or ascending. Basal leaves slightly rosette or not rosette, simple, entire at first, dentate or pinnatifid, obtuse at apex, petiolate, obovate-oblong; cauline leaves sessile, oblong-sagitte, auriculate, dentate, acute at apex. Inflorescences ebracteate, corymbose racemes, elongating in fruit; rachis straight. Flowers minute, pedicellated. Sepals oblong, erect, obtuse, hairy, not saccate at the base of inner pair. Petals yellow or yellowish-white, narrowly spathulate, obtuse at apex. Stamens 6; filaments free, without appendages; anthers oblong, rounded at base, obtuse at apex. Fruiting pedicels slender, spreading or ascending, hairy. Fruits dehiscent, linear, terete, slightly flate, slightly curved, hairy; style short; stigma capitate depressed on style; valves 1-nerved; septum membranous, pitted. Seeds in one row in each cell, oblong, brown, wingless; radicle incumbent.

Three species distributed in Asia, E. Europe and Egypt; only one species in Egypt.

1. **Olimarabidopsis pumila** (Stephan) Al-Shehbaz, O'Kane and Price, Novon 9: 303 (1999).
Basionym: *Sisymbrium pumilum* Stephan ex Willd., Sp. Pl. ed. 4, 3 (1): 507 (1800).
Type: From N. Iran, Stephan s. n. (holotype: LE; isotype: W).
Homotypic synonym: *Arabidopsis pumila* (Stephan ex willd.) Busch in Kusn., Busch and Fomin, Fl. Cauc. Crit. 3, 4: 457 (1909); Boulos, Fl. Egypt 1: 191 (1999).
Heterotypic synonym: *Sisymbrium griffithianum* Boiss., Fl. Orient. 1: 214 (1867).
Type: in sands of Afghanistan, near Hydozil (Griff) (not seen).
Icon: Zohary, Fl. Pal. 1, t. 373 (1966). As *Arabidopsis pumila*.
Annual herbs, 10-20 cm, covered with 2-3-4fid hairs, short stalked hairs. Stem simple or branched from the base, erect or ascending. Basal leaves 1.4-3.5 x 0.5-1.5 cm, slightly rosette or not rosette, petiolate 0.4-0.9 cm, obovate-oblong, dentate or pinnatifid or entire at first, obtuse at apex; cauline leaves 0.9-2 x 0.4-0.7 cm, linear to oblong-sagittate, auriculate, dentate, acute at apex, sessile. Inflorescences ebracteate, corymbose racemes, elongating in fruit. Flowers minute, pedicellate 2-3 mm long. Sepals 1.5-2 mm long, oblong, obtuse, hairy, not saccate at base. Petals 2-2.5 mm, yellow, narrowly spathulate, obtuse at apex. Filaments 1.5-2 mm long, free, without appendages; anthers 0.5 x 0.25 mm, oblong, obtuse at apex. Fruiting pedicels 3-5 mm long, slender, spreading or ascending. Fruits 1.5-3 x 0.1 cm, slightly flat, terete, linear, slightly curved, pubescent; style 1 mm long; stigma capitate, depressed on style; valves 1-nerved; septum membranous, pitted. Seeds uniseriate, oblong, brown, wingless, 0.9-1 x 0.4-0.5 mm; radicle incumbent.
Fl. & fr.: March-May.
Habitat: Sheltered wadi sides and Crevices.
Vernacular name: Um El-Grenat, " mother of the horn".
Distribution: E. Europe (C., E. S. Russia), Syria, Lebanon, Palestine, Israel, Oman, Turkey, Caucasus, Iran, Iraq, W. Pakistan, Afghanistan, China, Georgia, C. Asia, W. Tibet, India and Egypt (Sinai) (Map 39).

SPECIMENS EXAMINED:
EGYPT: **S**: in rocks of St. Catherine mountain Schimper 171, 14/4/1835(B); Along the steep way on Gebel Musa, S. Sinai, Täckholm et al. s.n., 22/4/1961 (CAI).
AFGHANISTAN: Hari-rud valley, J.E.T. Aitchison 163, 189 (K).
AZERBAIJAN: Mugan desert, near Baku, Michailowicz s.n., 4/1905 (LY).
IRAN: Valadabad Qazvin, Bonvan 9874 (CAI); SE Iran, prov. Yazd, Mt. Schir-Kuh, Bornmüller 2086 (BR, OXF & FHO); Near Tabriz, B. Gilliat-Smith 1811 (K); near Eli-unio, Sabethpol on rivers Kur and Kortschai, Hohenacker 1562/53 (B, BR, L, LY); prov. Mazandaran, road of Teheran-Amol, about 60 km from Amol, upper valley of the river Haraz, Lambinon 76/212 (BR); Prov. Isfahan, Djuifa, in aula monasterii armeniaci, H. & F. Rechinger 2660 (K).



Map 39: Distribution of *Olimarabidopsis pumila*

IRAQ: nr. Azair, 80 km SE of Amara, E. R. Guest et al. 17665 (K).
ISRAEL: top of the city wall Jerusalem, J. E. Dinsmore 2887 (K, L); C. Negev, Bor Hemet, near the road from Mizpe Ramon to Borot Loz, hills, Y. Gertman 27856 (HUJ).
SYRIA: near Damascus, road of Zahroub to Merdj, Baustam el Mahar, Gaillardot 779 (BR, L, LY, OXF & FHO); without location, Gaillardot 1553 (B, K).
TURKMENISTAN: Ashkabad, in garden, D. Litwinow 529 (LY).
UZBEKISTAN: prov. Bukhara, Samarkand-Termez, Roshewitz 26 (LY).

2. **Subtribe Brayinae** O.E. Schulz,

In Pflanzenr. 86 (IV, 105): 204 (1924).

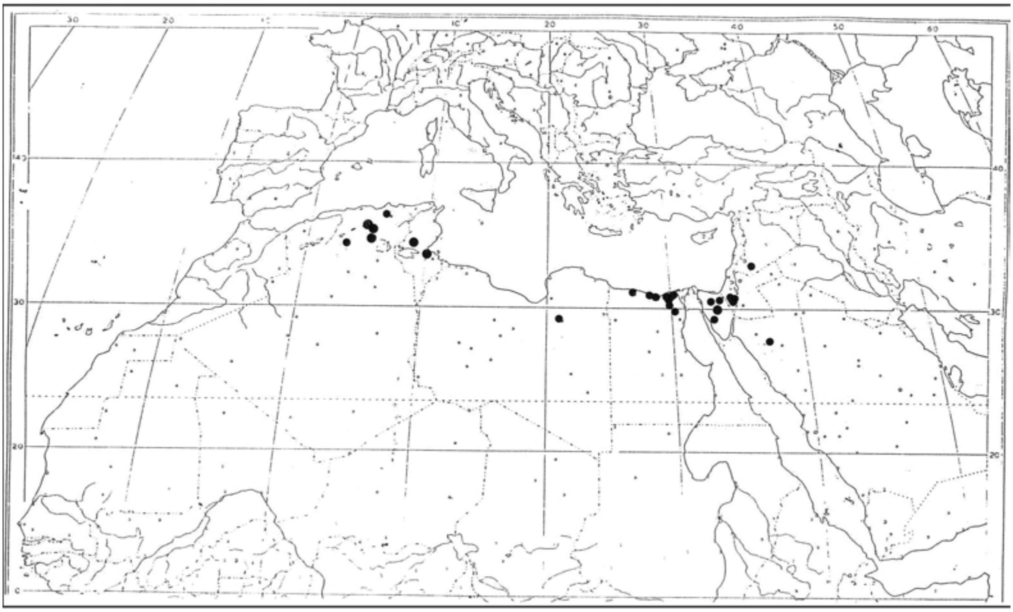
19. Nasturtiopsis Boiss.

Fl. Orient. 1: 237 (1867)

Annual herbs, usually pubescent with short, spreading simple hairs. Stems mostly numerous, branched, asecnding. Radicle leaves petiolate, narrow, dentate or deeply many lobed; cauline leaves sessile, small. Racemes corymbose, ebracteate. Flowers small, pedicellate, ebracteate. Sepals suborbicular, hairy, not saccate at the base. Petals yellow, longar than sepals, distinct to short clawed and obovate-round limb. Stamens 6; filaments linear, free; anthers short ovate; style short; stigma capitate or slightly 2-lobed. Fruiting pedicels filiform, spreading. Fruits dehiscent, oblong to linear, ± curved, glabrous; valves submembranous, 1-veined; septum

membranous. Seeds in two rows in each cell, ovoid to oblong-ellipsoid, brownish; radicle incumbent.
Two species in north Africa and Arabia, one species in Egypt.

1. **Nasturtiopsis coronopifolia** (Desf.) Boiss., Fl. Orient. 1: 237 (1867); Muschler, Manual Fl. Egypt 1: 402 (1912); Ozenda, Fl. Sah.261, Fig.76 (1958); Jafri, Fl. Libya 23: 185 (1977); El Hadidi & Fayed, Taeckholmia 15: 41 (1994-1995); Boulos, Fl. Egypt Checklist 38 (1995); Boulos, Fl. Egypt 1: 187 (1999).
Basionym: *Sisymbrium coronopifolia* Desf., Fl. Atlant. 2: 82 tab. 154 (1798).
Type: in sandy desert near Cafsam (not seen).
Heterotypic synonyms: *Nasturtiopsis arabica* Boiss., Fl. Orient. 1: 237 (1867).
Type: in Wadi Atal, Saudi Arabia (Schimper exs.192) (lectotype: E, isotype: B, OXF & FHO); in desert Tih in Palestine Contermino (Boiss.), (isotype: B)
Nasturtiopsis coronopifolia (Desf.) Boiss. var. *arabica* (Boiss.) O.E. Schulz, Pflanzenr. 86 (IV, 105): 254 (1924). Type: in Egypt (Mariut) (not seen).
Nasturtiopsis coronopifolia (Desf.) Boiss. subsp. *arabica* (Boiss.) Greuter & Burdet, Willdenowia 13: 94 (1983).
Icon: Jafri, Fl. Libya 23, 186, t. 59 (A-E) (1977).
Annual herbs, 10-22 cm, densely to sparsely spreading simple hairs. Stems ascending or erect, branched from the base. Lower leaves 1.5-5 x 0.5-1.2 cm, almost in a rosette, obovate-oblong or spathulate, dentate or pinnatifid with oblong linear lobes, tapering into a petiole 0.3-1 cm; upper leaves 1.1-2.5 x 0.3-0.5 cm, narrow, sessile. Racemes compact, numerous. Flowers small, pedicels 3-6 mm. Sepals 1.5-2 mm, erect to spreading, pubescent. Petals 2.5-3 mm, yellow, distinct into, short clawed and obovate-round limb. Filaments linear, 2-2.2 mm, anthers 0.7 x 0.4 mm, short, ovate; style 0.3-0.5 mm long; stigma capitate or slightly 2-lobed. Fruiting pedicels 4-10 mm, filiform, spreading. Siliques 0.6-1.5 x 0.1-0.15 cm, straight or upcurved, terete, glabrous, dehiscent; valves submembranous with acute base and obtuse apex; septum membranous. Seeds in two rows in each locule, oblong-ellipsoid, 0.7-1 x 0.4-0.5 mm, brownish; radicle incumbent.
Fl. & fr.: March-May.
Habitat: sandy and stony soils.
Vernacular name: Cred Abu-Rei (Schimper).
Uses: it is eaten by sheep and camels.
Distribution: Saudi Arabia, Palestine, Israel, Syria and N. Africa (Egypt to Morocco) (Map 40).



Map 40: Distribution of *Nasturtiopsis coronopifolia*

SPECIMENS EXAMINED:

ALGERIA: Biskra, Oued, B. Balansa 888 (WAG); Laghouat, in place covered with water, L. Chevallier 269 (B); in sand plain of El-Outaïa, S. Choulette 202 (LY); Constantine, El-Kantara, in stony ground, G. Rouy s.n., 24/4/1892 (LY); Bordj-bou-Arreridj, fields uncultivated and stony area, Maire 5140 (B).

EGYPT: **M**: the road between Matruh-Salum, M. Costantin s.n., 21/1/1970 (CAIM); Ras el-Heckma, A. Abbas & A. El Shaier s.n., 1/4/1969 (CAIM); Bahig, J.R. Shabetai s.n., 21/4/1934 (CAI); Burg el Arab on the calcareous hills, Täckholm s.n., March 1952 (CAI); Burg el Arab, Täckholm s.n., 17/2/1965 (CAI); Burg el Arab, Mariut, Ibrahim el Sayed s.n., 23/3/1956 (CAI); Ikingi Mariut, N.D. Simpson s.n., 16/3/1923 (CAIM); very stony places on limestone hill rocks by West bank lake Mariut, G.F. Scott Elliot 3717 (K); Mariut, El Amria, Täckholm s.n., 11/3/1956 (CAI). **Nv**: Cairo-Alexandria desert road 180 km from Cairo, in fields West of the road Täckholm s.n., 16/4/1967 (CAI); Wadi Natrun, R. Meinertzhagen s.n., 1928 (BM). **Di**: Wadi el-Arish, M. Drar s.n., 4/4/1939 (CAIM); Wadi el-Gedeirat, N. Sinai, M. Drar s.n., 4/3/1930 (CAIM); N. Sinai, Kuntilla plain, N of Gebel El Misheiti, G. Halevy s.n., 8/4/1970 (HUJ); N. Abu Zenima, S. Sinai, Shalaby and A. Khattab s.n., 17/2/1969 (CAIM).

LIBYA: Cyrenaica, near Soluk, along roadside, Kranz 1104 (K).

TUNISIA: Gabes, in waste lands, Kralik 174 (LY).

ISRAEL: S. Negev, Machtesh Rammon, marly soil, J. D. Angelis 516 (B, BR); Negev Highlands, 2 km NW of Yerokham, A. Danin et al. 17. 013 (B); Nahal Paran Junction with Rammon-Elat road, Pebbly Wadi beds, A. Danin et al. 27. 024 (B); Yell Yana, Handing 252 (K); Negev, Beer Sheba, Wadi between hills, Zohary 33806 (HUJ).

TUNISIA: Gafsa, C. J. Pitard 313 (B).

SAUDI ARABIA: without location, E. Bonar s.n., 1846 (OXF & FHO, WAG); Wadi Atal, Schimper 192, 27/3/1835 (B, E, OXF & FHO).

SYRIA: Wadi Zuweirah, S. Syria, B.T. Lowne s.n., 1863 (K, OXF & FHO).

20. **Neotorularia** Hedge & Léonard,

In Bull. Jard. Bot. Nat. Belg. 56: 389-395 (1986).

Synonym: *Torularia* O.E. Schulz, in Pflanzenr. 86 (IV, 105): 213 (1924).

Annual herbs, covered with simple and bifid hairs. Stems erect or ascending, branched. Radicle leaves rosulate, petiolated, oblong-linear, dentate, rarely pinnatifid, ± entire; cauline leaves subsessile to sessile. Racemes short, overtopped by young fruit. Flowers small, pedicellated. Sepals not saccate at the base, suberect, equal at the base. Petals white or pink, oblong-spathulate. Stamens 6; filaments without appendages, free; anthers sagittate; style thick, short; stigma capitate or slightly 2-lobed. Fruiting pedicels short, as thick as fruit ± spreading. Fruits a linear siliqua, dehiscent, rigid, straight or contorted, hispid or glabrous; valves firm; septum thick to submembranous. Seeds small, in one row in each locule, oblong-ovoid, brown; radicle incumbent.

About 16 species in SW and C Asia, Mediterranean region and Europe: two species in Egypt.

Key to species:

1. Annual herb, up to 29 cm long; glabrous or hispid with simple and bifid hairs; petals white; radicle leaves 0.9-5.5 cm long; fruits strongly curved or contorted; fruiting pedicels 1-1.5 mm long……………………………………………………………..………...**2. N. torulosa**
2. Annual herb, up to 8 cm long; glabrous except the fruits; petals pink; radicle leaves 1-2 cm long; fruits straight or slightly curved, thinner than above; fruiting pedicels 1.5-2.5 mm long ………………………………………………………………...…..**1. N. aculeolata**

1. Neotorularia aculeolata (Boiss.) Hedge & Léonard, Bull. Jard. Bot. Nat. Belg. 56: 393 (1986); El Hadidi & Fayed, Taeckholmia 15: 42 (1994-1995); Boulos, Fl. Egypt Checklist 39 (1995); Boulos, Fl. Egypt 1: 191 (1999).

Basionym: *Sisymbrium aculeolatum* Boiss., Ann. Sci. Bot., ser. 2, 17: 75 (1842).

Type: in shady area in Sinai, Schimper 124 (Holotype: B, isotype: E, L).

Homotypic synonyms: *Malcolmia aculeolata* (Boiss.) Boss., Fl. Orient. 1: 226 (1867),
Torularia aculeolata (Boiss.) O.E. Schulz, in Pflanzenr.86 (IV, 105): 223 (1924); Täckholm, Stud. Fl. Egypt ed. 2: 175 (1974).

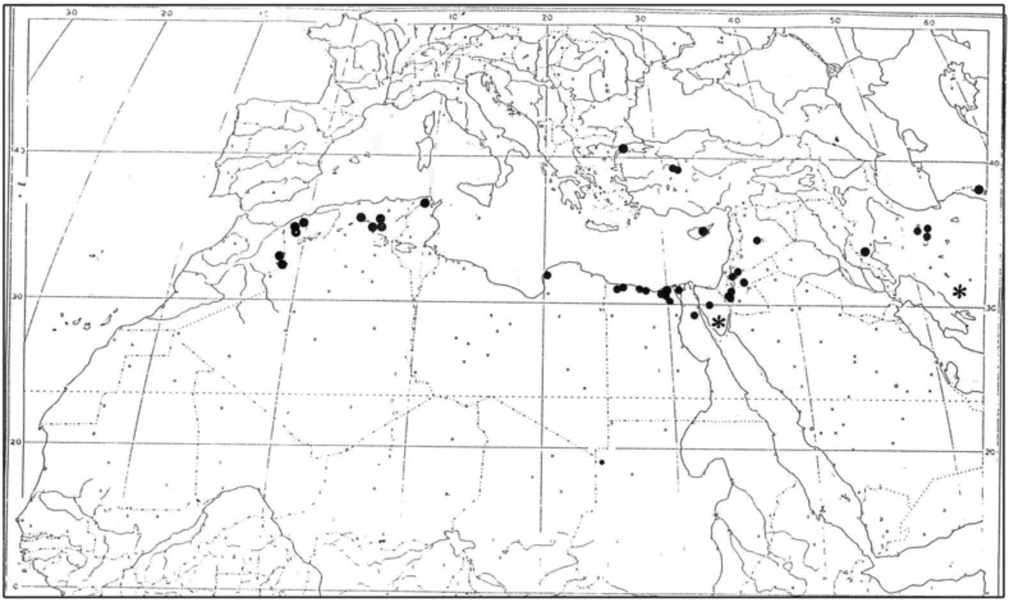
Icon: Jafri, Fl. W. Pakistan No. 55, 269, t. 35 E (1973). As *Torularia aculeolata*.

Dwarf annual herbs, 4-8 mm long, glabrous except the fruits. Stem simple or branched from the base, prostrate to ascending. Basal leaves 1-2 cm, a rosette at the base, petiolate 0.5-0.8 cm, oblong to spathulate, lyrate-pinnatifid, with 2-4 pairs of lateral lobes and obovate, obtuse terminal lobe; cauline leaves minute 0.5-1 cm, linear-oblong, entire. Racemes 1-5 flowers, ebracteate. Flowers pedicellate 2-2.5 mm. Sepals 1.5-2 mm, unequal, oblong to linear. Petals

2.5-3.5 mm, pink, oblong-spathulate. Filaments 1.5-2 mm, free; anthers ovate, 0.4 mm long; style extremely short, 1 mm long; stigma truncate-2-lobed. Fruiting pedicels 1.5-2.5 mm, as thick as fruit. Fruits 1.5-3 x 0.1 cm, straight or slightly curved, covered with scattered stiff simple hairs, linear, slender, erect-patent; valves un nerved, aculeolate; septum membranous. Seeds in one row in each cell, oblong, brown, 1.2-1.5 x 0.5 mm; radicle accumbent.
Fl. & fr.: March-May.
Habitat: in rock crevices and hillsides.
Distribution: Iran, Afghanistan, W. Pakistan, India and Egypt (Sinai) (Map 41).
SPECIMENS EXAMINED:
EGYPT: **S**. in shady area in Sinai, Schimper 124 (E, L).
INDIA: Zuetta, Nduttue 6809 (K).
IRAN: Fars, S. of Deh Bid, N. and W. facing soft basalt outcrops, J. C. Archibald 1227 (K); Küh Rah-Rui, N. B. Rard Wülk, Bornmüller 164 (B); West of Jaz Mūrīān, dunes with a lot of annuals, Léonard 5801 (BR).

2. **Neotorularia torulosa** (Desf.) Hedge & Léonard, Bull. Jard. Bot. Nat. Belg. 56: 395 (1986); Tutin, T. G., et al. Fl. Eur. ed. 2, vol. 1: 339 (1993); El Hadidi & Fayed, Taeckholmia 15: 42 (1994-1995); Boulos, Fl. Egypt Checklist 39 (1995); Boulos, Fl. Egypt 1: 190 (1999).
Basionym: *Sisymbrium torulosum* Desf., Fl. Atlant. 2: 84, t. 159 (1798).
Type: Tunis, Shibam, Desfontaines (holotype: P).
Homotypic synonyms: *Malcolmia torulosa* (Desf.) Boiss., Fl. Orient. 1: 225 (1867).
Torularia torulosa (Desf.) O.E. Schulz, in Pflanzenr. 86 (IV, 105): 214 (1924).
Icon: Jafri, Fl. Libya 23, 188, t. 60 (A-E) (1977). As *Torulara torulosa*.
Annual herbs, 11-29 cm long, glabrous or hispid with simple and bifid hairs. Stem ascending or prostrate, branched at base. Basal leaves 0.9-5.5 x 0.4-0.9 cm, rosulate, petiolate 0.5-2 cm, oblong-linear, sinuate-dentate or ± entire; cauline leaves 1.5-2 x 0.3-0.4 cm, oblong-linear, irregularly toothed, acute, sessile to short petiolate 0.3-0.5 cm. Racemes ebracteate, short, elongated in fruit. Flower pedicels 1-1.5 mm. Sepals 2 mm, subequal, suberect. Petals 3-4 mm, white, spathulate-oblong, truncate at apex. Filaments 1.5-2.5 mm long, free; anthers 0.5 mm long, sagittate; style short; stigma capitate. Fruiting pedicels 1-1.5 mm, as thick as fruit, rigid. Siliques 0.8-2 x 0.1-0.2 cm, rigid, hispid or glabrous, straight, curved or somewhat coiled above, tardily dehiscent; valves firm; septum thick to submembranous. Seeds one row in each locule, compressed, oblong-ellipsoid, brownish, 1-1.2 x 0.5-0.6 mm; radicle incumbent.
Fl. & fr.: March-May.
Habitat: sandy plains and sandy desert.
Vernacular names: Hassar, Qaraina (Iraq).
Uses: eaten by sheep.

Distribution: S. E. Europe (Crimea), Cyprus, Caucasus, Syria, Lebanon, Palestine, Israel, Jordan, Arabia, Kuwait, Turkey, Iran, Iraq, W. Pakistan, Afghanistan, N. W. India, C. Asia and N. Africa (Egypt to Morocco)(Map 41).



Map 41: Distribution of *Neotorularia aculeolata* ∗ and *N. torulosa* ●

Two varieties recognized in Egypt.

Key to varieties:

A. Fruit and upper part of plant hispid with simple and bifid hairs……………...2. var. **torulosa**

B. Fruit and upper part of plant glabrous…………………………......…..1. var. **scorpiuroides**

1. var. **scorpiuroides** (Boiss.) Hedge & Léonard, Bull. Jard. Bot. Nat. Belg. 56: 395 (1986).

Basionym: *Sisymbrium scorpiuroides* Boiss., Ann. Sci. Nat. Bot., ser. 2, 17: 74-75 (1842). Type: in Ispahan, N. 4166 (Iran). (holotype: B).

Homotypic synonym: *Torularia torulosa* var. *scorpiuroides* (Boiss.) O.E. Schulz, in Pflanzenr. 86 (IV, 105): 217 (1924).

Heterotypic synonym: *Malcolmia torulosa* (Desf.) Boiss., var. *leiocarpa* Boiss., Fl. Orient.1: 225 (1867). Type: Cum typo near Gaza (Boiss.); south Iran near Ispahan (Auch. exs. 4155). (not seen).

Fruit and upper part of the plant glabrous; fruits frequently spirally inrolled, curved, rarely straight.

2. var. **torulosa**

Type: Tunis, Shibam, Desfontaines (holotype: P).

Fruit and upper part of the plant hispid; fruits straight or slightly curved.

SPECIMENS EXAMINED:

ALGERIA: Gravels of Oued-Biskra, B. Balansa 902 (B); prov. Costantine, Bukerley s.n., 1868 (BR); prov. Oran, Sig, Wadi near village of Jelit, Doumergue s.n., 23/4/1891 (LY); Beguirat near to Bedeau, Doumergue s.n., 14/5/1894 (LY); El aricha, Doumergue s.n., 15/5/1894 (LY); in sands near Ksour, Botna, L. Kralik 4 (B, LY, OXF & FHO); near Biskra, Oued, Kuegler s.n., 25/2/1901 (B); in cultivated lands, near Biskra, G. Ruy 1141 (LY); prov. Constantine, Batna, G. Rouy s.n., 27/4/1892 (LY).

EGYPT: **M**: Wadi El Habs between Matruh and Agiba, Täckholm et al. s.n., 23/3/1974 (CAI); Mersa Matruh, Täckholm et al. s.n., April 1949 (CAI); Fuka, Mariut, Botany Dep. excur.15/3/1955 (CAI); Dabaa, Simpson 4662 (BM); Burg el Arab, Mariut, G. Täckholm s.n., 15/3/1928 (CAI); in fields around Ikingi Mariut, Täckholm et al. s.n., 7/3/1967 (CAI); in calcareous clay fields, near Mariut, Letourneuse 8 (LY); Amriya, El Hadidi s.n., March 1954 (CAI). **Nv**: fieds and field margines near Abusir, Simpson 3238 (BM); lower Egypt, Arenia, P.H. Davis 8385 (B); Cairo-Alexandria desert road, 180 km from Cairo, in fields West of the road, Täckholm et al. s.n., 16/4/1967 (CAI). **Dg**: Wadi Chafura, N. Galalas, Schweinfurth s.n., 12-14/4/1887 (BM); Wadi el Abiad, N. Galalas, about 1000M, Simpson 2696 (BM). **Di**: N. Sinai, Gebel E-Raha, near Gebel Zarqa, Danin s.n., 9/4/1970 (HUJ).

LIBYA: Benghasi, G. Ruhmer 14 (BR).

MOROCCO: prov. Figuig: 32 km between Bouarfa and Figuig, 21 km E Bouarfa, Vogt 10493, & Oberprieler 4941 (B); 19 km between Bouarfa and Oujda, 5 km N of Tendarara, Vogt 10629, & Oberprieler 5077 (B).

TUNISIA: Matmata, Kébira, in sands, J. Pitard 758 (LY).

IRAQ: Mesopotamia, Bisedjik, Haschmadi, O. Stapf 554 (LY).

IRAN: 20 km after Salehabad, towards Mehran, H. Akhani 8118 (B); S of Veramin, not far from the railway towards Teheran, Léonard 5266 (BR); S of Teheran, Léonard 5270 (BR); between Teheran and Tabas, in SW of Dasht-e-Kavir, Léonard 5378 (BR).

ISRAEL: Negev Highlands, 8 km SW of Yerokham, A. Danin et al. 24. 012 (B); N. Negev, sands of Nahal Sekher, 15 km S of BeerSheva, A. Danin et al. 16. 013 (B); Negev Highlands, Mizpe Ramon, weed in gardens and among houses, A. Danin et al. 18. 016 (B); Negev Highlands, 6 km SW of Dimona, A. Danin et al. 22. 037 (B); Negev, 12 km S of Beer Sheba, Wadi, Zohary 34454 (HUJ).

JORDAN: lower Jordan valley, 1 km NE of Pzael, 19 km N. of Jericho, A. Danin et al. 9. 006 (B).

PALESTINE: km 30 on the Jerusalem-Jericho road, E. Eig and A. Grizi 326 (BR, WAG).

SYRIA: Palmyra, J. Bouharmont 27393 (BR).

CYPRUS: Kythraea-mountains nearby, Sintenis and Rigo s.n., 5/1880 (LY).

ITALY: Cilicia, Aucher-Eloy 133 (OXF & FHO).

TURKMENISTAN: prov. Ashkabad, in sands, D. Litwinow 552 (LY); Ashkabad, Litwinow 559 (B).

TURKEY: 2.6 km NE of Kamisagil, Yaylasi (Konya), H.A. de Wit 79 (WAG); 1 km NW of Kamisagil Yaylasi (Konya), H.A. de Wit 153 (WAG); prov. Konya, Tuz Gölü, Nordufer, Hagemann et al. 2094 (B).

3. **Subtribe: Descurainiinae** O.E. Schulz

In Pflanzenr. 86 (IV, 105): 304 (1924).

21. Descurainia Webb & Berth.

Hist. Nat. Iles Canar. 1: 72 (1836-1840); O.E. Schulz, in Pflanzenr. 86 (IV, 105): 305-346 (1924) and Pflanzenfam. ed. 2, 17B: 649-652 (1936).

Annual or biennial herbs, with branched, simple or glandular hairs, rarely glabrous. Stems erect, branched. Lower leaves finely bi-or tri-pinnatisect, petiolated; upper leaves 2 or 3 pinnatisect, subsessile. Racemes ebracteate. Flowers small. Sepals erect to spreading, not saccate at the base. Petals yellow to creamy, as long as or smaller than sepals, spathulate. Stamens 6, exserted; filaments free, narrow, without appendages; anthers sagittate and curved from apex; style short; stigma capitate. Fruiting pedicels filiform. Fruits dehiscent, 2-celled, erect or curved, terete, glabrous or slightly hairs; valves torulose, slightly convex, with distinct midrib and lateral veins; septum membranous. Seeds uniseriate, many, mucilaginous on wetting, oblong; radicle incumbent.

About 45 species in the cold and temperate zones of Eurasia and America: only one species in Egypt.

1. **Descurainia sophia** (L.) Webb & Berthel., in Engl. & Prantl, Nat. Pflanzenfam. 3(2): 192 (1891); O.E. Schulz, in Pflanzenr. 86 (IV, 105): 309 (1924); Täckholm, Stud. Fl. Egypt ed. 1: 339 (1956); Hedge, in Fl. Turkey 1: 486 (1965); Zohary, Fl. Pal. 1: 256 (1966); Hedge, in Fl. Iran 57/28.2: 339 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 174 (1974); Hedge & Lamond, in Fl. Iraq 4, 2: 1080 (1980); Tutin, T. G., et al. Fl. Eur. ed. 2, vol. 1: 321 (1993); El Hadidi & Fayed, Taeckholmia 15: 41 (1994-1995); Boulos, Fl. Egypt Checklist 38 (1995); Luopeng et al. Acta Bot. Sinica, 39 (5): 477-479 (1997); Boulos, Fl. Egypt 1: 187 (1999).

Basionym: *Sisymbrium sophia* L., Sp. Pl. ed. 1: 659 (1753).

Type: in Europae maceriis, muris, tectis, herb. Linn. 836/31 (holotype: LINN).

Icon: Zohary, Fl. Pal. 1, t. 372 (1966).

Annual or biennial herbs, 10-74 cm, greyish-green, densely canescent with branched, simple and glandular hairs below and glabrous above. Stem erect, leafy, branched. Basal leaves petiolate 1-3 cm, finely 2-3 pinnatisect into narrow-oblong to linear, acute, entire lobes; cauline leaves 2-3 pinnatisect, sessile or short petiolate 0.3-0.7 cm. Inflorescences many flowered, corymbose, elongated in fruit. Flowers small, pedicels 3-7 mm. Sepals 1.7-2 mm, erect, hairy, not saccate at the base. Petals 1.5-1.7 mm, yellow, as long as or shorter than sepals, spathulate, long clawed. Filaments 2-3 mm, free, usually exceeding the sepals; anthers 0.3-0.5 mm, ovate to sagittate; style very short; stigma capitate. Fruiting pedicels 0.7-2 cm, filiform, spreading, straight or slightly curved, glabrous or slightly hairy. Fruits 1.5-2.5 x 0.05-0.1 cm, glabrous, straight or slightly curved ± torulose; valves torulose with distinct midrib; septum membranous. Seeds in one row in each locule, small, 1-1.3 x 0.6-0.8 mm, oblong, brownish-red; radicle incumbent.

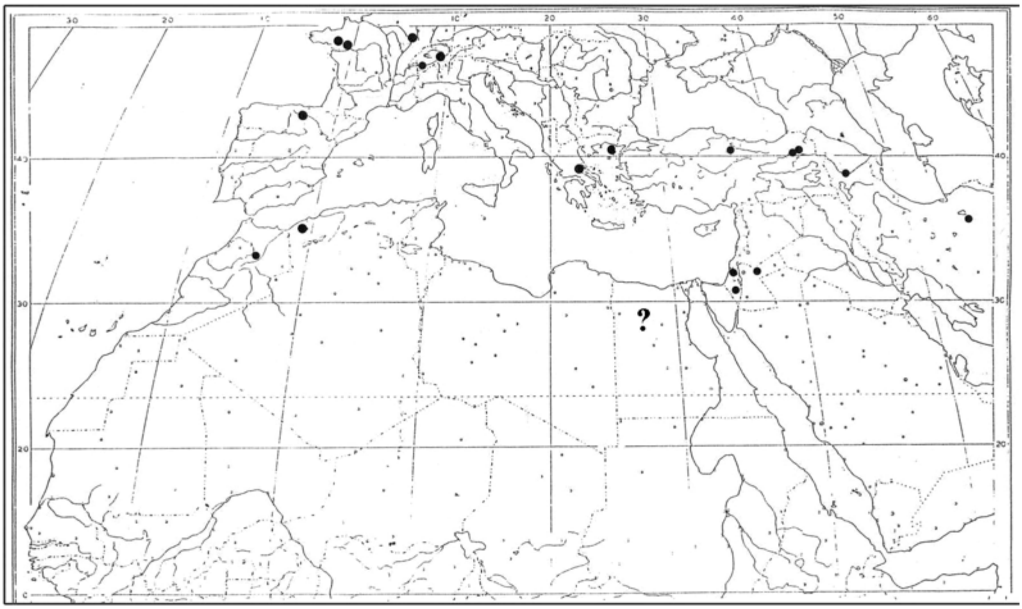
Fl. & fr.: March-May.

Habitat: weed in cultivated area and waste ground.

Vernacular name: Shamfatuq (Iraq).

Uses: Bush (1939) notes the seeds have a pungent flavour and are used in place of Mustard in the Caucasus; the ash contains saltpetre. Luo Peng et al. (1997) notes the seeds contain a high amount of oil content. It is suggested that this oil can be introduced for industrial utilization. Best (1977) notes that this plant can afford protection from erosion on fields lacking good cover of crop residues.

Distribution: Europe, Mediterranean region, Asia, N. America, S. Africa, N. Africa (Morocco, Algeria, Egypt) (Map 42).



Map 42: Distribution of *Discurainia sophia*

SPECIMENS EXAMINED:

ALGERIA: prov. Oran, El Aricha, Doumergue s.n., 11/2/1903 (1903)

MOROCCO: M. Atlas, Bekrit, calcareous roads, A. Jahandiez 619 (B).

AFGHANISTAN: S. Siologiske Sknitler, Voik 1417 (B).

IRAN: Prov. Shahrud, in Saxosis calc., K. H. Rechinger 55409 (B); Prov. Azerbaijan Orient, Kīyāmakī protected region, K. H. Rechinger 56913-A (B).

ISRAEL: Judean Mts., Jerusalem, along Rupin street, near the Monestery of the Cross, A. Danin s.n., 25/4/1992 (B); Eilat to Maam, Arava Valley, Edom, Zohary 27079 (HUJ).

JORDAN: El-Jubeiha, university campus, Dawud Al-Eisawi 1475 (B).

PAKISTAN: N. area, steppe region, Nüsser 1177 (B).

BELGIUM: near river Yser, Van der Veken 10198 (WAG).

ENGLAND: prov. Kiew, in waste land, Uman, E. Koljassinky 1556 (LY).
FRANCE: near Nancy towards Vincent, C. Billot 917 (LY); LansleBourg (Savoie), near to the road, Lombard 3620 (LY); in fields, near Bramois, not far from Sion, L. Marret 224 (LY).
GREECE: Phocis, near Delphi, Chr. Leonis 382 (LY).
GERMANY: Sleswich-Holstein, Hansen 468 (WAG); Thurinen, in uncultivated lands, near Pforta, Sagorski s.n., 6/1897 (LY).
NETHERLANDS: Zeeland Overveen, Anon s.n., 5/7/1934 (WAG); Wassenaar, dunes at the Waalsdorpervlakte, Brandhorst 101 (WAG); Gravenhage, Brandhorst 101a (WAG); Den Helder, J. Clear Ber Gen 425 (WAG); Wageningen, de Vries 797 (WAG); Naaldwijk, Staalduin, de Vries 1020 (WAG); Wageningen, J. de Bruijn 374 (WAG); Noordwijk near Leiden, Jongkindt Coninck s.n., 21/7/1869 (WAG); near Putten on the beach at unloading sirte, Kok Ankersmit s.n., 7/1867 (WAG); Ameland, near Kooiduinen, K. Setten 966 (WAG); Noordwijk, Valckenier Suringar s.n., 5/1892 (WAG); Deveurner, Pothoofd, Valckenier Suringar s.n., 7/1897 (WAG); Ede station, Valckenier Suringar s.n., 8/1900 (WAG).
SPAIN: Catalogne, Slivia, Chermins, F. Sennen s.n., 7/8/1915 (LY).
SWITZERLAND: Findeln, WE of Zermatt, Koperdraad s.n., 22/7/1964 (WAG); Stiria, in waste lands in Thalheim village, near Judenburg, K. Pilhatsch 535 (LY).
TURKEY: Anatolia, near Tokat, Bornmüller 3239 (OXF & FHO); Prov. Konya, Tuz Gülu, Hagemann et al. 2123 (B); Erzurum, Atatűrk University Farm, John M. Winter 154 (B); between Ispir and Rize, A8 Erzurum, 5 km after the branch off, M. Nydegger 19244 (B).

22. **Robeschia** Hochst.

In W. Schimper, Pl. Arab. Petr. ed. 2, Hohenacker N. 170 (1843); O.E. Schulz, in Pflanzenr. 86 (IV, 105): 359-360 (1924).
Small annual herb, pubescent with branched hairs. Stem erect or ascending, branched upward. Leaves pinnatisect, petiolated or sessile to subsessile in the upper ones. Racemes ebracteate, compact, elongating in fruit. Flowers minute, pedicellate. Sepals lanceolate, erect. Petals pink or white, spathulate. Stamens 6, erect, free; anther ovoid, obtuse; style short; stigma depressed capitate, scarcely bilobed. Fruiting pedicels short, thick. Fruits narrow, linear, slightly curved, terete, dehiscent, densely branched hairs; valves with distinct midrib; septum membranous. Seeds in one row in each locule, oblong, brown; radicle incumbent.
Monotypic genus.

1. Robeschia schimperi (Boiss.) O.E. Schulz, in Pflanzenr. 86 (IV, 105): 360 (1924); Täckholm, Stud. Fl. Egypt ed. 1: 339 (1956); Hedge, in Fl. Iran 57/28.2: 342 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 174 (1974); El Hadidi & Fayed, Taeckholmia 15: 41 (1994-1995); Boulos, Fl. Egypt Checklist 38 (1995); Boulos, Fl. Egypt 1: 187 (1999).
Basionym: *Sisymbrium schimperi* Boiss., Ann. Sci. Nat., ser. 2, 17: 76 (1842).
Type: M. Sinai (Egypt), W. Schimper 170 (holotype: W; isotype: B, BM, E, K, OXF & FHO,).
Homotypic synonyms: *Arabidopsis schimperi* (Boiss.) N. Busch, Fl. Cauc. Crit. 3, 4: 457 (1909).

Robeschia sinaica Hochst., in W. Schimper, Pl. Arab. Petr. ed. II, Hohenacker 170 (1843).

Icon: O.E. Schulz, in Pflanzenr. 86 (IV, 105), 360, t. 73 (A-M) (1924).

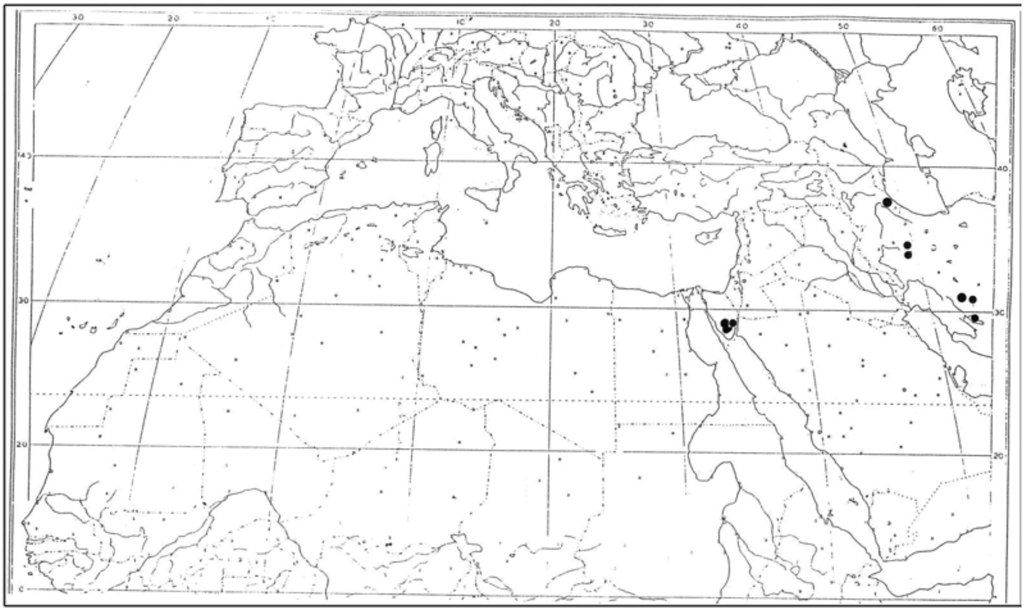
Annual herbs, 4-9 cm, pubescent with branched hairs. Stems erect or ascending, branched from the base. Leaves petiolate 0.2-1.1 cm long, 2-3 pinnatisect; lobes short, oblong, entire or sinuate, obtuse. Racemes compact, ebracteate. Flowers minute, short pedicels 1mm long. Sepals 2-3 mm, oblanceolate, hairy. Petals 3-4 mm, white or pink, slightly spathulate on oblong claw, minutely veins. Filaments 3-4 mm, linear, free; anthers 0.4 mm, ovoid-oblong, obtuse, curved when dry; style short; stigma depressed capitate. Fruiting pedicels 1-2 mm, hairy, as thick as fruit, erect. Fruits 1.1-3 x 0.1 cm, dehiscent, tapering siliqua, hairy, straight or slightly curved, erect; valves with one midrib, hairy; septum membranous. Seeds uniseriate in each locule, 1-1.3 x 0.5-0.6 mm, oblong, brown; radicle incumbent.

Fl. & fr.: April-May.

Habitat: in sandy areas and granitic rocks.

Vernacular name: Robesetii or robeschii (W. Schimper).

Distribution: Iran, Pakistan, Syria and Egypt (Sinai) (Map 43).



Map 43: Distribution of *Robeschia schimperi*

SPECIMENS EXAMINED:

EGYPT: **S**: Sinai, Gebel Musa, A. Kneucker s.n., 3/4/1902 (LY); Sinai mountains, between granitic rocks, W. Schimper 170, 9/4/1835 (B, BM, K, OXF & FHO, W); Sinai, E slopes of Gebel Catherine, 1900-2250 M, between granitic rocks and sandy areas, Gamal El Din and S. Heneidik s.n., 28/4/1991 (CAI); 10 km S of Monastry, Wadi Roteg, wadi bed in the black volcanic mountains, A. Shmida s.n., 4/4/1972 (HUJ).

IRAN: Fars, S of Deh Bīd, N and W facing volcanic outcrops of soft basalt, J. C. Archibald 1217 (B); Aznā, SE of Hamadan, altitude 4000 m, Agricultural land, Bowles Scholarship Bot. Exp.995 (B); Kuh-I-Sefid, Arak, 6000 ft. cornfield weed, Bowles Scholarship Bot. Exp.1756 (B); in M. Kuh-Barfi, Prov. Shiraz, Kotschy 337 (E, OXF & FHO); road from Sirjan to Kermān, 75 km from Sīrjan, Léonard 5956 (BR); prov. Kerman, between Kerman and Saidabad (Sirdjan), Rechinger 3076 (B); W. Qashqai, Akohruyeh, 25 km between Shahrez and Semirom, Rechinger 47555 (B).
PAKISTAN: Quetta, in Jugo, W of Ziarat, Rechinger 29316 (B).

4. Subtribe: Sisymbriinae (Prantl) O.E. Schulz,

In Pflanzenr. (IV, 105): 45 (1924).

Basionym: Sinapeae-Sisymbriinae Prantl in Engler-Prantl, Pflzfam. III. 2: 154 (1890).

23. Sisymbrium L.

Sp. Pl. ed. 1: 657 (1753); L., Gen. Pl. ed. 5: 296 (1754); O.E. Schulz, in Pflanzenr. 86 (IV, 105): 46-157 (1924) and Pflanzenfam. ed. 2, 17B: 590-601 (1936).

Annual or perennial herbs, glabrous or sparsely hairy with simple hairs. Stems erect or ascending, branched. Leaves pinnatifid-lyrate, runcinate or entire, lower ones petiolate, upper ones subsessile or sessile. Racemes many flowered, bracteate or ebracteate. Flowers small to large. Sepals erect, spreading not or scarcely 2-saccate at the base. Petals usually longer than sepals, yellow or whitish, usually with a distinct lamina and claw. Stamens 6, free, edentate; anthers sagittate, obtuse or subobtuse; style short, thick; stigma capitate or with depressed ± 2-lobed. Lateral nectar glands united with median glands. Fruiting pedicels spreading and more or less thick. Siliqua linear, aslender, dehiscent, straight or curved, erect to spreading, hairy or glabrous; valves convex, with distinct midrib and 2 lateral veins; septum thick or membranous. Seeds usually in one row in each cell, oblong to ovoid, yellowish-brown, not mucilaginus when wet; radicle incumbent.

About 90 species in Europe, Asia, Mediterranean region, S. Africa, N. America and the Andes; only 6 species in Egypt.

Key to the Sections:

1a. Racemes bracteate……………………………………...……….....**1. Sect. Chamaeplium**
1b. Racemes ebracteate…………………………….……………………….……... ….…………**2**
2a. Fruiting pedicels filiform, long, thinner than fruit…… ……….……..……..…...**2. Sect. Irio**
2b. Fruiting pedicels short, as thick as fruit……………………………… ……….…..……... .**3**
3a. Flowers large, 7-12 mm; fruit straight or curved; style thick………...**4. Sect. Pachypodium**
3b. Flowers small, 2-2.5 mm; fruit straight, subulate; style thinner than above………..
……………………………………………………………………….**3. Sect. Oxycarpus**

Key to the species:

1a. Inflorescence bracteate…………………..……. . ……………...………………..…... ….. **2**

1b. Inflorescenceebracteate……………………………………………….……………..…**3**

2a. Flowers solitary in axils of bract; petals 2.5-3 mm long; style almost as thick as fruit…………………..…… . …………………………….………..…..…..**S. runcinatum**

2b. Flowers 2-3 together in axils of bract; petals 1.5-2 mm long; style thinner than fruit…………………………..….. ………………………………………..**S. polyceratum**

3a. Fruiting pedicel thin, filiform, up to 1.6 cm long……………….……………….……**S. irio**

3b. Fruiting pedicel thick, pedicel shorter than above, up to 8 mm long………..…………..…**4**

4a. Upper leaves hastate to lanceolate, entire; fruit 6-12 x 0.1-0.2 cm, hirsute or glabrous at maturity………………………………………………………………………..**S. orientale**

4b. Upper leaves linear to lanceolate, pinnatifid; fruit 1.5-7 x 0.1-0.2 cm, shorter than above, glabrous…………………………..…………………………………………..………..…**5**

5a. Flower large, 0.8-1.2 cm long; style thick; fruit straight or curved………...…**S. septulatum**

5b. Flower small, 2-2.5 mm long; style thin; fruit straight, spreadin…………….**S. erysimoides**

1. Sect. Chamaeplium (Wallr.) Thell.

In Hegi, III. Fl. Mitt. Eur. IV, Fasc. 37: 156 (1919).

Racemes bracteate. Flowers axillary 1-6, subsessiles, small. Petals white or pale yellow. Stigma depressed capitate, 2-lobed. Fruiting pedicels short, thick. Fruit ± curved, hairy or glabrous. Style short.

Key to the species:

1a. Flowers frequently 3, in axils of leaves or bracts. Petals about 1.5-2 mm long. Style thinner than siliqua..……………………………..………………………...**1. S. polyceratum**

1b. Flowers solitary, in the axils of leaves or bracts. Petals about 2.5-3 mm long. Style as thick as the siliqua………..……………………………………..…………..**2. S. runcinatum**

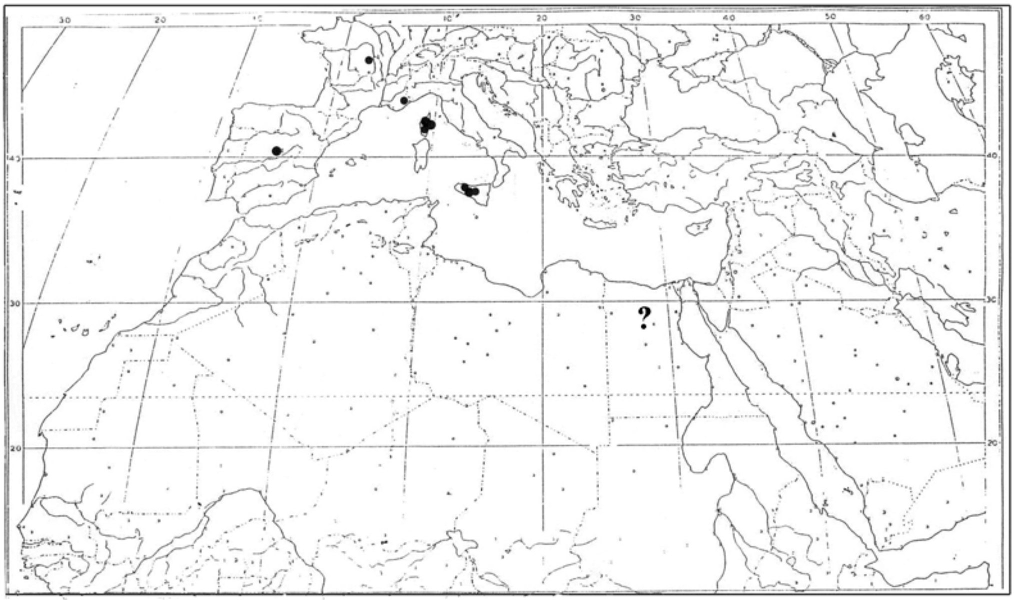
1. **Sisymbrium polyceratum** L., Sp. Pl. ed. 1: 658 (1753); Boiss., Fl. Orient. 1: 220 (1867); Muschler, Manual Fl Egypt 1: 407 (1912); O.E. Schulz, in Pflanzen. (IV, 105): 128 (1924); Täckholm, Stud. Fl. Egypt ed. 1: 338 (1956); Hedge, in Fl. Turkey 1: 482 (1965); Täckholm, Stud. Fl. Egypt ed. 2: 172 (1974); Jafri, Fl. Libya 23: 178 (1977); Tutin, T. G. et al. Fl. Eur. ed. 2, vol. 1: 320 (1993); El Hadidi & Fayed, Taeckholmia 15: 40 (1994-1995); Boulos, Fl. Egypt Checklist 38 (1995); Boulos, Fl. Egypt 1: 186 (1999).

Type: described from Switzerland and Italy, herb. Linn. 836/13 (holotype: LINN; isotype: B).

Icon: O.E. Schulz, in Pflanzenr. (IV, 105), 129, t. 23 (A-L) (1924).

Annual herbs, 20-40 cm, glabrous or slightly covered with simple hairs. Stems branched from base, erect or ascending to subprostrate. Basal leaves 1.3-3 x 0.6-1 cm, rosette, pinnatifid to pinnatisect, with 3-4 pairs of triangular lateral lobes, dentate to entire margin and acute apex; terminal lobe triangular to ovate, monutely serrate margin and acute apex, petiolate 0.5-1.4 cm; cauline leaves 0.8-1.8 x 0.3-0.6 cm, petioles 3-5 mm to subsessile, simple, oblong, dentate-crenate or subentire, apex acute. Racemes bracteate, elongate in fruit. Flowers two or three in axils of leaves or bracts, pedicellate 1 mm. Sepals 1.5 mm long, oblong. Petals equalling or slightly longer than sepals, 1.5-2 mm, cream, oblong-spathulate. Filaments 1-1.3 mm, free, linear; anthers sagittate, 0.5 mm long; style short, 0.5-1 mm, thinner than siliqua; stigma capitate to 2-lobed. Fruiting pedicels 1-1.5 mm, thick and appressed to axis. Siliques 0.8-2 x 0.1-0.15 cm, glabrous or with a few scattered curved simple hairs, usually broader at base than at apex, curved, dehiscent; valves thin, with 3-nerved, glabrous or covered with slightly curved hairs; septum thick and stiff. Seeds in one row in each locule, brown, oblong, 0.8-1 x 0.4-0.5 mm; radicle incumbent.
Fl. & fr.: March-May.
Habitat: sandy waste ground.
Distribution: S. Europe, Turkey and N. Africa (Egypt to Morocco)
(Map 44).

SPECIMENS EXAMINED:
FRANCE: Bastia (Corse), border of the sea sand, near the factory of Toga, Abb. Boullu 1511 (LY); Dep. Var: village la Gard-Freinet, Bertrand s.n., April 1904 (CAI)); near the fields of Castelli, near Bastia, Kralik 468 (LY); near the boulevards, along the old walls in the garonne bassin near Moissac, Lagreze-Fossat 1007 (WAG); Corse, dep. Haute-Corse, Bastia, Lambinon 97 (B); island of Corsica-Abco, Sam Segal 585 (WAG).
ITALY: Sicily, in road side area near Isnello, Nebrodum, Huet du Pavillon s.n., 22/6/1855 (WAG); dry road side, low area, Palermo, H. Ross 705 (B, WAG).
SPAIN: Madrid, in the border of cultivated lands, G. Ruy s.n., 9/6/1882 (LY).



Map 44: Distribution of *Sisymbrium polyceratum*.

2. **Sisymbrium runcinatum** Lag. Ex DC., Syst. Nat. 2: 478 (1821); Boiss., Fl. Orient. 1: 220 (1867); O.E. Schulz, in Pflanzenr. (IV, 105): 131 (1924); Täckholm, Stud. Fl. Egypt ed. 1: 338 (1956); Zohary, Fl. Pal. 1: 252 (1966); Hedge in Fl. Iran 57/28.2: 317 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 172 (1974); Jafri, Fl. Libya 23: 180 (1977); Hedge & Lamond in Fl. Iraq 4, 2: 1075 (1980); Tutin. T. G., et al. Fl. Eur. ed. 2, vol.1: 320 (1993); El Hadidi & Fayed, Taeckholmia 15: 40 (1994-1995); Boulos, Fl. Egypt Checklist 38 (1995); Boulos, Fl. Egypt 1: 186 (1999).

Type: in Locis ruderatis Hispaniae Circa Orcelin, Lagasca 1819 (holotype: G).

Homotypic synonym: *Sisymbrium runcinatum* var. *hirsutum* (Lag. ex DC.) Coss., Nat. Pl. Nouv. Crit. Espagne: 95 (1850).

Icon: Jafri, Fl. Libya 23, 181, t. 57 (A-E) (1977).

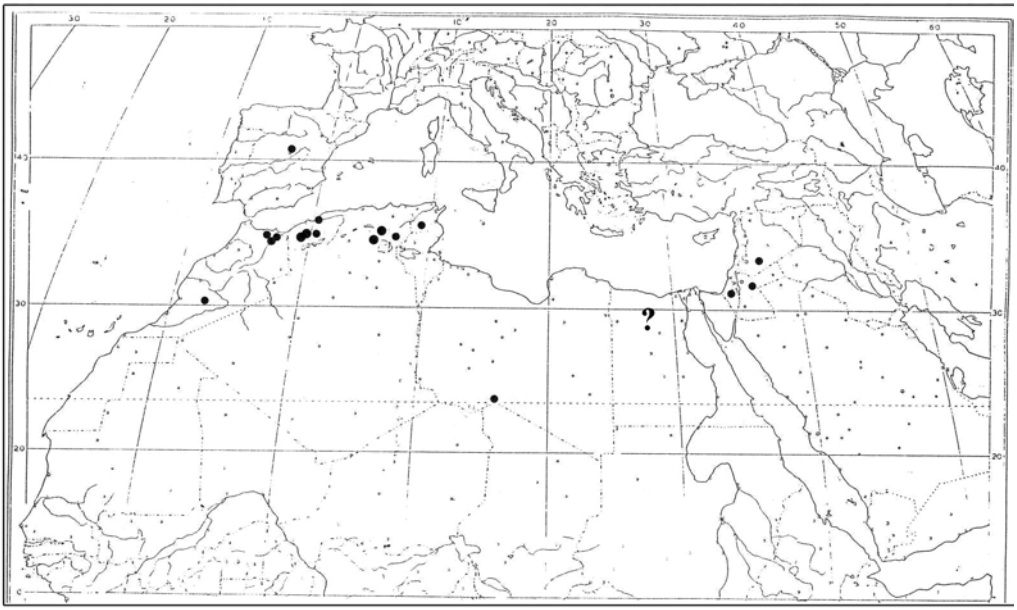
Annual herbs, 15-20 cm, covered with simple, hooked and vasculate hairs. Stem ascending-erect to prostrate, branched at the base. Radicle leaves 2.5-4.5 x 0.5-1 cm, petiolate 1.2-2.3 cm, rosette forming, runcinate-pinnatifid, with 5-7 pairs of alternate, acute lateral lobes and with acute terminal lobe; cauline leaves 0.8-1.7 x 0.3-0.5 cm, short petiolated, runcinate to subentire with oblong, acute terminal lobe. Racemes dense, bracteate. Flowers minute, solitary, short pedicellate 1mm long. Sepals 2mm, oblong, hairy. Petals 2.5-3 mm, yellow, oblong-obovate to spathulate. Filaments 2mm long, free; anthers sagittate, 0.50.75 mm long; style 1-2 mm, ± as thick as siliqua; stigma 2-lobed. Fruiting pedicels 1-2 mm long, thick, appressed to stem.

Siliques 1.5-2.5 x 0.1-0.2 cm, hairy, curved or erect, broader at base than apex, tardly dehiscent; valves thick, with distinct nerved; septum thick. Seeds in one row in each locule, oblong, yellow-orong or brown, 1-1.1 x 0.5-0.6 mm; radicle incumbent.

Fl. & fr.: March-May.

Habitat: sandy Wadis.

Distribution: S. W. Europe, Syria, Palestine, Israel, Jordan, Caucasus, Iran, Iraq, C. Asia (Mt. Turkmenia) and N. Africa (Egypt to Morocco) (Map 45).



Map 45: Distribution of *Sisymbrium runcinatum*.

SPECIMENS EXAMINED:

ALGERIA: Biskra, Adremtice 8 (LY); Caravanserail in Bouguirat, in the wheat farms, B. Balansa 116 (NMGM); prov. Oran, Sebdou, Cofron s.n., 14/4/1856 (LY); high plateaux area, uncultivated, Bedeau, A. Faure s.n., 31/5/1939 (BR); El Kantara, near Constantine, Rousean s.n., April 1929 (BR); prov. Constantine, Batna, in waste land, G. Ruy s.n., 27/4/1892 (LY); prov. Oran, Sidi-bel-Abbés, in border of cultivated lands, A. Warion 1094 and 1095 (LY)..

LIBYA: El-Mekhali, El Naggar s.n., May 1992 (SHG).

MOROCCO: in uncultivated land in Oudjda, A. Faure s.n., 8/4/1938 (BR); 15 km N. of Zaida, 3.5 km N of Boullajoul, on Azrou to Midelt road, Gavin Stark 267 (NMGM); Melilla, Mt Aruit, road side, Mauricio s.n., 26/4/1931 (BM).

TUNISIA: N of Sbeitla, 16 km from Sbiba, Davis and Lamond 57187 (BM).

ISRAEL: Negev, Har Hanegev, Nahal Lotz, Danin 34263 (HUJ).

JORDAN: 10-15 km W Zarqa, Walid Jallad 217 (CAI).

SYRIA: Gebel Rakham, Postin. Apud colleg. 848 (BM).

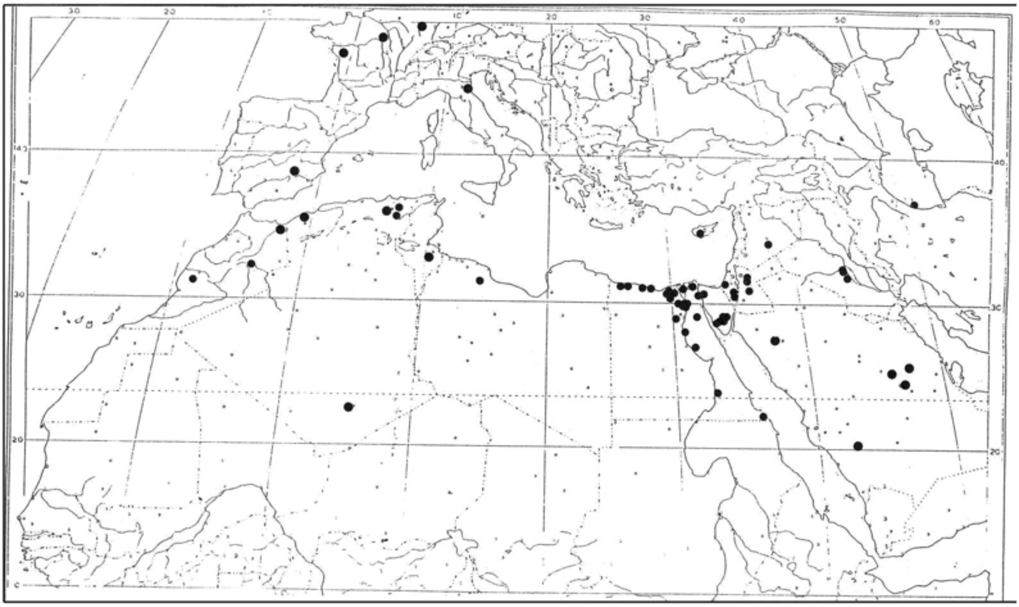
SPAIN: near Madrid, E. Bourgeau 2095 (WAG).

2. Sect. **Irio** DC.

Syst. Nat. 2: 463 (1821)

Racemes ebracteate. Petals yellow. Stigma ± 2-lobed. Fruiting pedicels filiform. ; valves 3-nerved.

1. **Sisymbrium irio** L., Sp. Pl. 1: 659 (1753); Bentham & Hooker, Gen. Pl. 1: 78 (1862); Boiss., Fl. Orient. 1: 217 (1867); Oliver, D., Fl. Trop. Afr. 1: 64 (1868); Muschler, Manual Fl. Egypt 1: 407 (1912); O.E. Schulz, Pflanzen. Veg. 86 (IV, 105): 89 (1924); Täckholm, Stud. Fl. Egypt ed. 1: 338 (1956); Hedge, in Fl. Turkey 1: 485 (1965); Zohary, Fl. Pal. 1: 253 (1966); Hedge, in Fl. Iran 57/28.2: 314 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 172 (1974); Jafri, Fl. Libya 23: 176 (1977); Hedge & Lamond, in Fl. Iraq 4, 2: 1070 (1980); Collenette, Illust. Flow. Pl. Saudi Arabia 207 (1985); Tutin, T. G. et al. Fl. Eur. ed. 2, vol. 1: 319 (1993); El Hadidi & Fayed, Taeckholmia 15: 40 (1994-1995); Boulos, Fl. Egypt Checklist 38 (1995); Boulos, Fl. Egypt 1: 186 (1999).
Type: Described from W Europe, Herb. Linn. 836/ 38-39 (holotype: LINN).
Heterotypic synonym: *Sisymbrium irioides* Boiss., in Ann. Sc. Nat. ser. 2, 17B: 76 (1842). Type: Mesopotamia (Auch. Exs. 140) (holotype: B).
Icon: Täckholm, Stud. Fl. Egypt ed. 2, 173, t. 51 B (1974).
Annual herbs, 13-45 cm, glabrous or sparsely with simple hairs. Stem erect, simple or branched. Lower leaves 1.5-6.2 x 0.5-2 cm, runcinate-pinnatisect to sublyrate with lobes oblong-linear, toothed to entire, petiolate 0.4-3 cm long; upper leaves 1.5-6 x 0.3-2 cm, short petiolated 0.3-1.2 cm, lyrate-runcinate, with a few lateral lobes or simple, hastate. Racemes compact, ebracteate, overtopped by young fruit. Flowers small, pedicellate 2-6 mm. Sepals 2-2.3 mm, oblong. Petals 2.5-3.5 mm, yellow, with oblong-spathulate blade narrowed into a short claw. Filaments 2-2.5 mm, long free, linear; anther sagittate, 0.5 mm; style short, thick, 0.5-1 mm; stigma 2-lobed. Fruiting pedicels 0.3-1.4 cm, hairy or glabrous, filiform, spreading. Siliques 1.5-4 x 0.1 cm, erect or incurved, terete, glabrous, dehiscent; valves thin, 3-nerved; septum white, membranous. Seeds many in one row in each locule, minute, 0.7-1 x 0.4-0.5 mm, yellowish-brown, oblong-ellipsoid; radicle incumbent.
Fl. & fr.: February-May.
Habitat: a common weed throughout much area in roadside and waste places.
Vernacular names: Shillyaat, Saleekha.
Uses: eaten by sheep and camels.
Distribution: Europe, Asia, Australia, Tropical Africa, N. Africa and N. America (Map 46).



Map 46: Distribution of *Sisymbrium irio*.

SPECIMENS EXAMINED:

ALGERIA: Oran, D'Alleizette 2953 (B); Tamanrasset, E. Bolay & Kromer s.n., 1971 (B); Ghardaia, Bou Nouara, in wasteland, Chevallier 35, 268 (WAG); Philippeville, S. M. Guichard 298 (BM); Constantine, in border of roads, V. Reboud 2369 (LY).

EGYPT: **M**: Matruh-El Qasr road, West of Matruh, K. Abdel Khalik 26 Cr.7/3/2000 (SHG); Wadi Rakham between Matruh and Agiba, Täckholm et al. s.n., 21/3/1975 (CAI); Ras El-Hekmah, Mustafa Imam s.n., 3/3/1956 (CAI); Bahig, Merxmuller et al. s.n., 9/3/1978 (CAI); Burg el Arab, Riad Halwagi s.n., 1961 (CAI); Burg el Arab, Amal Amin s.n., 13/3/1972 (CAI); Ikingi Mariut, G. Täckholm s.n., 22/1/1928 (CAI); Mariut in calcareous fields N of Ameria station, G. Täckholm s.n., 25/3/1927 (CAI); Alexandria: P. Forskal 97 (BM); near Ramleh, R. Massie-Blomfield s.n., 1881 (NMGM); Rosetta, Parquet s.n., 15/4/1872 (BM); Amirya, J. Gilbert 451 (BM).

Nv: Lower Egypt, A. Wiest 514 (OXF & FHO); Cairo-Alexandria desert road in fields west of the road, South of Amirya Täckholm et al. s.n., 5/5/1968 (CAI); Barrage, East side of Damietta branch, G. Täckholm s.n., 7/1/1927 (CAI); Alexandria-Cairo road, Schweinfurth s.n., 10/3/1902 (BM); El Mansoura, Abdel Fattah & Abdel Aziz s.n., 19/3/1974 (CAI); 110 km from Cairo, Cairo-Alexandria desert road, K. Abdel Khalik 21 (SHG); Cairo, R. Meinertzhagen 13 (BM); Cairo, Keller 163 (BM); wasteland in Cairo, Schweinfurth 1337 (BM); near Cairo, J. Ball 357 (OXF & FHO); Almaza, Cairo, G. H. Lupton s.n., 24/2/1946 (BM); Bahtin near Cairo, Chrek & Kosinova s.n., 4/4/1977 (CAI); Tahrir province, Täckholm s.n., 23/4/1965 (CAI); Giza, G. Täckholm s.n., 5/2/1927 (CAI); Faculty of Science garden, Giza, El Hadidi s.n., 12/1/1956 (CAI); Fayum, Ahmed Abdel Fadeel s.n., 12/7/1953 (CAI); Minya, Eastern side Deir El Azzra, Amry s.n., 2/2/1979 (CAI); Sohag in wastelands, K. Abdel Khalik 33 (SHG). **Nn**: Kom Ombo, El Hadidi s.n., 6/2/1975 (CAI). **Di**: El Qantara-el Gharbiya, Ismailiya, Alaa Amer s.n., 23/2/1983 (CAI); Ismailiya, as weed in park along the canal, G. Täckholm s.n., 18/3/1927 (CAI); Abu Kalifa (El Ballah) Ismailiya, Alaa Amer s.n., 5/11/1982 (CAI). **Dg**: Wadi Abiad, N. Galala, Schweinfurth 1000 (BM); Cairo-Zaafrana palace, as weed M. Hassib s.n., 7/3/1929 (CAI). **S**: Deir el-Rahebat, Wadi Feiran, as weed in garden, K. Abdel Khalik 31 (SHG); the garden of Deir el Rahba at the entrance of Wadi el Arbain, S. Sinai, Täckholm et al. s.n., 25/4/1961 (CAI); Feiran

Oasis, in fields, J. Kosinova & Chretex s.n., 12/4/1967 (CAI); in the garden of Deir el Arbain, S. Sinai, Täckholm s.n., 12/5/1956 (CAI); the area up to 25 km NE of St. Catherine Monastery, Darwish Al-Far s.n., April 1955 (CAI); 10 km S of the Catherine Monastery, Wadi Roteg, Wadi bed in the black volcanic mountains, A. Danin s.n., 4/4/1972 (B); Naqb el Hawa, 9 km NW of Monastry, Danin s.n., 25/3/1968 (HUJ). **Sa**: Gebel Elba, G. Täckholm & Lefnawy s.n., 23/11/1929 (CAI).

LIBYA: Gargaresc, K. Guichard 298 (BM).

MOROCCO: Maison forestiere Talate, between Youkak and Asni, W. de Wilde 2198 (WAG); road from Imilchil to tinghir, L. Jury et al. 17667 (BM); Mts Beni Sanassen, road from Beni Ammar to Taforalt towards to Tanezzert, Vogt 11297, & Oberprieler 5745 (B).

TUNISIA: Gebel Djelound, J. Pitard 23 (B).

IRAN: prov. Mazandaran, Z. van Chalus in El Bruzgeb, M. Van Oosten 264 (WAG).

IRAQ: near Abushir and Schīrās, Kotschy 150 (WAG); on mud roof of agricultural station in Karbala, Liwa, K. H. Rechinger 151 (WAG).

ISRAEL: Judean desert, Han Hatrur, in the courtyard, Amdursky & Grizi 325 (B, WAG); Negev Highlands, Mizpe Ramon, weeds in gardens, A. Danin et al. 18. 006 (B); Negev, Zohary 34168 (HUJ).

JORDAN: Jericho, B. T. Lowne s.n., April 1863 (OXF & FHO); Lower Jordan valley, 1 km NE of Pzael N. of Jericho, A. Danin et al. 9. 002 (B); South Ghor, Ghor Safi, near cultivated area, Dawud Al-Eisawi 2262 (B).

PALESTINE: Gaza town, in garden, Boulos s.n., 7/4/1955 (CAI)

SAUDI ARABIA: Kaffs Ban Ban, 100 km N Riyadh, Hilleoot 277 (BM); Al-Baha, Ibrahim Ghamidi 101 (KSU); Korais road, Jafi valley, Migahid 13684 (KSU); Horimela valley, Migahid and Doalgey 13682 (KSU); Riyadh, Thomas 898 (KSU).

SYRIA: Tadmur, ruins of Palmyra, hill and ruins of Qala Ibn Maan, W. Licht s.n., 11/3/1979 (B).

FRANCE: in garden in Paris, L. Kralik 916, 1008 (B); collection from Wadis Loire river, Delaunay 916 (B).

GREECE: Sarmaca, G. Druce 84 (OXF & FHO).

ITALY: Aemilia, Bononia (Bologna), in waste lands, Andrea Fiori 549 (LY)

SPAIN: in fields of Hellin, E. Bourgeau 547 (B).

3. Sect. Oxycarpus Paol.

In Fiori et Paol., Fl. Anal. Ital. 1: 434 (1898).

Racemes ebracteate. Petals yellow, small. Stigma depressed, slightly 2-lobed. Fruiting pedicels short, as thick as fruit, hairy or glabrous. Fruit spreading, subulate, tapering to a short style.

1. Sisymbrium erysimoides Desf., Fl. Atlant. 2: 84 (1798); Vivi., Fl. Libya Spec. 36 (1824); Boiss., Fl. Orient. 1: 217 (1867); Oliver, Fl. Trop. Afr. 1: 64 (1868); Muschler, Manual Fl. Egypt 1: 408 (1912); O.E. Schulz, Pflanzen. Veg. (IV, 105): 134 (1924); Täckholm, Stud. Fl. Egypt ed. 1: 338 (1956); Zohary, Fl. Pal.1: 255 (1966); Hedge, in Fl. Iran 57/28.2: 318 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 172 (1974); Jafri, Fl. Libya 23: 182 (1977); Hedge & Lamond, in Fl. Iraq 4, 2: 1076 (1980); Jonsell, B., Fl. Trop. East Afr. 64 (1982); Collenette, Illust. Flow. Pl. Saudi Arabia 206 (1985); Tutin, T. G. et al. Fl. Eur. ed. 2, vol. 1: 321 (1993); El Hadidi & Fayed, Taeckholmia 15: 40 (1994-1995); Boulos, Fl. Egypt Checklist 38 (1995); Boulos, Fl. Egypt 1: 185 (1999).

Type: Tunis, Kairouan, Desfontaines (holotype: P; isotype: B).

Icon: Jafri, Fl. Libya 23, 183, t. 58 (A-G) (1977).

Annual herbs, 15-35 cm, glabrous or covered with sparse spreading simple hairs. Stems erect, simple or branched, sometimes violet at the base. Radicle leaves 1.2-8 x 0.6-4.5 cm, petiolate 1-3 cm, lyrate-pinnatifid with 3-4 pairs of lobes, obovate to oblong, acute, irregular dentate; terminal lobe obovate, obtuse to undulate; cauline leaves 1.5-4 x 0.4-2 cm, petiolate 0.5-1.5 cm, few, lyrate-pinnatifid, with hastate to truncate terminal lobe and 2-3 pairs of lateral lobes. Raceme ebracteate, dense elongate in fruit. Flowers small, pedicellate 1-2 mm. Sepals 1.5-2 mm, erect, oblong, obtuse. Petals 2-2.5 mm, yellow, spathulate. Filaments 2-1.2 mm, linear; anthers sagittate, 0.5 mm; style short 1-2 mm; stigma slightly 2-lobed. Fruiting pedicels 3-4 mm, spreading or erect-spreading, as thick as fruit, glabrous or covered with scattered simple hairs. Siliques 2.5-4 x 0.1 cm, straight, spreading, rigid, terete, usually glabrous, broader at the base than apex; valves submembranous with a distinct midrib; septum membranous. Seeds 1-1.1 x 0.5 mm, oblong, yellowish-brown; radicle incumbent.

Fl. & fr.: January-May.

Habitat: Shaded and sheltered wadi sides or stony crevices.

Vernacular names: Thowwaat, Saleekh.

Uses: eaten by sheep and camels in Elba mountains.

Distribution: Mediterranean Europe, Crimea, Syria, Jordan, Palestine, Israel, N. Africa, Arabia, Oman, Iran, Iraq, Caucasus, W Pakistan, Macaronesia, introduced in Australia, Tropical Africa and N America (Map 47).

SPECIMENS EXAMINED:

ALGERIA: Biskra, in sands, B. Balansa s.n., 4/1853 (LY); Mostaganem, B. Balansa 525 (B); Ghardaia, in crop land and land cultivated with palm, L. Chevallier 401 (WAG); prov. Oran, Doumergue s.n., 10/2/1890 (LY); Macta, near Mostaganem, A. Faure s.n., 7/5/1916 (B); Constantine, in rocks of Sidi Merzoug, G. Rouy s.n., 10/4/1982 (LY).

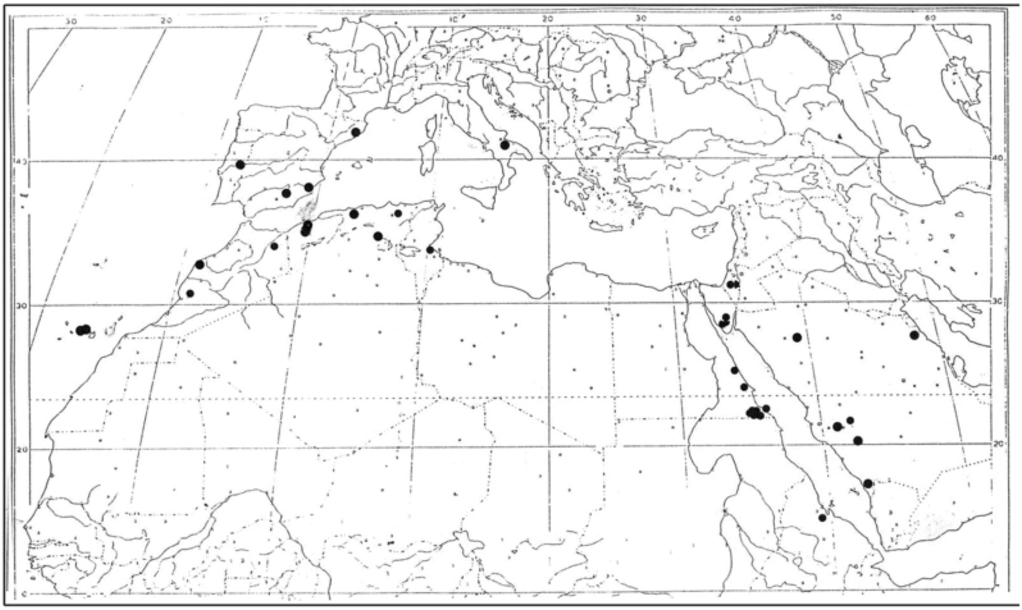
EGYPT: **R**: Wadi Halos, Red Sea coast, Täckholm et al. s.n., 6/2/1961 (CAI).

S: Wadi Feiran, Deir Feiran, El Naggar s.n., 20/3/1998 (SHG); Deir El Rahebat, Wadi Feiran, K. Abdel Khalik 32 (SHG); Naqb el Hawa, 9 km NW of the Monastry, Danin s.n., 25/3/1968 (HUJ). **Da**: Gebel Hamata, Täckholm et al. s.n., 7/2/1961 (CAI). **Sa**: Mersa Tobash, Red Sea coast, Täckholm et al. s.n., 1/2/1962 (CAI); Gebel Elba: M. Hefnawy s.n., 2/2/1929 (CAIM); G. Täckholm, s.n., 23/1/1929 (CAIM); Khattab s.n., 20/1/1928 (CAIM); J. R. Shabetai s.n., 23/2/1933 (CAIM); Wadi Theekwal, Täckholm et al. s.n., 22/11/1962 (CAI); Khor Wadi Yahameib, Täckholm et al. s.n., 22/11/1962 (CAI); Wadi Kan Sisrob, Täckholm et al. s.n., 3/2/1962 (CAI); NW and W slopes of Gebel Asotriba, Täckholm et al. s.n., 28/1/1962 (CAI); Wadi Derna, Boulos s.n., 20/1/1967 (CAI); Wadi Shallal (Bir area), Täckholm et al. s.n., 24/11/1962 (CAI); Wadi Shallal, K. Abdel Khalik 18 Cr.10/3/1999 (SHG); Wadi Aak, Täckholm et al. s.n., 28/11/1962 (CAI); Wadi Oolak, Täckholm et al. s.n., 27/11/1962 (CAI); Bir Akwaomtra, Täckholm et al. s.n., 3/2/1962 (CAI); Bir Kan Sisrob, Täckholm et al. s.n., 3/2/1962 (CAI); Wadi Drawina, K. Abdel Khalik 19Cr. 10/3/1999 (SHG).

ERITREA: 15 km on the road Asmara to Massawa, J. de Wilde 4525 (WAG).

ETHIOPIA: North shore, lake Langano, near hotel, Ethiopian Rift valley, J.W. Ash 2579 (WAG); Addis Ababa, square 58, J.W. Ash 2995 (WAG); 4 km from Der on the road to Sire, E. Westphal 1544 (WAG).

MOROCCO: 20 km SW of Taroudant in the valley of Sous, W. de Wilde et al.s.n., 1977 (WAG); 6 km SE of Sidi Abdallah, along minor road to Bab-Bou-Idir, Gavin Stark 1006 (NMGM); Atlas, Rebias, E. Jahandiez 498 (B).
TUNISIA: Gabes, in palm oasis, L. Kralek 29 (NMGM)
ISRAEL: Dead Sea Valley, near Mizpe Dragot, 15 km N of En Gedi slopes and small cliffs of dolomite and wadis, A. Danin et al. 6. 028 (B); N Negev, Mishor Yamin, 7 km S of Dimona, Danin 72631 (HUJ).
OMAN: Mascate, Aucher-Eloy 4162 (OXF & FHO); Gebel Al-Akhdar and adjacent areas, J.P. Mandaville 6316 (BM).
SAUDI ARABIA: Gabel El-Sharagily, Fayfa region, M. Alaallah 1813 (KSU); Al-Baha, Al-Farhan 591 (KSU); near Al-Howtah, Al-Farhan & Thomas 10391 (KSU); Taif, Al-Shafa sumit, 40 km W of Taif, A. Fayed 1264 (B); Taif highlands, Leiaew 17062/5 (BM); El-Soudah, Mekky & Chaudhary 14094 (KSU).
CANARY ISLANDS: Tenerifa: Santa-Cruz, in sands, E. Bourgeau 1248 & 1249 (B); Fuerteventura, Puerto Cabras, in dry sands, J. Pitard 31 (LY); Guimar, near Vias, J. Pitard 466 (B).
ITALY: Sekalda, Maschita, Richard 97 (B).
PORTUGAL: Madeira, Funchal, Dürbye 798 (B).
SPAIN: Sierra, Murcia, E. Bourgeau 1060 (B); prov. Granada, Lecrin, M. Ladero et al. 10261 (B); in sands of Barcelona, F. Tremols s.n., 5/1879 (LY).
AUSTRALIA: S. Australia, lake Eyre Basin, NW, 80 miles S. Kulgera by borehead, P.G. Wilson 2320 (B).



Map 47: Distribution of *Sisymbrium erysimoides*.

4. **Sect. Pachypodium** (Webb et Berth.) Fourn.,

Recherch. Crucif. 86 (1865).

Racemes ebracteate. Petals yellow. Stigma often deeply 2-lobed. Fruiting pedicels straight, thick. Fruit straight, spreading. Style thick.

Key to species:

1a. Plant ± villous, white-green. Upper leaves hastate. Fruit long 6-11.5 x 0.1-0.2 cm ……………………………………………………………………………………………1**. S. orientale**

1b. Plant glabrous or covered with long dispersed hairs, green. Upper leaves pinnatisect. Fruit shorter than above, 1.5-7 x 0.1-0.2 cm………………………………………………**2. S. septulatum**

1. **Sisymbrium orientale** L., Cent. Pl. 2: 24, No. 173 (1756); Boiss., Fl. Orient. 1: 217 (1867); O.E. Schulz, Pflanzen. (IV, 105): 122 (1924); Täckholm, Stud. Fl. Egypt ed. 1: 338 (1956); Hedge in Fl. Turkey 1: 484 (1965); Zohary, Fl. Pal. 1: 254 (1966); Hedge in Fl. Iran 57/28.2: 317 (1968); Täckholm, Stud. Fl. Egypt ed. 2: 174 (1974); Jafri, Fl. Libya 23: 178 (1977); Hedge & Lamond, in Fl. Iraq 4, 2: 1074 (1980); Jonsel, B., in Fl. Trop. East Afr. 64 (1982); Collenette, Illust. Flow. Pl. Saudi Arabia 207 (1985); Tutin, T. G. et al. Fl. Eur. ed. 2, vol. 1: 320 (1993); El Hadidi & Fayed, Taeckholmia 15: 41 (1994-1995); Boulos, Fl. Egypt Checklist 38 (1995); Boulos, Fl. Egypt 1: 186 (1999). Type: Described from Europe (in Oriente Miller), herb. Linn. 836/43 (holotype: LINN; isotypes: B, L).

Icon: Jafri, Fl. Libya 23, 179, t. 56 (A-F) (1977).

Annual herbs, 10-66 cm tall, indumentum soft, spreading or retrose, simple, varing in length and distribution. Stem erect, simple or branched. Radicle leaves 1.5-12 cm long, subrosulate, petiolate 1.2-3.5 cm, pinnatisect to lyrate, terminal lobe triangular-ovate, obtuse or acute apex, repand-dentate to crenate margin, with proximal lateral lobes; Cauline leaves 1.5-7 x 0.4-1 cm, petiole 0.5-2 cm, hastate or lyrate with oblong, linear, hastate terminal lobe and few small lateral lobes, margin entire, apex acute. Racemes ebracteate, dense, overtopped by young fruit. Flowers pedicellate 3-4 mm. Sepals 4-5 mm, hairy. Petals 7-9 mm, yellow, distinct into long claw and obovate limb, rounded to truncate apex. Filaments 4-6 mm, linear, free; anthers 1.5-2 mm, sagittate; style 1-3 mm, thick; stigma 2-lobed. Fruiting pedicels 4-8 mm, as thick as fruit, spreading hairy or glabrous. Siliques 6-11.5 x 0.1-0.2 cm, straight, cylindrical-linear ± spreading, tardly dehiscent, hairy at the first and become glabrous on maturity; valves straight, 3-nerved; septum thick. Seeds in one row in each cell, 1.1-1.4 x 0.7-0.9 mm, oblong, orange-brown; radicle incumbent.

Fl. & fr.: March-May.

Habitat: waste ground, weed of sandy cultivated lands.

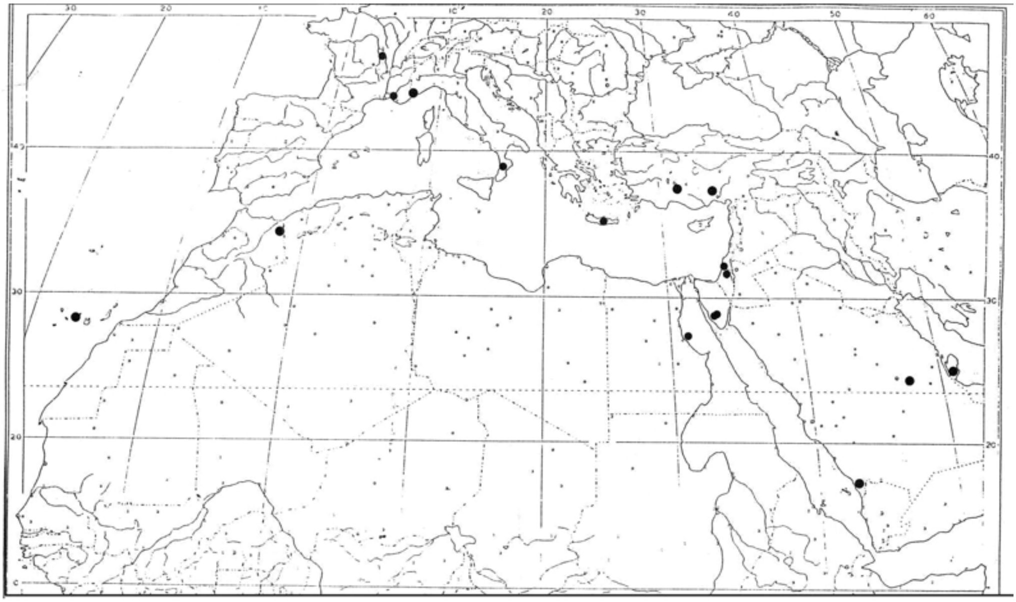
Vernacular name: Saleekh.

Distribution: Europe, Asia, N America, N and S Africa and Egypt (Map 48).

SPECIMENS EXAMINED:

AUSTRALIA: S Australia, upper Yorke Peninsula, mt. lyell, 140 km NNW of Adelaide, B. Copley 293 (B).

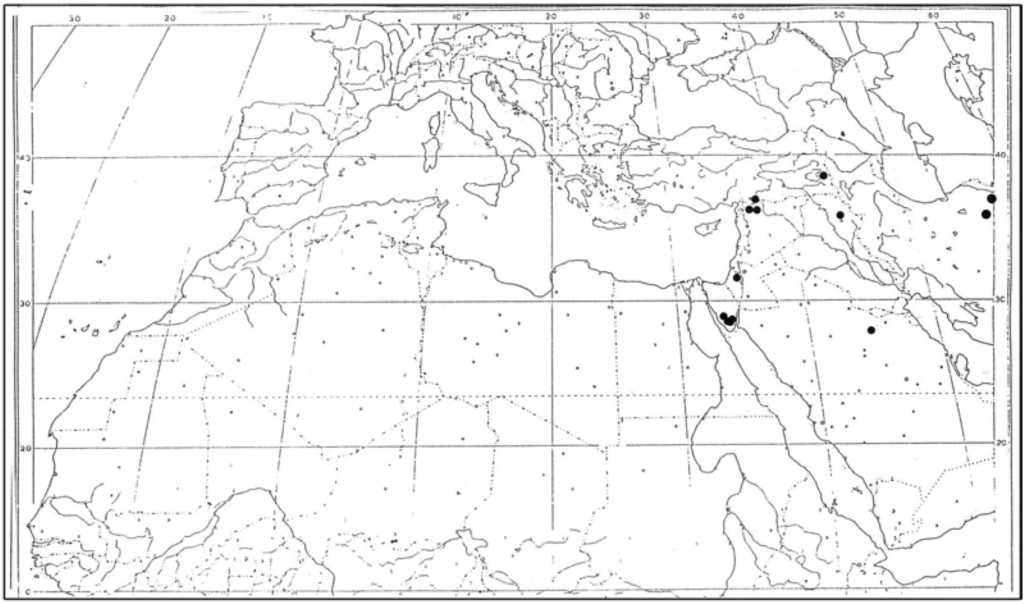
U.S.A: California, Tejon pass between Gorman and Lebec, Davis & Lighto Wlers 67021 (B).



Map 48: Distribution of *Sisymbrium orientale*.

EGYPT: **S**: Deir el-Rahebat, Wadi Feiran, K. Abdel Khalik 32 Cr. 11/3/2000 (SHG); Deir Feiran, Wadi Feiran, K. Abdel Khalik 11 (SHG); Deir Feiran, Sinai, weed in the garden, Täckholm et al. s.n., 26/4/1961 (CAI); in the garden of the small Feiran Monastry, Wadi Feiran, S Sinai, Täckholm s.n., 10/5/1956 (CAI). **Nv**: Wadi El Assuity, El Naggar s.n., 16/3/1998 (SHG).
MOROCCO: Mts Beni-Snassen road through the Gorge of Oued Zegzel between Taforalt and Berkane, Vogt 11533, & Oberprieler 5981 (B).
ISRAEL: Tel-Aviv, ruins, M. Zohary & A. Grizi 513 (B, WAG); Arava Valley, 5 km S of Yotvata, Zohary 34240 (HUJ).
QATAR: Lawns facing Gulf hotel Doha, Boulos 11001 (B).
SAUDI ARABIA: Dillam, Al-Farhan & Thomas 10221 (KSU); Gabel Fayfa, Gabel Khash'aa, M. Hassan 2112 (KSU).
AUSTRIA: in waste lands of Laaerberg in Vindobonensi, Vierhapper 2888 (LY); Botsen-Bolsamo, Zallinger s.n., 1855 (WAG).
ENGLAND: on the site of an old fowl-run on the sandhills off St. Andrew, S. road, Charles Bailey 125B (L).
FRANCE: near Toulon, field of Cambrien, A. Huet 2615 (WAG); Montpellier, road side, K. Kummel 165 (WAG).
GERMANY: Bautzen, between the stones of rail station, Hemepl 2947 (B); Baden, Am Rheinhafen near Karlsruhe, A. Kneucker 4 (LY); Schwabing near Münch to Schutt, J. Kraenzle 511 (LY).
GREECE: Crete, Van Soest 142 (L).
IRELAND: roadside Howth, J. Dorgelo s.n., 19/7/1958 (WAG).
ITALY: S Tirol, along road near Bolzano, Housmanny 124 (WAG).
NETHERLANDS: Nijmegen, along Waal river, Koornaf s.n., 21/6/1902 (WAG); Limburg, Hammert, J. Valckenier s.n., 8/1893 (WAG).
SPAIN: Tenerifa, in cultivated lands, E. Bourgeau 700 (LY).
TURKEY: Izmir (Smyrna), B. Balansa 83 (NMGM, WAG); prov. Mersin, Kuyuluk, 10 km W of Mersin, Davis and Hedge 26537 (B); Antalya, H. Ern 98 (B).

2. **Sisymbrium septulatum** DC., Syst. Nat. 2: 471 (1821); Boiss., Fl. Orient. 1: 217 (1867); O.E. Schulz, in Pflanzen. (IV, 105): 120 (1924); Täckholm, Stud. Fl. Egypt ed. 1: 338 (1956); Hedge in Fl. Turkey 1: 484 (1965); Hedge in Fl. Iran 57/28.2: 316 (1968); Nouv., Fl. Syr. 2: 98 (1970); Täckholm, Stud. Fl. Egypt ed. 2: 174 (1974); Hedge & Lamond in Fl. Iraq 4, 2: 1073 (1980); Collenette, Illust. Flow. Pl. Saudi Arabia 207 (1985); El Hadidi & Fayed, Taeckholmia 15: 40 (1994-1995); Boulos, Fl. Egypt Checklist 38 (1995); Boulos, Fl. Egypt 1: 186 (1999).
Type: in Syria, near Aleppo, Russell s.n., (holotype: BM).
Heterotypic synonyms: *Sisymbrium rigidulum* Decaisne, in Annal. Sc. Nat. Bot. 2, Ser. III: 272 (1835). Type: top of Sinai mountain, Bove 138. (holotype: BR).
Lectotype: in moist area, at Sinai mountain, Schimper 122, 11/4/1835 (B).
Sisymbrium pannonicum Boiss., Fl. Orient.1: 217 (1867).
Type: in waste and cultivated area in Thraciae (Friv); Asia minor (Heldreich); Armenia (Huet); Syria near Aleppo and Damascum (Gaillardot); Mesopotamia (Aucher exs. 118); Persiae (Oliv. Ky exs. 423) (not seen).
Homotypic synonyms: *Sisymbrium septulatum* DC. var. *rigidulum* (Tchi.) O.E. Schulz in Pflanzenr. (IV, 105): 121 (1924).
Sisymbrium bilobum (C. Koch) Grossh., Fl. Cauc.2: 163 (1930); Zohary Fl. Pal.1: 254 (1966).
Icon: Zohary, Fl. Pal.1, t. 368 (1966) As *Sisymbrium bilobum.*
Annual herbs, 12-45 cm, glabrous or covered with simple spreading hairs below and pilose above. Stems erect, simple or branched. Basal leaves 1.5-5 x 0.7-2 cm, petiolate 0.7-2.2 cm, rosette forming, ± pinnatisect with 4-7 pairs of often recurved lobes, terminal lobe obtuse apex, crenate margin; lateral lobes triangular-ovate, apex obtuse or acute, margin crenate-dentate; cauline leaves 1-2 cm long, petiolate 0.5-0.9 cm, deeply pinnatisect, terminal lobe oblong-lanceolate, obtuse or acute apex, entire margin; lateral lobes linear. Racemes ebracteate, few flowers, elongating in fruits. Flowers pedicellate 4-5 mm. Sepals 4-6 mm, linear, hairy. Petals 8-12 mm, lemon yellow, with abroad, obovate, veined blade and a filiform claw. Filaments 5-7 mm, free; anthers linear, 3 mm long with narrow apex and recurved when dry; style 3-4 mm long; stigma deeply 2-lobed. Fruiting pedicels 4-6 mm, thick, as broad as fruit, spreading or obliquely erect. Siliques 1.5-7 x 0.1-0.2 cm, glabrous, straight or slightly recurved, tardly dehiscent; valves straight, thick walled, 3-nerved; septum membranous. Seeds in one row in each locule, brown, oblong-ovoid, 1-1.3 x 0.6-0.7 mm; radicle incumbent.
Fl. & fr.: April-June.
Habitat: on rocky mountain slopes.
Vernacular names: Silihg (Sinai), Huwaira (Iraq).
Uses: eaten by the Badawin (Egypt) in spring as vegetable.
Distribution: Syria, Lebanon, Palestine, Israel, Jordan, Turkey, Arabia, Kuwait, Turkey, Caucasus, Iran, Iraq, Afghanistan, C. Asia and Egypt (Sinai) (Map 49).



Map 49: Distribution of *Sisymbrium septulatum.*

SPECIMENS EXAMINED:

EGYPT: **S**: S Sinai: Deir Rahba, M. Drar s.n., 3/5/1939 (CAIM); Gebel Musa, A. Khattab & M. Abdallah s.n., 22/4/1964 (CAIM); Wadi el Arbain, El Hadidi s.n., 12/5/1956 (CAI); Sinai mountain region, M. Hassib s.n., April 1940 (CAI); outside the garden of the Deir el Arbain, El Hadidi s.n., 12/5/1956 (CAI); Wadi Ferieh, S Sinai, Täckholm et al. s.n., 24/4/1961 (CAI); mountain Sinai, N. Bove 138, 6/1832 (BR); in moist land in mountain of Sinai, Schimper 122 (L); St. Catherine area, grown in botanical garden, Shmida & Arbel 3012 (HUJ); Wadi Rumhan, near Gebel Umm Shomar, Danin & Shmida s.n., 28/4/1968 (HUJ).

IRAQ: Near Shaklava river, Erbil town, Bornmüller 881 (BR).

ISRAEL: Arava Valley, near to Kibbuth Lot, O. Fragman 34276 (HUJ).

SAUDI ARABIA: Eastern province, 14 km ESE Umm Ushar, P. Mandaville 3893 (BM).

SYRIA: Aleppo, Montbret s.n., 1812 and 1834 (W); near Aleppo, Russell s.n., (BM).

TURKEY: River side, below Solakli, N of Posanti, Segran, F.A. Bisby 38 (OXF & FHO); Biredjik in sand, O. Stapf 617 (BR).

3.

SEED MORPHOLOGY OF SOME TRIBES OF BRASSICACEAE

(IMPLICATIONS FOR TAXONOMY AND SPECIES IDENTIFICATION FOR THE FLORA OF EGYPT)

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ABSTRACT

Seed morphology of 45 taxa belonging to 23 genera of Brassicaceae were examined using light and scanning electron microscopes. The taxa included representatives of the tribes Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae which occur in Egypt. Macro and micromorphological characters: seed shape, colour, size, radicle and SEM examination of the epidermal cell shape, anticlinal boundaries, the outer periclinal cell wall and relief of outer cell walls are presented. Three types of basic anticlinal cell wall boundaries were recognized and six different shapes of the outer periclinal cell wall were described. A key for the identification of the investigated taxa based on seed characters is provided.

Key words: Brassicaceae, SEM, seed coat.

3. 1. INTRODUCTION

The Brassicaceae (Cruciferae) are one of the largest angiosperm families, comprising approximately 340 genera and more than 3350 species in 10 poorly defined tribes, distributed throughout the world, chiefly in temperate regions of the Northern Hemisphere (Al-Shehbaz, 1984). The major centres 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 plant families, represented by about 102 species belonging to 55 genera, assigned to 9 tribes (Schulz, 1936). Species of the tribes Lepideae, Brassiceae and Alysseae (63 species belonging to 32 genera) have been the subject of an earlier study (El Naggar, 1987). The remaining Brassicaeae, belonging to the tribes Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae (Schulz, 1936), 39 species in 23 genera exhibit great diversity, as shown in this revision. The members of these tribes are distributed over a wide range of habitats as weeds of farmland and waste places; desert sub-shrubs or herbs; Mediterranean coastal land; the oases; Mountains of Sinai and Elba; as well as inland flats and canal banks.

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 microscopy in the study of systematic problems, as very valuable information has been provided by using this technique. During the last decades, scholars have applied SEM to morphological studies of seeds and small fruits. Micromorphology and ultra-structural data have contributed useful information for evolution and classification of seed plants and play an important role in the modern synthetic systems of Angiosperms (Dahlgren, 1979-80).

Most of the following studies focused on intrageneric seed coat variation (Chuang & Heckard, 1972; Hill, 1976; Heyn & Herrnstadt, 1977; Newell & Hymowitz, 1978; Clark & Jernstedt, 1978; Crow, 1979; Canne, 1979; Wofford, 1981; Juan et al., 2000 and Segarra & Mateu, 2001). On variation among several closely related genera (Musselman & Mann, 1976; Seavey et al., 1977; Canne, 1980; Chance & Bacon, 1984; Matthews et al., 1986; Fayed & El Naggar, 1988, 1996; Shanmukha & Leela, 1993; Haridasan & Mukherjee, 1993; Karam, 1997; Kanak Sahai et al., 1997; Koul et al., 2000). Less commonly, SEM level variation was used to place taxa into tribes (Whiffin & Tomb, 1972).

For further information and references concerning seed forms and internal structures see Corner (1976). Seed appendages were studied by Kapil et al. (1980); for seed size and number see Aniszewski et al. (2001); for the colours of seeds refer to Berggren, 1962; Huber, 1969; Dahlgren & Clifford, 1982; Barthlott, 1984; while epidermal cell patterns and distribution of elements such as trichomes, glands and stomata are given by Stace (1965). The distribution of cells are of importance between species and genus level (Barthlott 1981, 1984; Haridasan & Mukherjee, 1993); while outer periclinal walls are also a good diagnostic character for the lowest taxonomic categories (Barthlott, 1981, 1984, Fayed & El Naggar, 1988, 1996).

In Brassicaceae, the external features of the seeds colour and shape are studied by Kondo (1917); McGugan (1948); Musil (1948); Murley (1951) and Berggren (1962) investigated the external morphology and anatomy of seeds testa of *Brassica.* Vaughan & Whitehouse (1971) studied the external morphology and anatomy of seeds of 90 genera and 200 species of the Cruciferae and paid special attention to the relationships between seed structure and existing taxonomy.

Prasad (1976) investigated the seed coat structure and development in certain species of Brassicaceae. Mulligan & Baily (1976) and Stork et al. (1980) studied some taxa of *Brassica* seeds with SEM and they suggested other data that help in the reclassification of the genus. Fayed & El Naggar (1988) investigated the seed coat sculpture in species of the tribe *Brassiceae* in Egypt by using SEM, several details offer taxonomic value at the generic and subtribal levels such as the shape, size, epidermal cells pattern, anticlinal wall boundaries and outer periclinal cell walls.

Jonsell (1975) studied the seed coat of *Lepidium* in East tropical Africa; Fayed & El Naggar (1996) investigated the seed morphology and taxonomy with SEM in the tribe *Lepidieae* in Egypt.

Jonsell (1986) studied the seed coat of genus *Farsetia* by using SEM to distinguish between species. Stork (1971, 1972c) and Stork & Wüest (1978) investigated the seed coats and development of epidermal slime bodies of *Malcolmia* groups and found large differences between the different groups. Jonsell (1979) used SEM on the seed surface to distinguish *Matthiola, Morettia* and *Diceratella.* Stork & Wüest (1980) studied the seed coat morphology, particularly the epidermal slime structure of *Morettia*. Koul et al. (2000) investigated the seed coat microsculpturing in *Brassica* and allied genera and provided evidence for the close relationships among various genera within subtribe *Brassicinae* and closeness of subtribes *Raphaninae* and *Moricandiinae* respectively with the *Brassicinae.*

The present investigations deal with the micro- and macromorphological (LM & SEM) characters of seeds of 23 genera (39 species) of 6 tribes from the family *Brassicaceae* in Egypt, to decide on the importance of seed characters as a criterion for separating genera and species in this family.

The terminology used here follows authors such as Barthlott (1981, 1984); Fayed & El Naggar (1988, 1996); Karam (1997) and Koul et al. (2000) with some modifications by the author.

3. 2. MATERIAL AND METHODS

Some of the investigated seeds were collected from mature plants in Egypt during 1998-2000. The others were supplied by INIA, Madrid, Spain or taken from herbarium specimens, see table 3. 1.

Only mature seeds were taken for investigation. The dried seeds were first examined by light microscope (Carl Zeiss 475002), and 7-15 seeds for each taxon were chosen to cover the range of variation. Seeds were mounted on stubs with double adhesive tape. The stubs were sputter-coated with gold-paladium for 2-3 min. in a Polaron Equipment Ltd. SEM coating unit E 5100. After coating, the specimens were examined with a Jeol JSM 5200 scanning electron microscope, using accelerating voltages at 15-20 KV. All photomicrographs were taken at the department of Plant Cytology and Morphology, SEM laboratory, Wageningen University, the Netherlands.

3. 3. RESULTS

Seed characters are very important to separate among genera and species levels in Brassicaceae. The seed shape varies from orbicular, suborbicular, oblong, ovoid, or oblong-ovoid. The seed size varies from large (3-8 x 2.5-7 mm) to small (0.5-3 x 0.3-1.7 mm) and helps to separate between species. The seed colour brown varies from yellow-brownish to red-brownish. Radicle position relative to cotyledons varies from accumbent to incumbent. Epidermal cell shape varies from isodiametric, 4-5-6-polygonal to elongate in one direction. Anticlinal boundaries vary from raised to channelled; anticlinal walls vary from straight to sinuous or slightly sinuous; and they present smooth to fine or coarse folds. Periclinal cell walls showed a large variation among genera and species level, and can be either flat, concave,

convex or domate; smooth, micro- or macroreticulate, striate, and possess fine to coarse folds and papillae.
The seed shape, presence/absence awing, size, colour, radicle position relative to cotyledons, epidermal cell shape, and the characters of anticlinal boundaries and periclinal cell wall of each taxon (39 species belong to 23 genera) are given in table 3. 2.

Table 3. 1. List of Brassicaceae seed specimens used in Scanning Electron Microscope (SEM) studies

Taxon	Collection No.	Place of collections
1. Tribe Arabideae		
Arabis alpina L. sub sp. *caucasica* (Willd.) Briq.	1313	Morocco, Taza, around gebel Tazzeka (NMGM)
Arabis nova Vill.	20273	Switzerland, Valois, Val de Bagnes (BR)
Nasturtium officinale R.BR.	415	
Rorippa indica (L.) Hiern	s.n.	Egypt, Qena, El Mahrosa island (SHG)
Rorippa integrifolia Boulos	9	Egypt, Middle of Sinai, about 5 km before Ras Sedr (SHG)
Rorippa palustris (L.) Besser	20	Egypt, along the canal of Ismailiya (SHG)
2. Tribe Euclidieae		
Anastatica hierochuntica L.	327	Egypt, Cairo-Suez road, 95 km from Cairo (CAI)
Neslia paniculata (L.) Desv.	64	Iran, near Gere between Abushir and Shiraz (WAG)
Ochthodium aegyptiacum (L.) DC.	129	Palestine, Jerusalem: Mt. Scopus (BM)
Schimpera arabica Hochst & Steud.	3747-75	Spain, Madrid (I. N. I. A)
3. Tribe Hesperideae		
Eremobium aegyptiacum (Spreng.) Asch. & Schweinf. subsp. *aegyptiacum*	29	Egypt, El Arish area beside the Airport, N. Sinai (SHG)
Eremobium aegyptiacum subsp. *lineare* (Delile) Abdel Khalik	s.n.	Egypt, El Tor desert, Sinai (L)
Eremobium aegyptiacum subsp. *longisiliquum* (Coss.) Maire	s.n.	Egypt, in sands near Asswan (LY)
Erysimum repandum L.	1163-67	Spain, Madrid (I. N. I. A)
Leptaleum filifolium (Willd.) DC.	s.n.	Egypt, Wadi Chafura, north Galala (BR)
Malcolmia africana (L.) R.Br.	2	Egypt, Deir el Rahba, Wadi el Arbain, S. Sinai (SHG)
Malcolmia nana (DC.) Boiss.	28	Egypt, El Arish-Rafah road, 23 km from El Arish (SHG)
Malcolmia pygmaea (Del.) Boiss.	22	Egypt, Alexandria.-Matruh coastal road, 26 km, Sidi Krer, (SHG)
4.Tribe Lunarieae		
Ricotia lunaria (L.) DC.	45.004	Syria, Golan, Yahudiya forest (B)
5. Tribe Matthioleae		
Diceratella eliptica (DC.) Jonsell	17	Egypt, Gebel Elba, Wadi Shallal (SHG)
Matthiola arabica Boiss.	12	Egypt, Wadi el Arbaien, S Sinai (SHG)
Matthiola fruticulosa (L.) Maire	1221-66	Spain, Madrid (I. N. I. A)

Table 3. 1. Continued

Taxon	Collection No.	Place of collections
Matthiola longipetala subsp. *bicornis* (Sibth.) Ball	4379	Turkey, Tassia, in sands near Saban Dagi (BR)
Matthiola longipetala subsp. *hirta* (Conti) Greuter & Burdet	23	Egypt, Alex.-Matruh coastal road, near Burg el Arab (SHG)
Matthiola longipetala subsp. *kralikii* (Pomel) Maire	7	Egypt, Cairo-Alexandria desert road, 100 km from Alexandria (SHG)
Matthiola longipetala subsp. *livida* (Delile) Maire	27	Egypt, Cairo-Ismailiya desert road, 23 km before Ismailiya (SHG)
Matthiola longipetala (Vent.) DC. subsp. *longipetala*	25	Egypt, 28 km before Matruh, Alexandria-Matruh road (SHG)
Matthiola parviflora (Schousboe) R.Br.	0907-66	Spain, Madrid (I. N. I. A)
Morettia canescens Boiss.	1098-67	Spain, Madrid (I. N. I. A)
Morettia parviflora Boiss.	16984/2	Saudi Arabia, Wadi Harjab, rocky hillsides (BR)
Morettia philaeana (Delile) DC.	3	Egypt, 35 km from Qena on the road Qena-Safaga (SHG)
Notoceras bicorne (Ait.) Caruel.	1052	Egypt, Gebel Elba, Saddle between Gebel Asotriba and Makin
6. Tribe Sisymbrieae		
Crucihimalaya kneuckeri (Bornm.) Al-Shehbaz, O'Kane & Price	49785	Egypt, Sinai, E slopes of Gebel Catherine (CAI)
Descurainia sophia (L.) Webb & Berth.	1475	Jordan, El-Jubeiha, university campus (B)
Nasturtiopsis coronopifolia (Desf.) Boiss.	3663-76	Spain, Madrid (I. N. I. A)
Neotorularia aculeolata (Boiss.) Hedge & Léonard	5801	Iran, West of Jaz Murian (BR)
Neotorularia torulosa (Desf.) Hedge & Léonard	1461-68	Spain, Madrid (I. N. I. A)
Olimarabidopsis pumila (Stephan) Al-Shehbaz, O'Kane & Price	779	Syria, near Domascus, road of Zahroub to Merdj, Baustam el Mahar (L)
Robeschia schimperi (Boiss.) Schulz	170	Egypt, Sinai mountains, between granitic rocks (B)
Sisymbrium erysimoides Desf.	19	Egypt, Gebel Elba, Wadi Drawina (SHG)
Sisymbrium irio L.	31	Egypt, S. Sinai, Deir el-Rahebat, Wadi Feiran, as weed in garden (SHG)
Sisymbrium orientale L.	11	Egypt, S. Sinai, Deir Feiran, Wadi Feiran (SHG)
Sisymbrium polyceratum L.	6627-84	Spain, Madrid (I. N. I. A)
Sisymbrium runcinatum Lag. ex DC.	s.n.	Algeria, El Kantara, near Constantine (BR)
Sisymbrium septulatum DC.	3719-75	Spain, Madrid (I. N. I. A)

Table 3.2. Seed descriptions of Brassicaceae

Taxon	Seed shape	Seed wing	Seed size (mm)	Seed colour	Radicle	Epidermal cell shape	Anticlinal boundaries	Periclinal cell wall
1. Tribe Arabideae								
Arabis alpina sub sp. *caucasica*	Sub-orbicular	Wide	1.3-1.5 x 1.2-1.3	Light brown	Accumbent	Isodiametric, polygonal	Channelled, straight to slightly sinuous; smooth	Domate with flat or concave central position; folds to smooth
Arabis nova	Oblong-ovoid	None	0.7-1 x 0.3-0.4	Light brown	Accumbent	Isodiametric, 5-6-polygonal	Raised, straight to sinuous; coarse folds	Domate with globular central papilla; radiate-striate
Nasturtium officinale	Ovoid	Narrow	0.9-1 x 0.75-0.9	Brown	Accumbent	4-5-6 gonal, elongate in one direction	Raised, straight; folded	Flat; macro-reticulate
Rorippa indica	Ovoid	Narrow	0.8-1 x 0.7-0.8	Red-brown	Accumbent	Isodiametric, polygonal	Raised, straight to slightly sinuous; smooth to medium folds	Flat to concave; smooth to micro-reticulate
Rorippa integrifolia	Ovoid to ellipsoid	None	0.8-1 x 0.5-0.75	Orange-brown	Accumbent	4-5-polygonal, elongate in one direction	Raised, straight to slightly sinuous; smooth to fine folds	Flat to slightly convex; striate
Rorippa palustris	Cordiform to ovoid	None	0.5-0.9 x 0.3-0.6	Brown	Accumbent	Isodiametric, 4-5 gonal	raised, straight to slightly sinuous; smooth to fine folds	Flat to concave; smooth to micro-reticulate
2. Tribe Euclidieae								
Anastatica hierochuntica	Ovoid	None	1-1.9 x 1-1.7	Brown	Accumbent	Isodiametric	Channelled, straight; smooth to fine folds	Flat to convex with slightly sunken central papilla; smooth to fine folds
Neslia paniculata	Ovoid to sub-orbicular	None	1.5 x 1.3	Brown	Incumbent	4-polygonal	Raised-channelled, straight to sinuous; smooth to fine folds	Concave; smooth to medium folds
Ochthodium aegyptiacum	Ovoid-oblong	None	2.5-3 x 1.5-1.7	Brown	Incumbent	Elongate in one direction, polygonal	Slightly raised, sinuous; smooth to fine folds	Flat to slightly concave; micro-reticulate
Schimpera arabica	Oblong-ovoid	None	1.2-2.7 x 0.5-1.2	Brown	Incumbent	5-6 gonal, elongate in one direction	Slightly raised-channelled, straight to slightly sinuous; smooth to fine folds	Flat or slightly convex; micro-reticulate

Table 3.2. continued

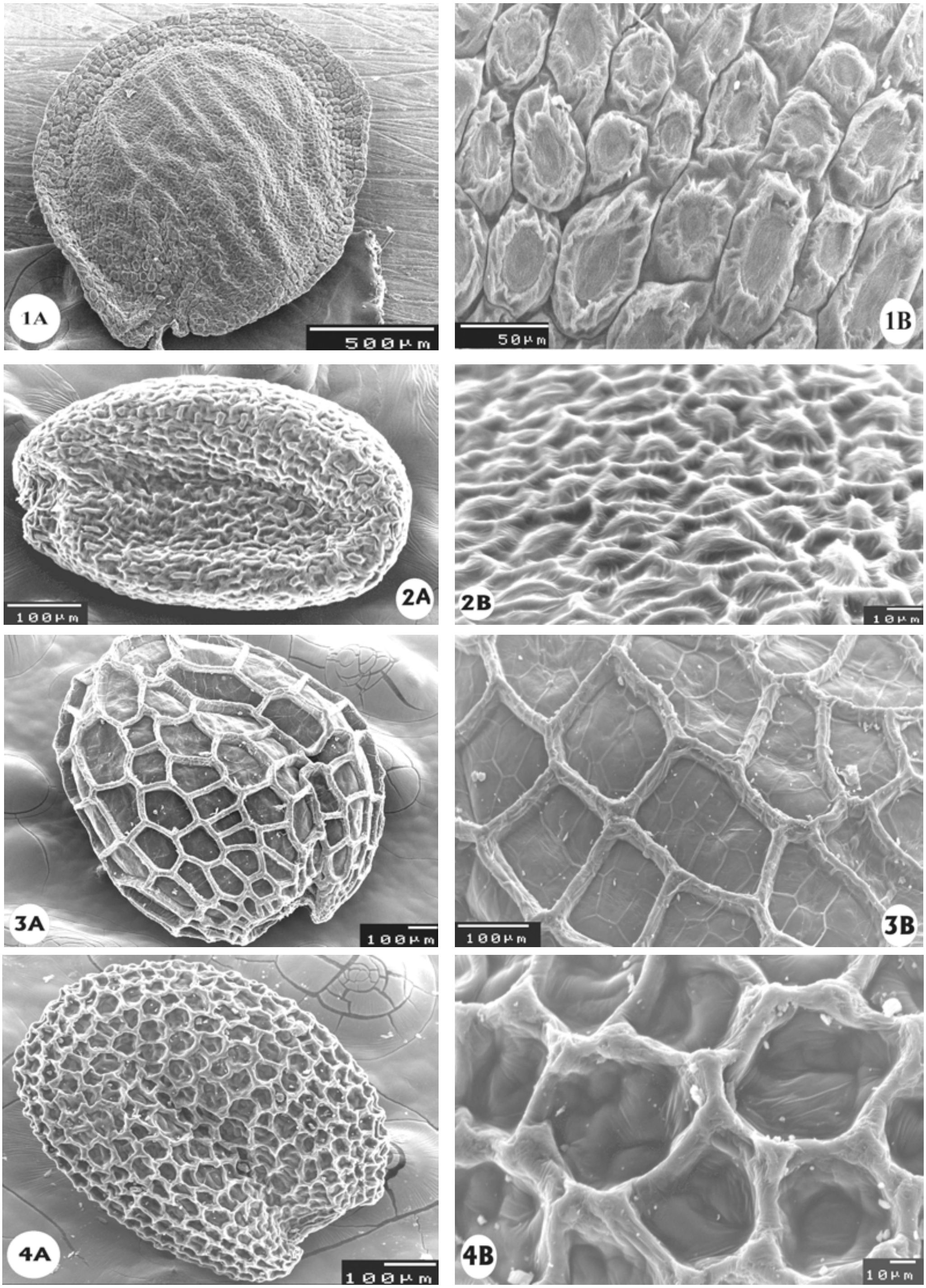
Taxon	Seed shape	Seed wing	Seed size (mm)	Seed colour	Radicle	Epidermal cell shape	Anticlinal boundaries	Periclinal cell wall
3. Tribe Hesperideae								
Eremobium aegyptiacum subsp. *aegyptiacum*	Oblong	Narrow	2.2 x 1.2	yellow-brownish	Accumbent	Isodiametric, 4-5-6 gonal	Slightly raised, straight; smooth	Flat to convex; smooth to fine folds
Eremobium aegyptiacum subsp. *lineare*	Sub-orbicular to ovoid	Wide	2.1 x 1.6	Red-brownish	Accumbent	Isodiametric, 5-6 gonal, elongate in one direction	Slightly raised, straight; smooth	Flat to convex; smooth to micro-papillate
Eremobium aegyptiacum subsp. *longisiliquum*	Oblong	Narrow	2.1 x 1	Brown	Accumbent	Isodiametric, polygonal	Raised, straight to slightly sinuous; smoth to fine folds	Flat to concave; smooth to fine folds
Erysimum repandum	Oblong	None	1.6 x 0.7	yellow-brownish	Incumbent	Isodiametric, 5-6 gonal	Raised, straight; smooth to fine folds	Domate with globular central papilla; radiate-striate
Leptaleum filifolium	Oblong-ovoid	None	0.6-0.7 x 0.4-0.5	yellow-brownish	Incumbent	polygonal	Channelled, sinuous to slightly straight; smooth	Domate with flat or concave central position; striate
Malcolmia africana	Oblong	None	1.2-1.7 x 0.5-0.8	Brown	Incumbent	Isodiametric, olygonal	Raised, straight to sinuous; smooth	Flat to convex with flat central portion; fine to coarse folds
Malcolmia nana	Oblong-ellipsoidal	None	0.6-0.8 x 0.3-0.4	Yellow-brownish	Incumbent	Isodiametric, 4-5-6 gonal, elongate in one direction	Raised, straight to slightly sinuous; smooth to fine folds	Flat to convex; striate
Malcolmia pygmaea	Ovoid	None	0.7-0.8 x 0.5-0.6	Yellow-brownish	Incumbent	Isodiametric, 5-6 gonal, elongate in one direction	Slightly raised, straight; smooth to fine folds	Flat to convex; striate
4.Tribe Lunarieae								
Ricotia lunaria	Orbicular	None	3-8 x 2.5-7	Brown	Accumbent	Isodiametric, polygonal	Channelled, straight to sinuous; smooth	Flat to convex; smooth to micro-papillate
5. Tribe Matthioleae								
Diceratella eliptica	Sub-orbicular to elliptic	Narrow	1-1.1 x 0.8-1	Light brown	Accumbent	Isodiametric, 4-5-6 gonal; elongate in one direction	Raised, straight; smooth	Flat to convex with sunken central papilla; smooth to fine folds
Matthiola arabica	Oblong	Narrow	1.1-1.3 x 0.7-0.8	Brown	Accumbent	4-5-6 gonal, elongate in one direction	Raised, straight; smooth to fine folds	Convex; smooth to fine folds
Matthiola fruticulosa	Oblong	Wide	2.2 x 1.2	Brown	Accumbent	Isodiametric, 5-6 gonal, elongate in one direction	Raised, straight; smooth to fine folds	Flat to convex; fine to medium striate

Table 3.2. continued

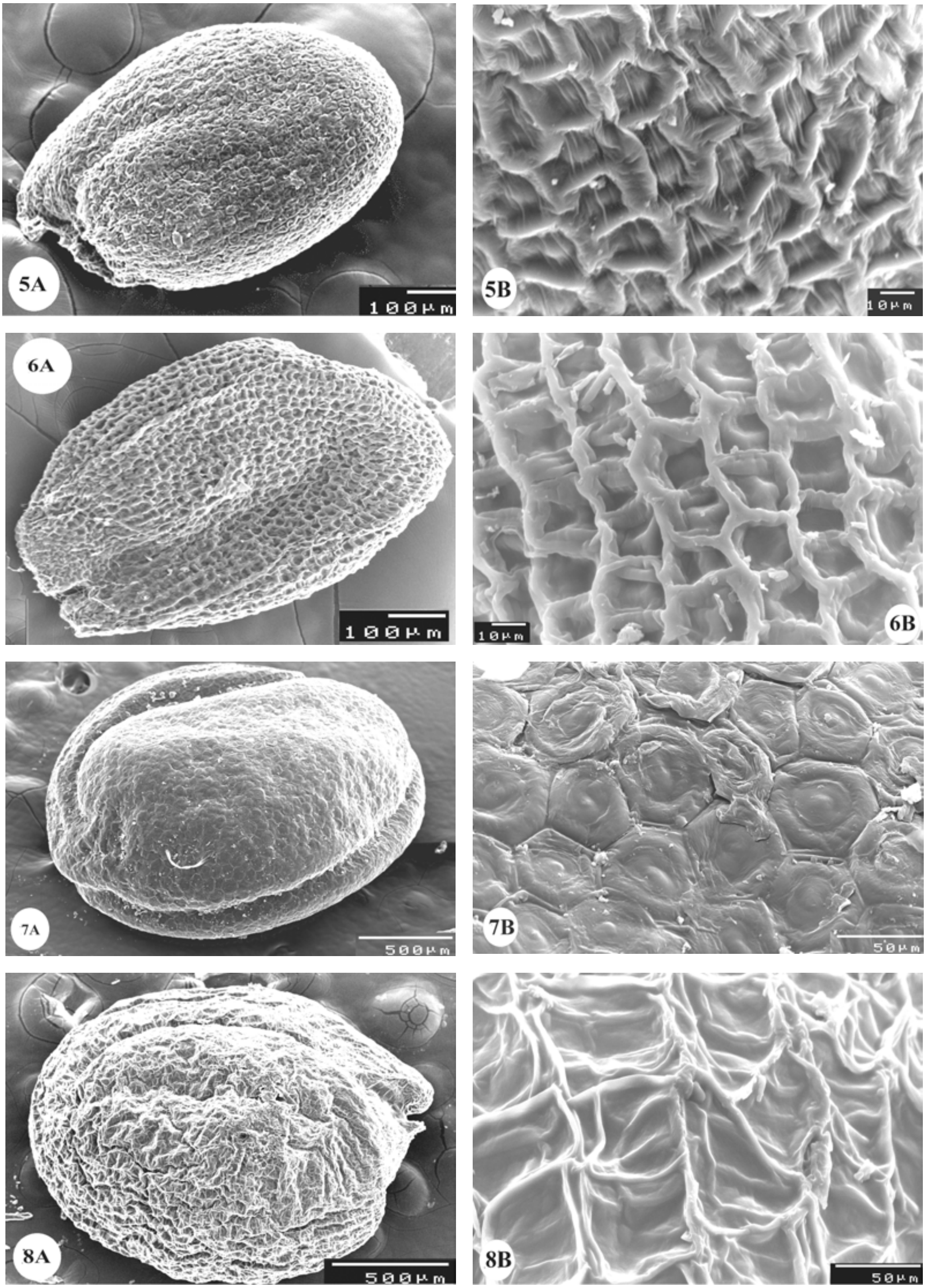
Taxon	Seed shape	Seed wing	Seed size (mm)	Seed colour	Radicle	Epidermal cell shape	Anticlinal boundaries	Periclinal cell wall
Matthiola longipetala subsp.*bicornis*	Oblong	Wide	1.5-1.8 x 0.7-1	Brown	Accumbent	Isodiametric, polygonal	Raised, straight to sinuous; smooth to fine folds	Flat to slightly concave; fine to coarse folds
Matthiola longipetala subsp. *hirta*	Sub-orbicular	Narrow	1-1.3 X 0.9-1.1	Yellow-brownish	Accumbent	Isodiametric, 5-6-polygonal	Raised, straight; smooth	Flat to slightly convex; smooth to fine folds
M. longipetala subsp. *kralikii*	Oblong-ovoid	Narrow	1-1.1 x 0.7- 0.8	Yellow-brownish	Accumbent	Isodiametric, 5-6-polygonal	Raised, straight to slightly sinuous; smooth to fine folds	Flat to slightly convex; smooth to fine folds
Matthiola longipetala subsp. *livida*	Oblong	Narrow	0.8-1 x 0.4-0.6	Brown	Accumbent	4-5-polygonal	Slightly raised, straight to sinuous; smooth to fine folds	Flat or slightly concave; coarse folds
Matthiola longipetala subsp. *longipetala*	Oblong-ovoid	Narrow	1-1.2 x 0.7-0.8	Yellow-brownish	Accumbent	Isodiametric, 4-5-6 gonal	Raised, straight to slightly sinuous; smooth to fine folds	Flat; smooth to fine folds
Matthiola *parviflora*	Oblong-ovoid	Narrow	1.2-1.5 x 1-1.2	Brown	Accumbent	Isodiametric, elongate in one direction, 4-5-6 gonal	Slightly raised, straight; smooth	Flat or slightly concave; micropapillate
Morettia canescens	Ovoid	None	1-1.3 X 0.9-1.1	Light brown	Accumbent	Isodiametric, 4-5 gonal	Raised, straight; fine to coarse folds	Convex; smooth
Morettia *parviflora*	Ovoid	None	1-1.2 x 0.8-1	Light brown	Accumbent	Isodiametric,4-5-6 gonal	Raised, straight to slightly sinuous; smooth	Domate with aglobular central papillae; fine folds to radiate-striate
Morettia *philaeana*	Ovoid	None	1.5-1.7 x 1.3-1.5	Brown	Accumbent	Isodiametric, 5-6 gonal	Raised, straight; smooth	Convex; smooth
Notoceras bicorne	Rounded	None	1-1.5 x 0.9-1.3	Brown	Accumbent	Isodiametric, 5-6 gonal, elongate in one direction	Raised, straight to slightly sinuous; smooth to fine folds	Convex; medium striate
6. Tribe Sisymbrieae								
Crucihimalaya kneuckeri	Oblong	None	0.8-1 x 0.3-0.4	Brown	Incumbent	Isodiametric, polygonal	Raised, straight to slightly sinuous; fine foldes	Flat to concave; folded to micro- reticulate
Descurainia sophia	Oblong	None	1-1.3 x 0.6-0.8	Red-brownish	Incumbent	Isodiametric, 4-5-polygonal	Raised, straight; smooth to fine folds	Flat to convex; smooth to fine folds
Nasturtiopsis coronopifolia	Oblong-ellipsoidal	None	0.7-1 x 0.4-0.5	Brown	Incumbent	5-6-polygonal, elongate in one direction	Raised, straight to sinuous; smooth to fine folds	Flat to convex with sunken central papilla; fine to coarse folds

Table 3.2. continued

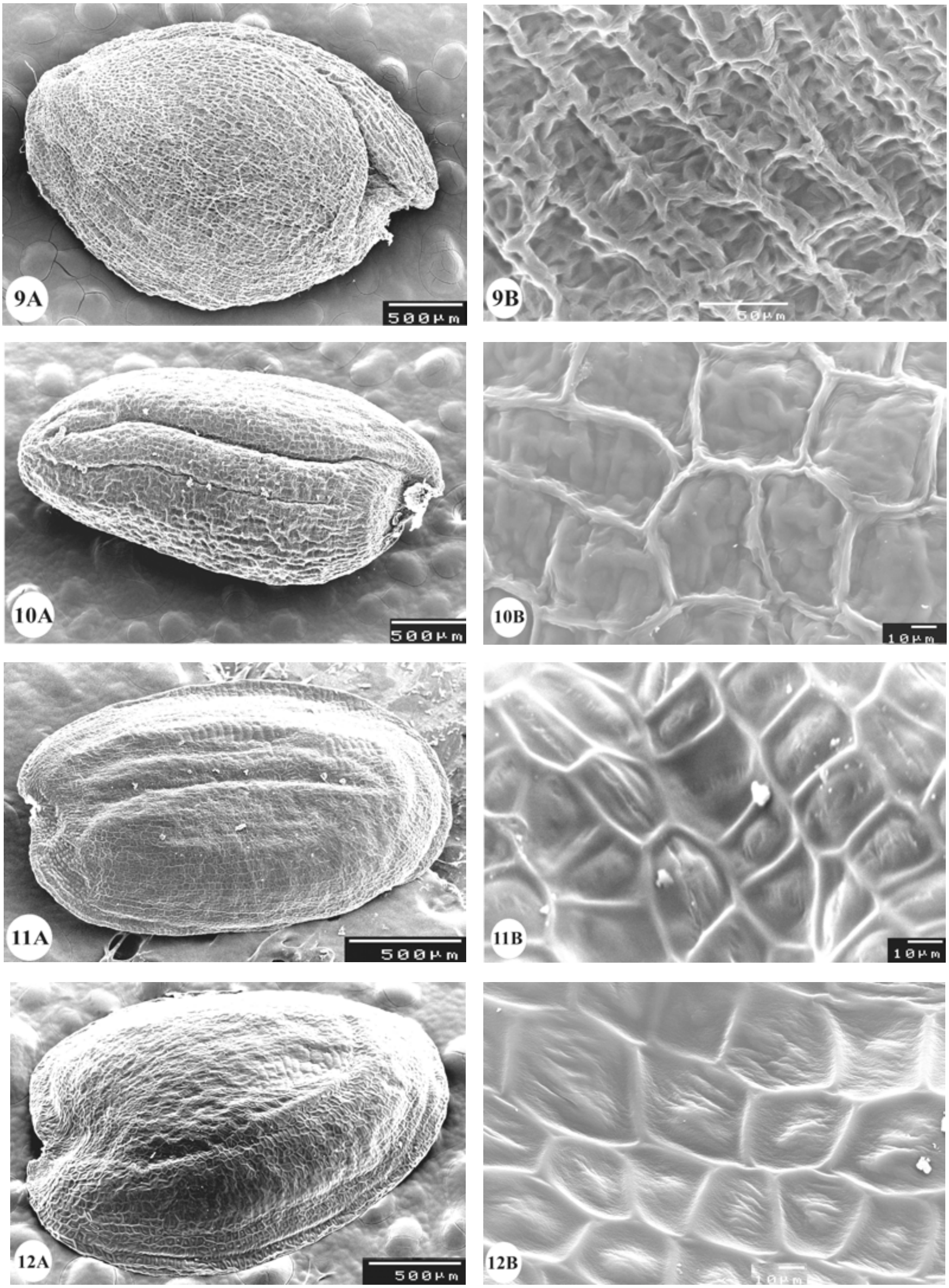
Taxon	Seed shape	Seed wing	Seed size (mm)	Seed colour	Radicle	Epidermal cell shape	Anticlinal boundaries	Periclinal cell wall
Neotorularia aculeolata	Oblong	None	1.2-1.5 x 0.4-0.5	Brown	Incumbent	Isodiametric, polygonal	Channelled, sinuous ; smooth	Domate with sunken central portion; smooth to fine folds
Neotorularia torulosa	Oblong-ellipsoidal	None	1-1.2 x 0.5-0.6	Brown	Incumbent	Isodiametric, 5-6 gonal	Slightly raised, straight; smooth	Convex; smooth to fine folds
Olimarabidopsis pumila	Oblong	None	0.9-1 x 0.4-0.5	Brown	Incumbent	Isodiametric, polygonal	Raised, straight; smooth to fine folds	Domate with globular central papilla; smooth
Robeschia schimperi	Oblong	None	1-1.3 x 0.5-0.6	Brown	Incumbent	Isodiametric, 5-6-polygonal	Raised, straight to slightly sinuous; smooth to deep folds	Domate with globular central papilla; medium striate
Sisymbrium erysimoides	Oblong	None	1-1.1 x 0.5	Yellow-brownish	Incumbent	Isodiametric, polygonal	Channelled, straight to sinuous; smooth to fine folds	Domate with flat or concave central position; radiate-striate
Sisymbrium *irio*	Oblong-ellipsoidal	None	0.7-1 x 0.4-0.5	Yellow-brownish	Incumbent	Isodiametric, 4-5 gonal	Slightly raised, straight; smooth	Flat to slightly convex with flat or concave central portion; micro-reticulate
Sisymbrium *orientale*	Oblong-ovoid	None	1.1-1.4 x 0.7-0.9	Orange-brown	Incumbent	Isodiametric, 5-polygonal	Raised, straight to slightly sinuous; smooth to fine folds	Flat to slightly convex; micro-reticulate
Sisymbrium *polyceratum*	Oblong	None	0.8-1 x 0.4-0.5	Brown	Incumbent	Polygonal, elongate in one direction	Channelled, sinuous to slightly straight; smooth	Flat to convex; smooth to fine folds
Sisymbrium *runcinatum*	Oblong	None	1-1.1 x 0.5-0.6	Yellow-brownish	Incumbent	polygonal	Channelled, sinuous; smooth to fine folds	Domate with sunken central portion; fine folds
Sisymbrium septulatum	Oblong-ovoid	None	1-1.3 x 0.6-0.7	Brown	Incumbent	Isodiametric, polygonal	Raised-channelled, straight to slightly sinuous; smooth	Domate with globular central papilla; smooth to fine folds



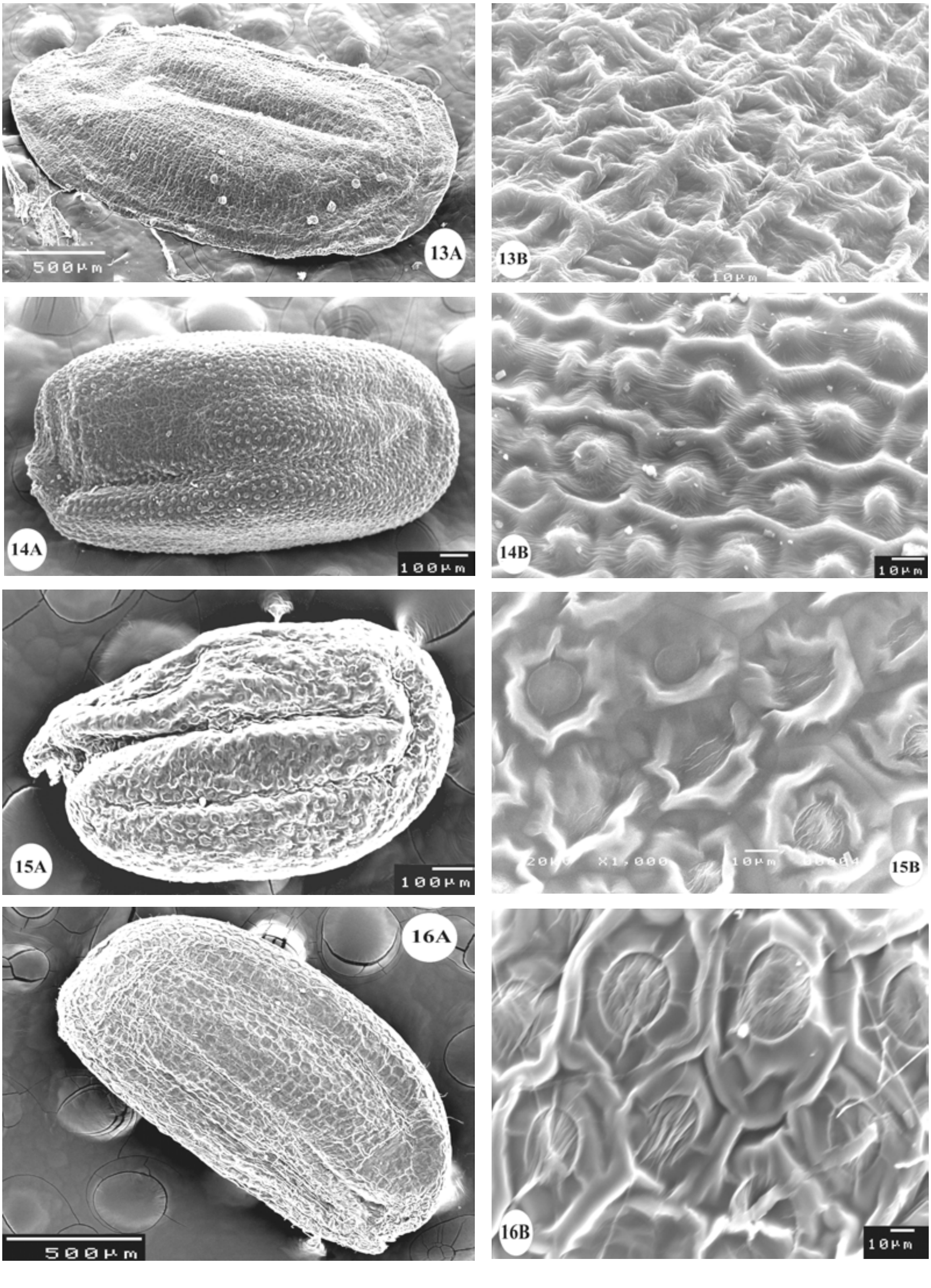
Figs. 3.1-4. SEM photographs of seeds. A: entire seed, B: enlargement of seed coat & bars indicate size. **1**. *Arabis alina* subsp. *caucasica*. **2**. *Arabis nova*. **3**. *Nasturtium officinale*. **4**. *Rorippa indica.*



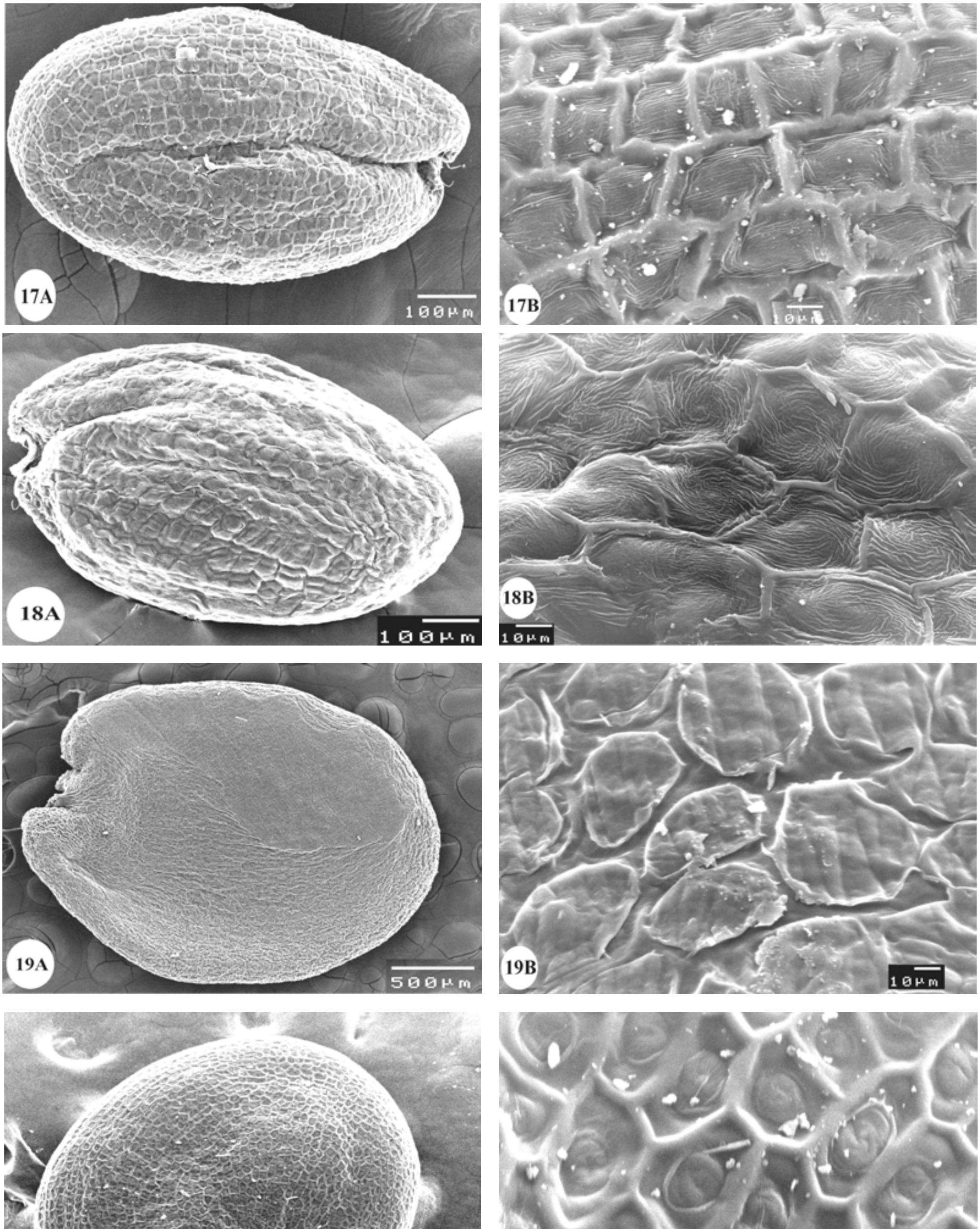
Figs. 3.5-8. SEM photographs of seeds. **5**. *Rorippa integrifolia.* **6**. *Rorippa palustris.* **7**. *Anastatica hierochuntica.* **8**. *Neslia paniculata.*



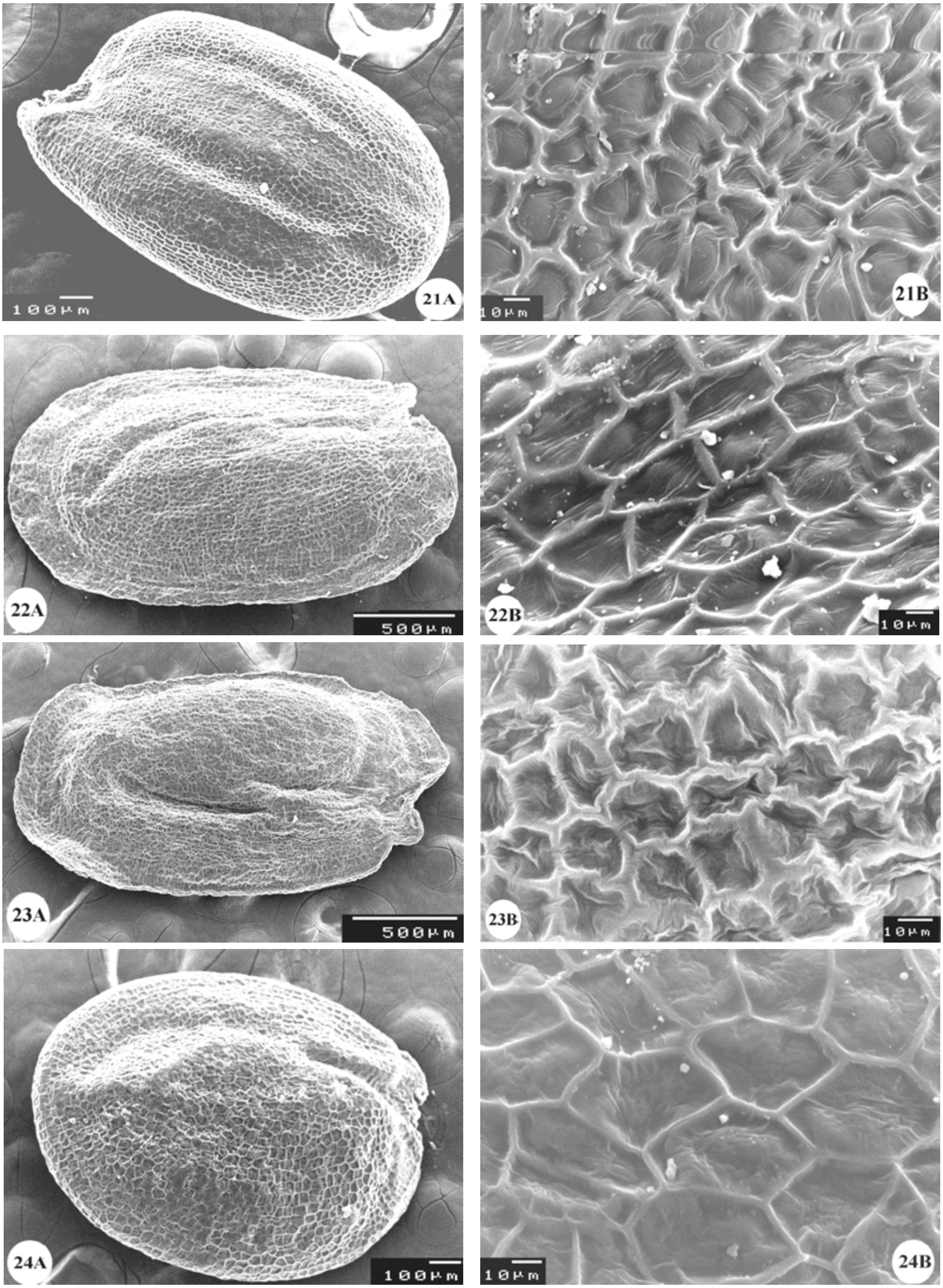
Figs. 3.9-12. SEM photographs of seeds. **9**. *Ochthodium aegyptiacum*. **10**. *Schimpera arabica.* **11**. *Eremobium aegyptiacum* subsp. *aegyptiacum.* **12**. *Eremobium aegyptiacum* subsp.*lineare.*



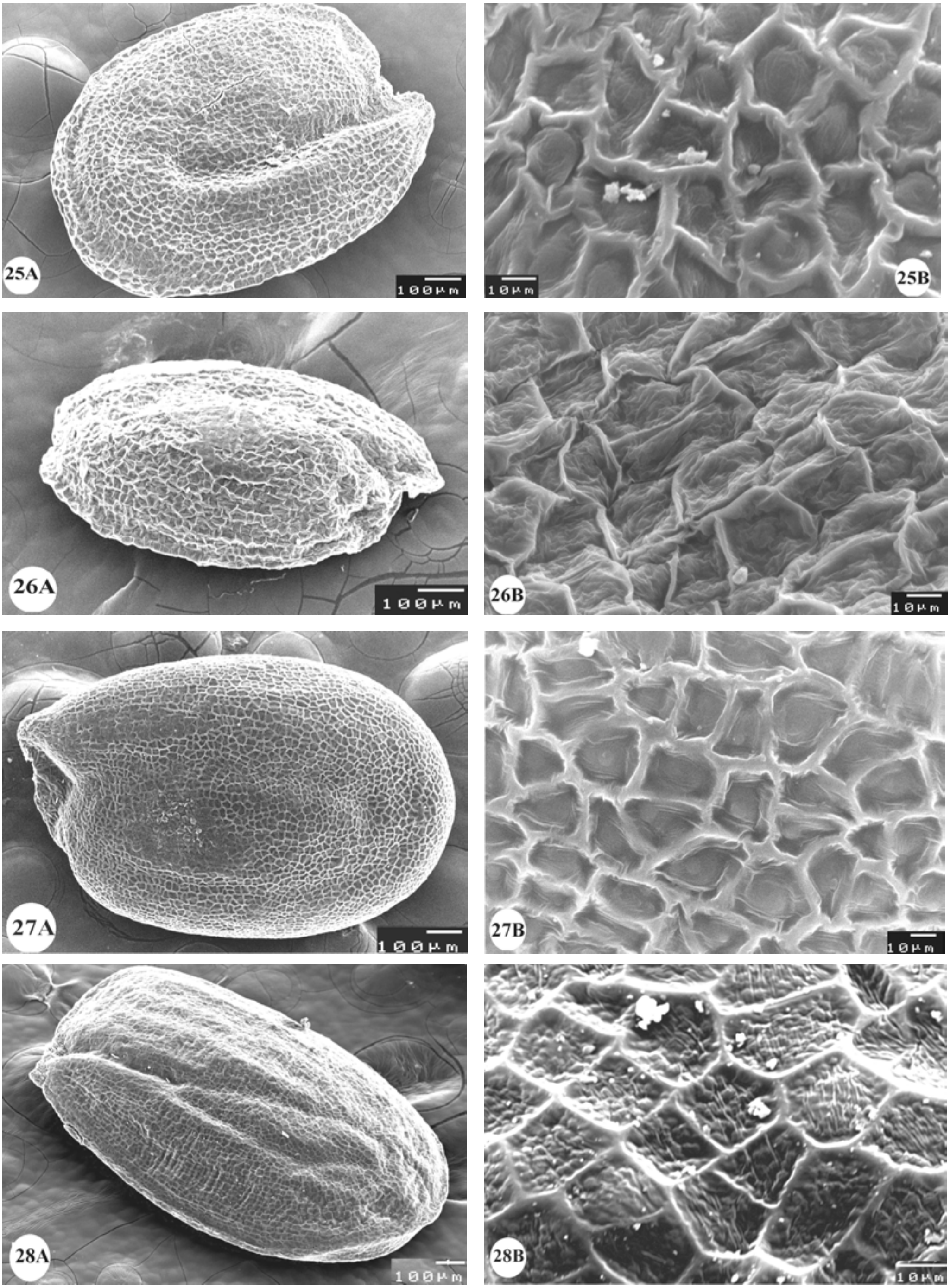
Figs. 3.13-16. SEM photographs of seeds. **13**. *Eremobum aegyptiacum* subsp. *longisiliquum*. **14**. *Erysimum repandum*. **15**. *Leptaleum filifolium*. **16**. *Malcolmia africana*.



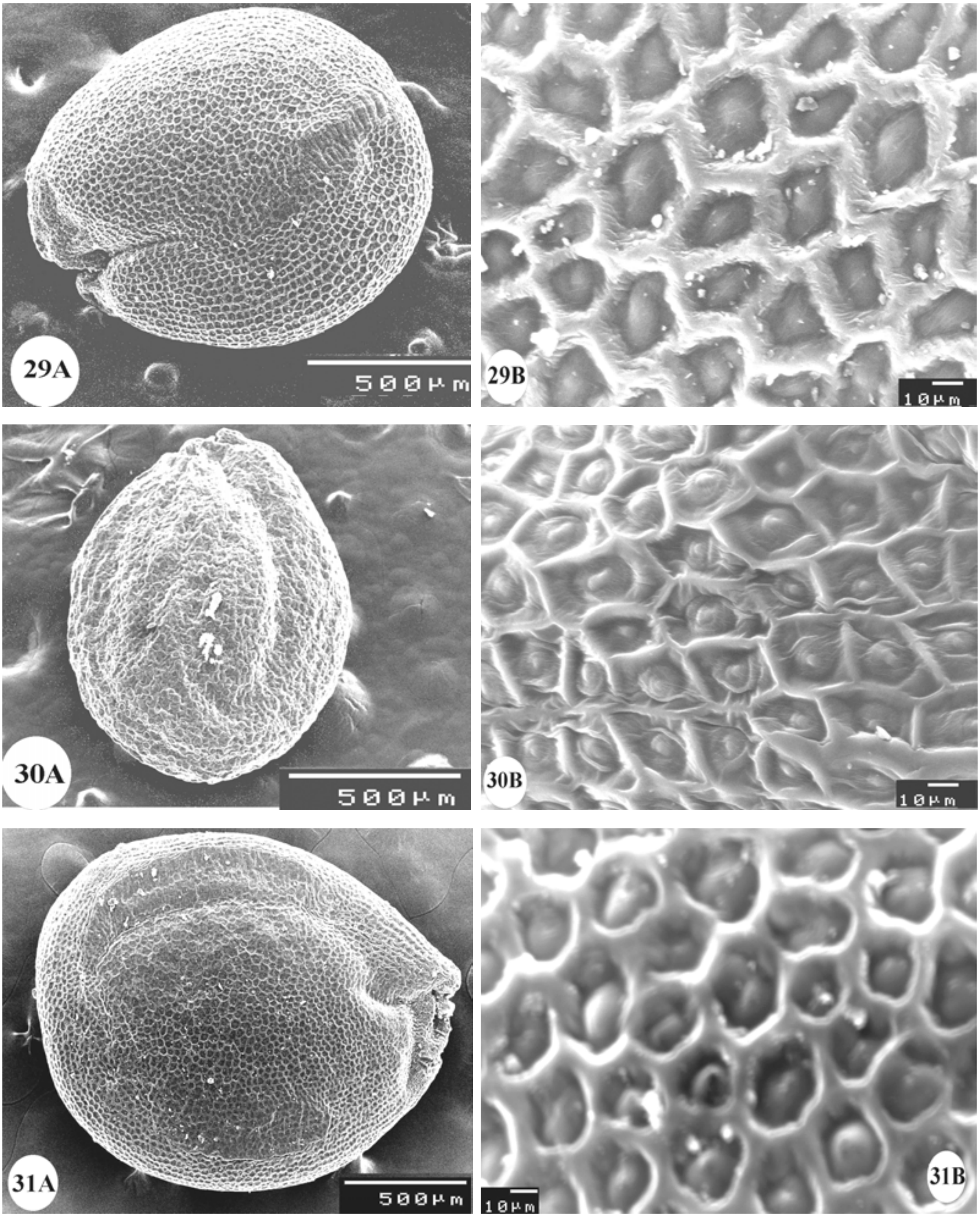
Figs. 3.17-20. SEM photographs of seeds. **17**. *Malcolmia nana.* **18**. *Malcolmia pygmaea.* **19**. *Ricotia lunaria.* **20**. *Diceratella elliptica.*



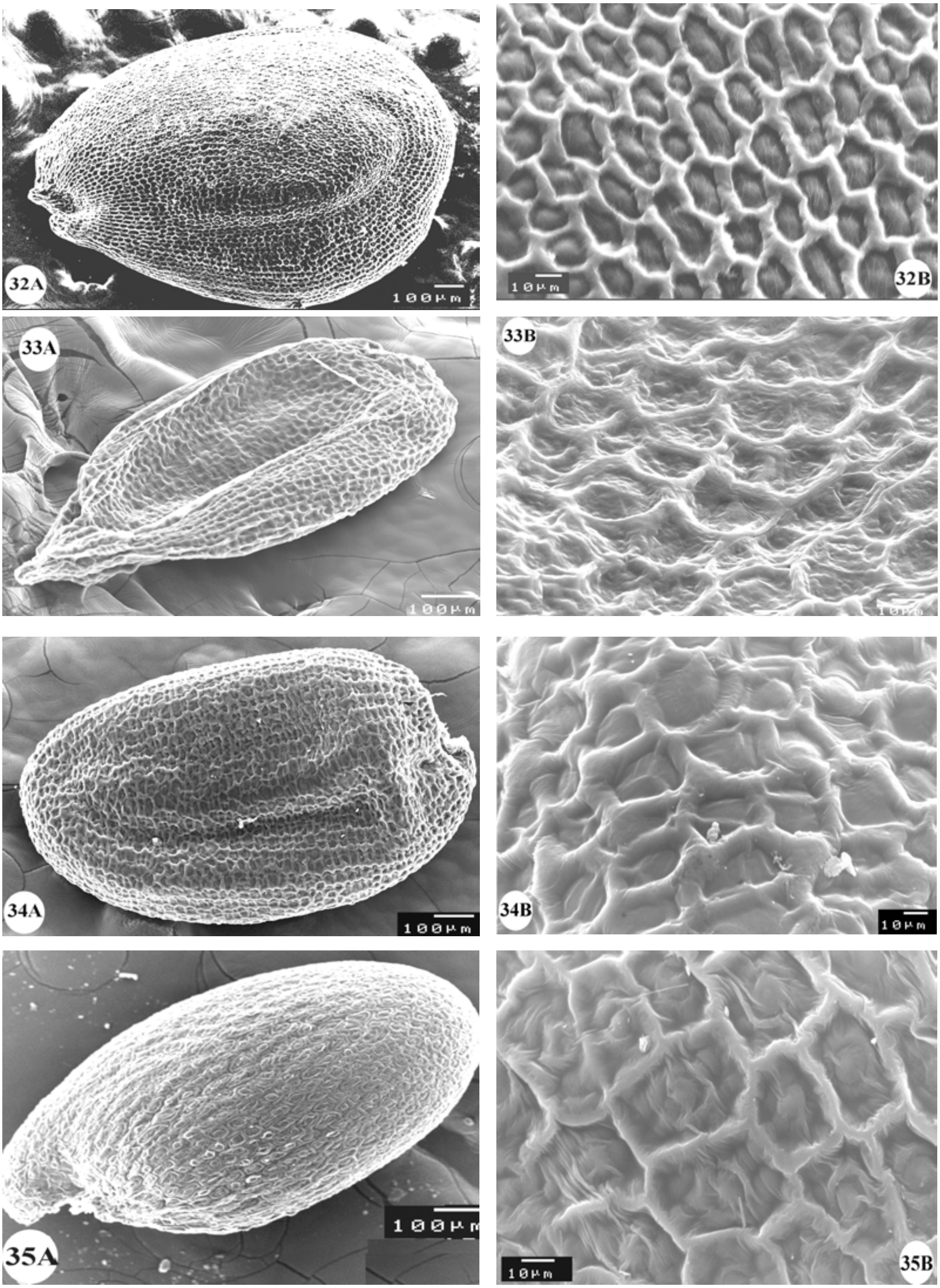
Figs. 3.21-24. SEM photographs of seeds. **21**. *Matthiola arabica*. **22**. *Matthiola fruticulosa*. **23**. *Matthiola longipetala* subsp. *bicornis.* **24**. *Matthiola longipetala* subsp. *hirta.*



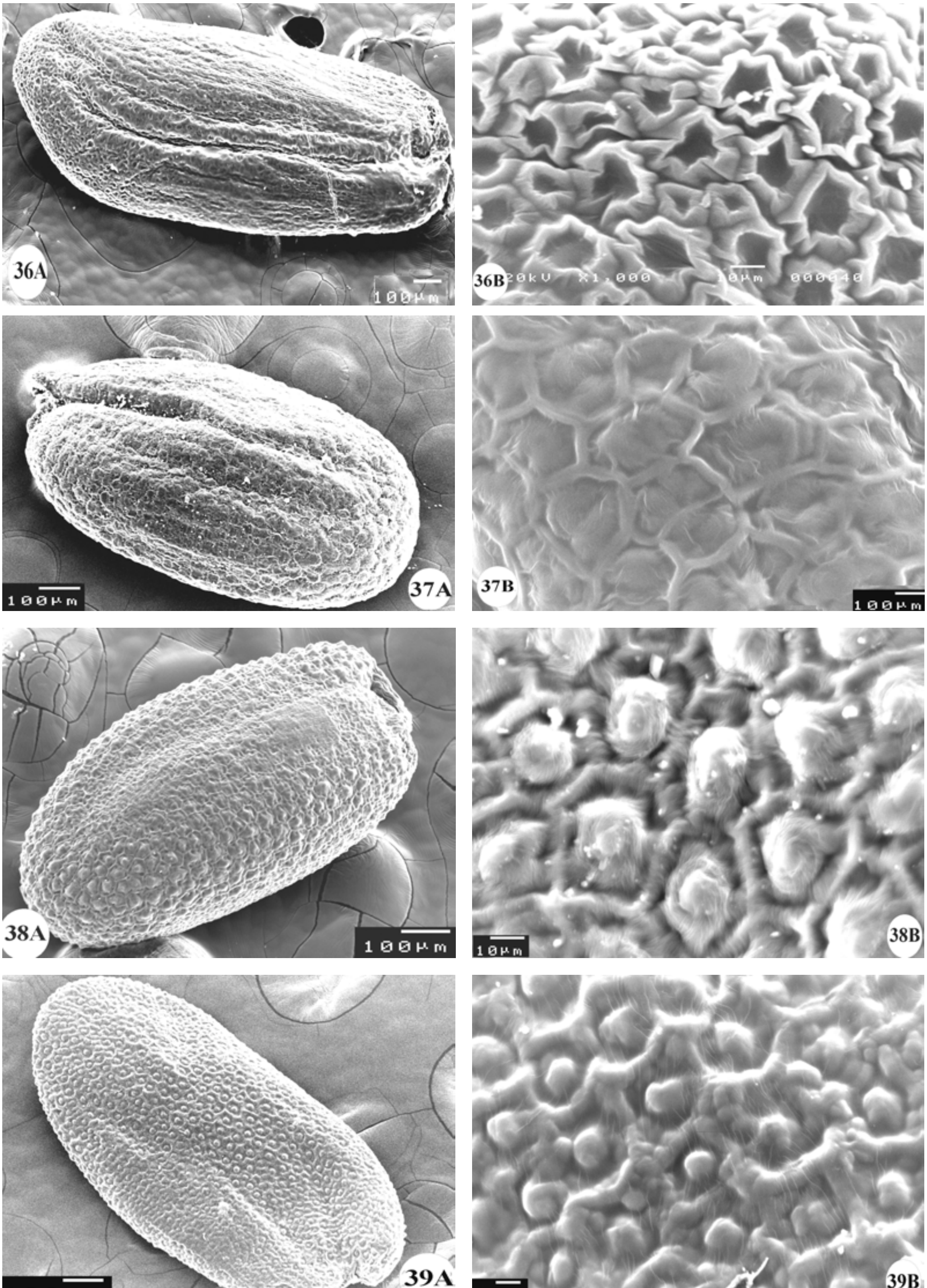
Figs. 3.25-28. SEM photographs of seeds. **25**. *Matthiola longipetala* subsp. *kralikii*. **26**. *Matthiola longipetala* subsp. *livida*. **27**. *Matthiola longipetala* subsp. *longipetala*. **28**. *Matthiola parviflora*.



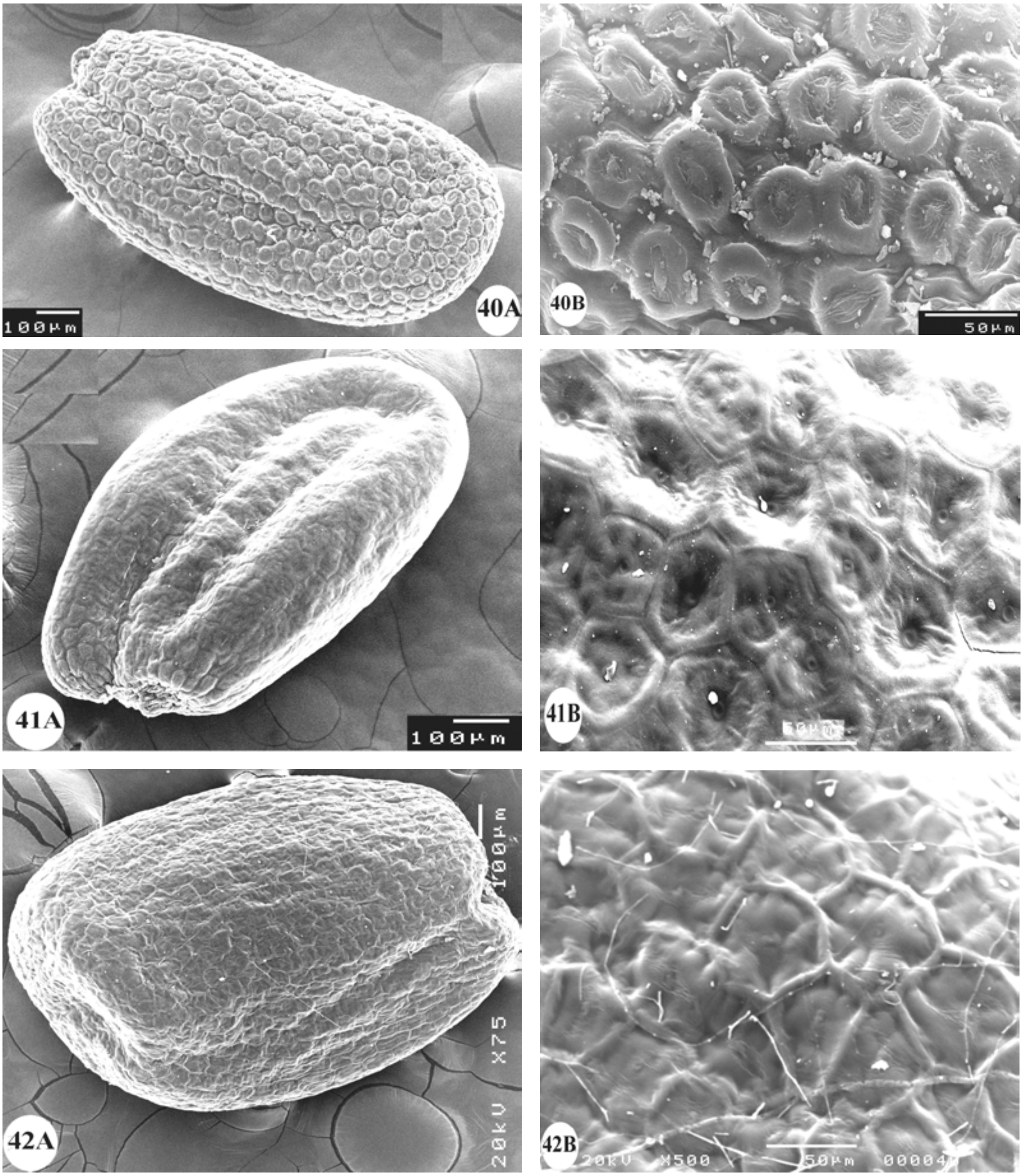
Figs. 3.29-31. SEM photographs of seeds. **29**. *Morettia canescens.* **30**. *Morettia parviflora.* **31**. *Morettia philaeana.*



Figs. 3.32-35. SEM photographs of seeds. **32**. *Notoceras bicorne.* **33**. *Crucihimalaya kneuckeri* **34**. *Descurainia sophia.* **35**. *Nasturtiopsis coronopifolia.*



Figs. 3.36-39. SEM photographs of seeds.**36**. *Neotorularia aculeolata*. **37**. *Neotorularia torulosa.* **38**. *Olimarabidopsis pumila.* **39**. *Robeschia schimperi.*



Figs. 3.40-42. SEM photographs of seeds. **40**. *Sisymbrium erysimoides*. **41**. *Sisymbrium irio.* **42**. *Sisymbrium orientale.*

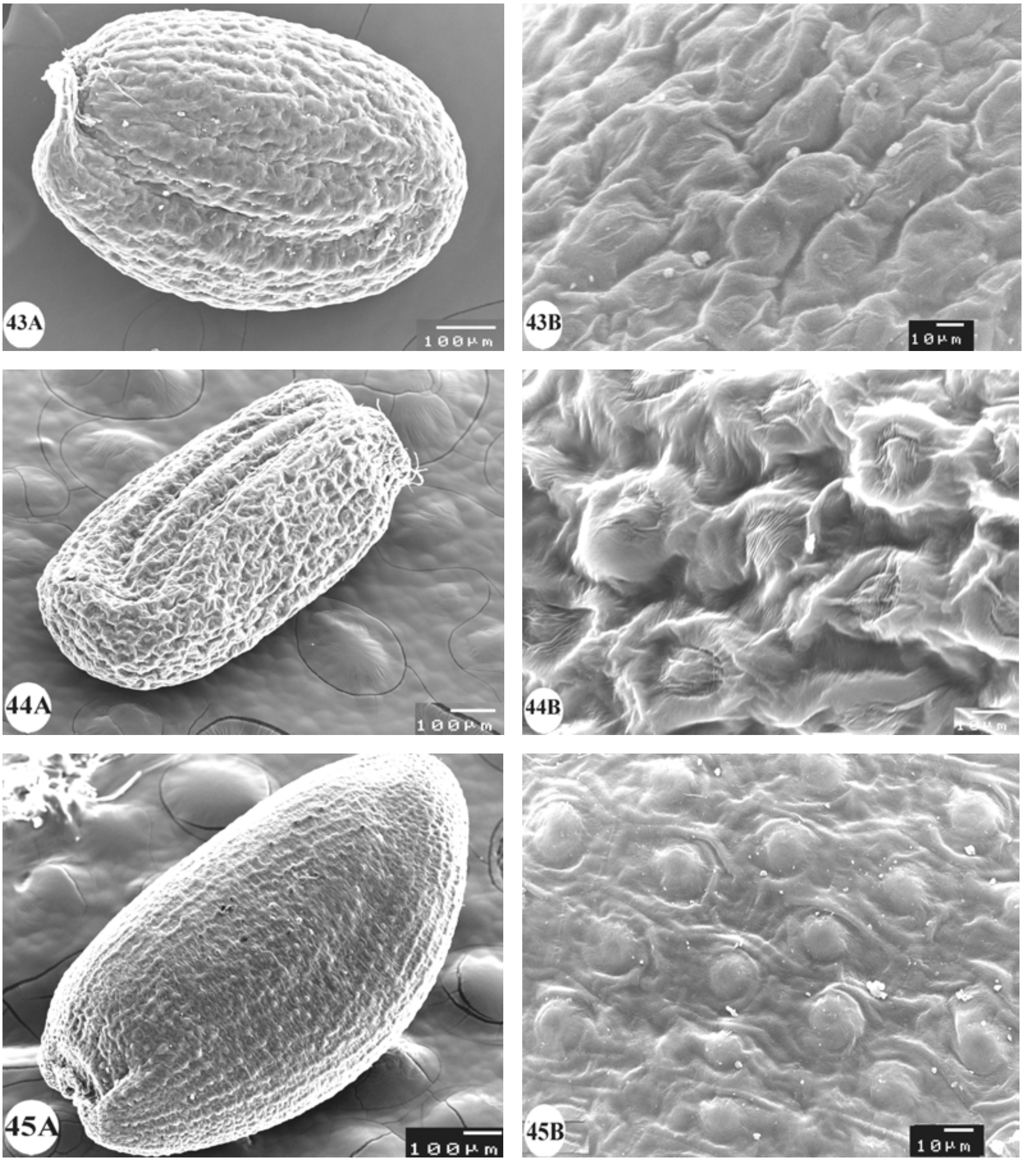


Fig. 3.43-45. SEM photographs of seeds. **43**. *Sisymbrium polyceratum*. **44**. *Sisymbrium runcinatum*. **45**. *Sisymbrium septulatum.*

3. 4. DISCUSSION OF SEED CHARACTERS

4. 4. 1. Seed shape

The shape of seeds among the investigated taxa showed a large variation. Most of the seeds vary from oblong or ovoid to oblong-ovoid or oblong-ellipsoidal (table 3.2), however they are orbicular in *Ricotia lunaria* (fig. 3.19)*;* sub-orbicular to sub-orbicular-ovoid in *Matthiola longipetala* subsp. *hirta*, *Arabis alpina* subsp. *caucasica*, *Neslia paniculata*, *Eremobium egyptiacum* subsp. *lineare* and *Diceratella elliptica*. Seed shape was found useful to separate the closely allied genera *Matthiola* with oblong seeds; *Morettia* with ovoid seeds and *Diceratella* with suborbicular to elliptical seeds. The shape of seeds showed a significant difference between the subspecies of *Eremobium aegyptiacum*, they are oblong in subsp. *aegyptiacum* and subsp. *longisiliquum,* and sub-orbicular to ovoid in subsp. *lineare* (figs. 3.11-13).

Most of the seeds examined have no or narrow wings, but in *Arabis alpina* subsp. *caucasica*, *Eremobium aegyptiacum* subsp. *lineare*, *Matthiola fruticulosa* and *Matthiola longipetala* subsp. *hirta* seeds have a broad wing.

3. 4. 2. Seed size

Seed dimensions vary greatly among the examined taxa, the largest orbicular seeds in *Ricotia lunaria* have a diameter of 3-8 x 2.5-7 mm, and the smallest seeds measure 0.5-1 x 0.3-0.9 mm in *Arabis nova, Nasturtium officinale, Rorippa, Leptaleum filifolium, Malcolmia nana, M. pygmaea, Nasturtiopsis, Crucihimalaya kneuckeri, Olimarabidopsis pumila, Sisymbrium irio* and *S. polyceratum,* while the rest of the species have slightly larger seeds of 1-3 x 0.4-1.7 mm. The seed size was found useful to separate between two species of *Arabis*, species of *Malcolmia* and species of *Sisymbrium.*

3. 4. 3. Seed colour

The colours of seeds are of high diagnostic and systematic interest among taxa. The colour of seeds varies from brown, yellow, red-brownish to orange-brownish. In the genus *Rorippa*, the colour varies from red-brown in *R. indica*, orange-brown in *R. integrifolia* to brown in *R. palustris* but the colour in *Sisymbrium* varies from yellow-brownish in *S. erysimoides, S. irio* and *S. runcinatum*; brown in *S. polyceratum* and *S. septulatum* to orange-brown in *S. orientale.* In *Malcolmia,* the colour is brown in *M. africana*; green-yellowish in *M. nana* and yellow-brown in *M. pygmaea*

The colour is also used to distinguish between subspecies of *Eremobium aegyptiacum*; it is yellow-brownish in subsp. *aegyptiacum* and subsp. *longisiliquum* and red-brownish in subsp. *lineare.*

3. 4. 4. Radicle/cotyledons position

Radicle/cotyledons position is a significant character to separate among tribes. In Brassicaceae there are 3 types of this position: conduplicate is common in tribe Brassiceae (El Naggar, 1987); incumbent and accumbent are present throughout the rest of the family (see fig. 2.15, chapter 2)), this character can vary within the tribe; in tribes Euclidieae and Hesperideae (accumbent and incumbent), in the tribe Euclidieae, accumbent in *Anastatica hierochuntica* and incumbent in the rest of the tribe, and in the tribe Hesperideae accumbent in *Eremobium* and incumbent in the rest of tribe.

3. 4. 5. Epidermal cells

3. 4. 5. 1. Shape

The cellular shapes can be of considerable diagnostic and systematic value. The cells are almost isodiametric or elongate in one direction, they are usually 4-6-polygonal in most taxa. Epidermal cells of almost all seed coats are randomly arranged but in *Nasturtiopsis coronopifolia, Crucihimalaya kneuckeri, Nasturtium officinale, Malcolmia nana* and *Sisymbrium erysimoides* (figs.3. 3, 17, 33, 35, 40) are arranged in parallel rows. The cell shapes show significant variation between taxa of tribe Euclidieae: isodiametric in *Anastatica hierochuntica*, 4-polygonal in *Neslia paniculata*, polygonal to elongated in one direction in *Ochthodium aegyptiacum* and 5-6 gonal to elongated in one direction in *Schimpera arabic* (figs. 3. 7-10).

3. 4. 5. 2. Anticlinal cell wall boundaries

These are generally well developed. There are three types of cell wall boundaries: 1. Channelled, straight to sinuous; smooth or folded in *Arabis alpina* subsp. *caucasica, Anastatica hierochuntica, leptaleum filifolium, Ricotia lunaria, Neotorularia aculeolata, Sisymbrium erysimoides, S. polyceratum,* and *S. runcinatum* (figs. 3. 1, 7, 15, 19, 36, 40, 43, 44); 2. Raised-channelled, straight to sinuous; smooth to folded in *Neslia paniculata* and *Sisymbrium septulatum* (figs. 3. 8, 45); 3. Raised, straight to sinuous; smooth to folded in the rest of the taxa.

The anticlinal cell wall boundaries showed a great variation between species and subspecies, in the genus *Arabis*, they vary from channelled, straight to sinuous and smooth in *A. alpina* subsp. *caucasica* to raised, straight to sinuous and folded in *A. nova*. In the genus *Sisymbrium,* it varies from channelled, straight to sinuous and smooth to folded in *S. erysimoides, S. polyceratum* and *S. runcinatum*; raised, straight to sinuous and smooth to folded in *S. orientale;* slightly raised, straight and smooth in *S. irio,* to raised-channelled, straight to sinuous and smooth in *S. septulatum* (figs. 3. 40-45). In the genus *Neotorularia* it varies from channelled, sinuous and smooth in *N. aculeolata* to slightly raised, straight and smooth in *N. torulosa* (figs. 3. 37-38).

At subspecies level, this character separates between subspecies of *Eremobium aegyptiacum*, from slightly raised, straight and smooth in subsp. *aegyptiacum* and subsp. *lineare* to raised, straight to slightly sinuous and smooth to finely folded in subsp. *longisiliquum* (figs. 3. 11-13).

3. 4. 5. 3. Periclinal cell wall

3. 4. 5. 3. 1. Outer periclinal cell walls

The curvature of outer walls can serve as a good diagnostic character for the lowest taxonomic categories. There are 6 different shapes for outer periclinal cell wall: Domate, concave, convex, flat, flat to convex and flat to concave:

Shape 1. Domate is divided into three types A. Domate with flat or concave central portion in *Arabis alpina* subsp. *caucasus*, *Leptaleum filifolium* and *Sisymbrium erysimoides* (figs. 3. 1, 15, 40). B. Domate with globular central papillae in *Arabis nova, Erysimum repandum, Morettia parviflora, Olimarabidopsis pumila, Robeschia schimperi* and *Sisymbrium septulatum* (figs. 3. 2, 14, 30, 38, 39, 45). C. Domate with sunken central portion in *Neotorularia aculeolata* and *Sisymbrium runcinatum* (figs. 3. 36, 44).

Shape 2. Concave in *Neslia paniculata* (fig. 3. 8).

Shape 3. Convex in *Matthiola arabica, Morettia canescens, M. philaeana, Notoceras bicorne* and *Neotorularia torulosa* (figs. 3. 21, 29, 31, 32, 37).

Shape 4. Flat in *Nasturtium officinale* and *Matthiola longipetala* subsp. *longipetala* (figs. 3. 3, 27).

Shape 5. Flat to concave in *Rorippa indica, R. palustris, Ochthodium aegyptiacum, Eremobium aegyptiacum* subsp. *longisiliquum*, *Matthiola longipetala* subsp. *bicornis*, *Matthiola longipetala* subsp. *livida*, *Matthiola parviflora* and *Crucihimalaya kneuckeri* (figs. 3. 4, 6, 9, 13, 23, 26, 28, 33).

Shape 6 is divided into three types:A. Normal flat to convex in *Rorippa integrifolia, Schimpera arbica, Eremobium aegyptiacum* subsp. *aegyptiacum*, *Eremobium aegyptiacum* subsp. *lineare, Malcolmia nana, M. pygmaea, Ricotia lunaria, Matthiola fruticulosa, Matthiola longipetala* subsp. *hirta* and *Matthiola longipetala* subsp. *kralikii* (figs. 3. 5, 10, 11, 12, 17, 18, 19, 22, 24, 25). B. Flat to convex with flat or concave central portion in *Malcolmia africana* and *Sisymbrium irio* (figs. 3. 16, 41). C. Flat to convex with sunken central papillae in

Nasturtiopsis coronopifolia, Diceratella elliptica and *Anastatica hierochuntica* (figs. 3. 7, 20, 35).

3. 4. 5. 3. 2. Secondary cell wall sculpture

The surface of the outer cell wall show a great variation among taxa, it varies from radiate-striate in *Arabis nova, Erysimum repandum, Matthiola fruticulosa, Morettia parviflora, Notoceras bicorne* and *Sisymbrium erysimoides* (figs. 3. 2, 14, 22, 30, 32, 40); to striate in *Rorippa integrifolia, Leptaleum filifolium, Malcolmia nana* and *Robeschia schimperi* (figs. 3. 5, 15, 17, 39); micro-papillate in *Eremobium aegyptiacum* subsp. *lineare, Ricotia lunaria* and *Matthiola parviflora* (figs. 3. 12, 19, 28); micro-reticulate in *Rorippa indica*, *Ochthodium aegyptiacum, Schimpera arabica, Crucihimalaya kneuckeri, Sisymbrium irio* and *S. orientale* (figs. 3. 4, 9, 10, 33, 41, 42); macro-reticulate in *Nasturtium officinale* (fig. 3. 3); smooth in *Morettia canescens* to smooth to folded in the rest of the taxa.

Key to the studied taxa based on seed characters

1a Seeds orbicular, 3-8 x 2.5-7 mm .... **Ricotia lunaria**
1b Seeds suborbicular, ovoid, oblong or rounded, 0.6-2.2 x 0.3-1.5 mm................................**2**
2a Anticlinal boundaries channelled **3**
2b Anticlinal boundaries raised or raised-channelled...**9**
3a Seeds winged; periclinal cell wall domate with flat to concave central portion; folded to smooth...**Arabis alpina** subsp. **caucasica**
3b Seeds wingless; periclinal cell wall domate with sunken central portion or flat to convex; striate, radiate-striate, micro-reticulate or smooth to folded...**4**
4a Periclinal cell wall domate with sunken central portion... ……………………….....**Neotorularia aculeolata** & **Sisymbrium runcinatum**
4b Periclinal cell wall flat to convex or domate with flat to concave central portion **5**
5a Periclinal cell wall domate with flat to concave central portion **6**
5b Periclinal cell wall flat to convex **7**
6a Seeds oblong-ovoid; the sculpture of periclinal cell wall striate .... ……………………..……………………………………………….**Leptaleum filifolium**
6b Seeds oblong; the sculpture of periclinal cell wall radiate-striate ....**S. erysimoides**
7a Seeds ovoid; sculpture of periclinal cell wall smooth to folded……………………………. ....**Anastatica hierochuntica**
7b Seeds oblong-ellipsoidal or oblong; sculpture of periclinal cell wall micro-reticulate or smooth to folded...**8**
8a Seeds yellow-brownish; cell shapes isodiametric to 4-5 gonal ....**S. irio**

8b Seeds brown; cell shapes polygonal and elongate in one direction............ **S. polyceratum**
9a Anticlinal boundaries raised-channelled **10**
9b Anticlinal boundaries raised without channels..**12**
10a Periclinal cell wall concave; smooth to folded..**Neslia paniculata**
10b Periclinal cell wall domate or flat to slightly convex; smooth to folded or micro-reticulate**11**
11a Epidermal cell shapes isodiametric and polygonal; periclinal cell wall domate with globular central papillae; smooth to folded..**S. septulatum**
11b Epidermal cell shapes 5-6 gonal and elongate in one direction; periclinal cell wall flat to slightly convex; micro-reticulate...**Schimpera arabica**
12a Seeds winged...**13**
12b Seeds wingless **24**
13a Seeds with wide wings **14**
13b Seeds with narrow wings...**16**
14a Periclinal cell wall flat to slightly concave; folded ....
…...………………………………………..……**Matthiola longipetala** subsp. **bicornis**
14b Periclinal cell wall flat to convex; striate or smooth to micropapillate **15**
15a Sculpture of periclinal cell wall smooth to micropapillate; seeds red-brownish ....
…...……………………………………………**Eremobium aegyptiacum** subsp. **lineare**
15b Sculpture of periclinal cell wall striate; seeds brown ....**M. fruticulosa**
16a Periclinal cell wall flat...**17**
16b Periclinal cell wall convex, flat to concave or flat to convex **18**
17a Sculpture of periclinal cell wall macro-reticulate; seeds ovoid..
....**Nasturtium officinale**
17b Sculpture of periclinal cell wall smooth to fine folds; seeds oblong-ovoid..........................
....**M. longipetala** subsp. **longipetala**
18a Periclinal cell wall convex; smooth to fine folds .... **M. arabica**
18b Periclinal cell wall flat to convex or flat to concave **19**
19a Periclinal cell wall flat to convex **20**
19b Periclinal cell wall flat to concave **22**
20a Periclinal cell wall with sunken central papilla; seeds sub-orbicular to elliptic
....**Diceratella elliptica**
20b Periclinal cell wall with smooth to fine folds; seeds oblong, sub-orbicular or oblong-ovoid**21**
21a Seeds oblong, 2.2 x 1.2 mm ....E. **aegyptiacum** susp. **aegyptiacum**
21b Seeds sub-orbicular or oblong-ovoid; 1-1.3 x 0.7-1.1 mm..
…….. **M. longipetala** subsp. **hirta** & subsp. **kralikii**
22a Sculpture of periclinal cell wall smooth to micro-reticulate; seeds ovoid............................
.... **Rorippa indica**

22b Sculpture of periclinal cell wall smooth to folds or micro-papillate; seeds oblong or oblong-ovoid **23**

23a Sculpture of periclinal cell wall micro-papillate; seeds oblong-ovoid .... **Matthiola parviflora**

23b Sculpture of periclinal cell wall smooth to folds; seeds oblong .... **M. longipetala** subsp. **livida** & **E. aegyptiacum** subsp. **longisiliquum**

24a Periclinal cell wall convex **25**

24b Periclinal cell wall domate, flat to concave or flat to convex **28**

25a Sculpture of periclinal cell wall striate; seeds rounded .... **Notoceras bicorne**

25b Sculpture of periclinal cell wall smooth or smooth to fine folds; seeds ovoid or oblong-ellipsoidal **26**

26a Radicle incumbent; seeds oblong-ellipsoidal .... **N. torulosa**

26b Radicle accumbent; seeds ovoid **27**

27a Anticlinal boundaries folded .... **Morettia canescens**

27b Anticlinal boundaries smooth .... **M. philaeana**

28a Periclinal cell wall domate with globular central papilla **29**

28b periclinal cell wall flat to concave or flat to convex **33**

29a Sculpture of periclinal cell wall smooth .... **Olimarabidopsis pumila**

29b Sculpture of periclinal cell wall striate or radiate-striate **30**

30a Radicle incumbent; seeds oblong **31**

30b Radicle accumbent; seeds oblong-ovoid or ovoid **32**

31a Sculpture of periclinal cell wall radiate-striate; anticlinal boundaries smooth to finely folded .... **Erysimum repandum**

31b Sculpture of periclinal cell wall striate; anticlinal boundaries smooth to deeply folded .... **Robeschia schimperi**

32a Anticlinal boundaries folds; seeds oblong-ovoid .... **A. nova**

32b Anticlinal boundaries smooth; seeds ovoid .... **M. parviflora**

33a Periclinal cell wall flat to concave **34**

33b Periclinal cell wall flat to convex **36**

34a Radicle accumbent; seeds cordiform to ovoid .... **R. palustris**

34b Radicle incumbent; seeds ovoid-oblong or oblong **35**

35a Seeds ovoid-oblong, 2.5-3 x 1.5-1.7 mm; shapes of cell elongate in one direction and polygonal; anticlinal walls sinuous .... **Ochthodium aegyptiacum**

35b Seeds oblong, 0.8-1 x 0.3-0.4 mm; shapes of cell isodiametric and polygonal; anticlinal walls straight to slightly sinuous .... **Crucihimalaya kneuckeri**

36a Sculpture of periclinal cell wall striate, smooth to fine folds or micro-reticulate **37**

36b Sculpture of periclinal cell wall fine to coarse folds **40**

37a Sculpture of periclinal cell wall micro-reticulate .... **S. orientale**

37b Sculpture of periclinal cell wall striate or smooth to finely folded **38**

38a Sculpture of periclinal cell wall smooth to fine folds; seeds oblong; red-brownish.............
…………………………………………………………………….....**Descurainia sophia**

38b Sculpture of periclinal cell wall striate; seeds ovoid, oblong-ellipsoidal or ovoid to ellipsoid; orange-brown or yellow-brownish **39**

39a Radicle accumbent; seeds ovoid to ellipsoid.. **R. integrifolia**

39b Radicle incumbent; seeds ovoid or oblong-ellipsoidal... .**Malcolmia nana** & **M. pygmaea**

40a Sculpture of periclinal cell wall with flat central portion; cell shapes isodiametric and polygonal; seeds oblong.. **M. africana**

40b Sculpture of periclinal cell wall with sunken central papilla; cell shapes 5-6-polygonal and elongate in one direction; seeds oblong-ellipsoidal.......................................
. ... …..**Nasturtiopsis coronopifolia**

4.

POLLEN MORPHOLOGY OF SOME TRIBES OF BRASSICACEAE FROM EGYPT AND ITS SYSTEMATIC IMPLICATIONS

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ABSTRACT

Pollen morphology of 39 species belonging to 23 genera of tribes Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae of Brassicaceae from Egypt were studied by using scanning electron microscope. The pollen grains are tricolpate. Their shape varies from prolate spheroidal, subprolate to prolate. Three pollen types can be distinguished based on the size of the lumina. The exine sculpture of pollen grains varies between genera within tribes and between species within the same genus. The ornamentation of pollen was found useful to distinguish among closely related genera such as *Matthiola, Morettia* and *Diceratella* and among species in the same genus such as *Arabis, Morettia, Malcolmia* and *Neotorularia*. Our results suggest that tribes Sisymbrieae, Matthioleae, Hesperideae and Arabideae are heterogeneous because all three types of ornamentation are found among the genera of these tribes. However, the tribes Euclidieae and Lunarieae are homogeneous because we found only one type of ornamentation among the genera.

Keywords: Pollen grains; Brassicaceae; Ornamentation; SEM

4. 1. 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 centres 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 plant 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 (63 species belonging to 32 genera) have been the subject of an earlier study (El Naggar, 1987, 1992, 1993, El Naggar & El Hadidi, 1998). The remaining Brassicaeae, belonging to the tribes Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae (O.E. Schulz's system, 1936) 39 species in 23 genera exhibit great diversity. The members of these tribes are distributed over a wide range of habitats: weeds of farmland and waste places; desert subshrubs or herbs; Mediterranean coastal land; the Oases; mountains of Sinai and Elba; as well as inland and maritime salt marshes.

Taxonomically the Brassicaceae is a large and rather homogeneous family, and the problems of classification emerge at two levels: 1. On suprageneric level, the natural links within the family cause difficulties for the grouping of the genera into tribes and subtribes. 2. On infrageneric level, the taxonomic problems relate to the differentiation of the species within the group of closely related species especially in large genera (Anchev & Deneva, 1997). Pollen morphology data may be useful to solve these problems.

Brassicaceae is a stenopalynous family, the pollen grains are usually reticulate and tricolpate (Erdtman, 1972; Reille, 1992; El Ghazali, 1993).

Rollins and Banerjee (1979) examined the pollen grains of 227 species in 132 genera representing subfamilial groupings of the family Brassicaceae and found that the commonest pollen type is tricolpate but reported tetracolpate pollen in *Dithyrea californica* and 5,6,7,9 or 10 colpi within species of *Physaria, Lesquerella, Dimorphocarpa* and *Nerisyrenia*.

Erdtman (1972), Jonsell (1979) and Laham & El-Eisawi (1987) reported nonaperturate or slightly colpate pollen grains in a few *Matthiola* species.

Laham & Al-Eisawi (1987) studied 87 species of Brassicaceae and found that the majority of the pollen grains are tricolpate. Few species have inaperturate or weakly tricolpate or tetracolpate pollen while the exine sculpture of pollen grains is reticulate or finely reticulate.

Anchev & Deneva (1997) investigated 17 Brassicaceae species and classified these into two types; the first type is reticulate with lumina equal to or exceeding the muri in size, this type is found in all tribes; the second type has perforated reticulate sculpture with lumina equal in size or smaller than the muri; with an obtuse angular or almost round shape, and is found in *Erysimum, Alyssum* and *Brassica*.

The aim of the present work is to verify the pollen 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.

4. 2. MATERIALS AND METHODS

All investigations were carried out on unacetolysed pollen grains. All scanning electron microscopy (SEM) micrographs were made from pollen material obtained from accessions given in Table 4.1.

For scanning electron microscopy (SEM) observations, dried flowers or buds were taken. Pollen grains from mature anthers were mounted using a fine needle on aluminum stubs with double-sticky tape. Prepared stubs were sputter-coated with gold in two minutes (Balzersunion, Sputter-Anlage 07120). After coating the specimens were examined with a Jeol JSM 5200 Scanning Electron Microscope, at 15-25 KV. Measurements of pollen grains were taken from the SEM micrographs and are based on a sample size of 10 grains.

All photomicrographs were taken at the laboratory of Plant Cell Biology, Wageningen University, the Netherlands.

The terminology of pollen grains follows that by Punt et al. (1994).

4. 3. RESULTS

4. 3. 1. Size

The size of pollen grains varies considerably (Table 4.2). In the smallest (*Schimpera arabica*), the length of polar axis is 16 µm and the equatorial diameter 15 µm. In the largest (*Malcolmia pygmaea*), the length of polar axis is 37 µm and the equatorial diameter 21.5 µm.

4. 3. 2. Shape

The ratio between the mean polar axis (P) and the mean equatorial diameter (E) can be used to assign the pollen grains to shape classes as follows (Erdtman, 1943).

P/E 1 Spheroidal
P/E 1-1.14 Prolate spheroidal
P/E 1.14-1.33 Subprolate
P/E 1.33-2 Prolate
P/E > 2 Perprolate

In figure 1 mean polar axis is plotted against mean equatorial diameter for each species measured. Perfectly spheroidal grains would lie along the 45° line in figure 1, with prolate and perprolate grains below this line and prolate spheroidal and subprolate near the line.

In the investigated species there is no broad variation in pollen shapes. In tribes Arabideae, Lunarieae and Sisymbrieae the shape of pollen grains is prolate.

In the tribe Matthioleae, we can distinguish two shapes of pollen grains, subprolate in *Matthiola parviflora, (*Plate I, 5) and prolate in the rest of the taxa. In the genera of tribes Euclidieae and Hesperideae we can distinguish three shapes of pollen grains: prolate spheroidal in *Ochthodium aegyptiacum,* and *Schimpera arabica* (Plate III, 13-14); subprolate in *Anastatica hierochuntica* and *Erysimum repandum* and prolate in the rest of the taxa.

Table 4.1. List of specimens used in studies of pollen grains in Brassicaceae

Taxon	Collection No.	Place of collections
1. Tribe Arabideae		
1. *Arabis alpina* L. sub sp. *caucasica* (Willd.) Briq.	1115	Ethiopia, prov. Begemder, Semien Mts (WAG)
2. *Arabis nova* Vill.	s.n.	Egypt, S. Sinai, Gebel Musa (CAI)
3. *Nasturtium officinale* R.BR.	764	Egypt, Abu Atwa, S. Ismailia (CAI)
4. *Rorippa indica* (L.) Hiern	s.n.	Egypt, Qena, El Mahrosa island (SHG)
5. *Rorippa integrifolia* Boulos	9	Egypt, middle of Sinai, about 5 km before Ras Sedr (SHG)
6. *Rorippa palustris* (L.) Besser	20	Egypt, along the canal of Ismailiya (SHG)
2. Tribe Euclidieae		
7. *Anastatica hierochuntica* L.	327	Egypt, Cairo-Suez road, km 95 from Cairo (CAI)
8. *Neslia paniculata* (L.) Desv.	158	Egypt, Sinai mountains (BM)
9. *Ochthodium aegyptiacum* (L.) DC.	s.n.	Egypt, without location (L)
10. *Schimpera arabica* Hochst. & Steud.	34	Egypt, Sinai, Wadi Sidr (B)
3. Tribe Hesperideae		
11. *Eremobium aegyptiacum* (Spreng.) Asch. & Schweinf. subsp. *aegyptiacum*	29	Egypt, El Arish area beside the Airport, N. Sinai (SHG)
12. *Erysimum repandum* L.	s.n.	Egypt, between Fuka and Matruh (CAI)
13. *Leptaleum filifolium* (Willd.) DC.	s.n.	Egypt, Wadi Chafura, north Galala (BR)
14. *Malcolmia africana* (L.) R.Br.	2	Egypt, Deir el Rahba, Wadi el Arbain, S. Sinai (SHG)
15. *Malcolmia. nana* (DC.) Boiss.	28	Egypt, El Arish-Rafah road, 23 km from El Arish (SHG)
16. *Malcolmia pygmaea* (Del.) Boiss.	22	Egypt, 26 km, Sidi Krer, Alex.-Matruh coastal road (SHG)
4.Tribe Lunarieae		
17. *Ricotia lunaria* (L.) DC.	s.n.	Egypt, without location (BR)
5. Tribe Matthioleae		
18. *Diceratella eliptica* (DC.) Jonsell	17	Egypt, Gebel Elba, Wadi el Shallal (SHG)
19. *Matthiola arabica* Boiss.	12	Egypt, Wadi el Arbaien, S. Sinai (SHG)
20. *Matthiola fruticulosa* (L.) Maire	34	Egypt, Alexandria (K)
21. *Matthiola longipetala* (Vent.) DC. subsp. *longipetala*	25	Egypt, 28 km before Matruh, Alexandria-Matruh road (SHG)
22. *Matthiola parviflora* (Schousboe) R.Br.	s.n.	Egypt, Wadi Natroun (CAI)
23. *Morettia canescens* Boiss.	10	Egypt, Wadi Feiran, S. Sinai (SHG)
24. *Morettia parviflora* Boiss.	16984/2	Saudi Arabia, Wadi Harjab, rocky hillsides (BR)
25. *Morettia philaeana* (Delile) DC.	3	Egypt, 35 km from Qena at the road Qena-Safaga (SHG)
26. *Notoceras bicorne* (Ait.) Caruel	1052	Egypt, Gebel Elba, Saddle between Gebel Astriba and Makin (CAI)
6. Tribe Sisymbrieae		
27. *Crucihimalaya kneuckeri* (Bornm.) Al-Shehbaz, O'Kane & Price	49785	Egypt, Sinai, E slopes of Gebel Catherine (CAI)

Table 4.1. continued

28. *Descurainia sophia* (L.) Webb & Berth.	1475	Jordan, El-Jubeiha, University campus (B)
29. *Nasturtiopsis coronopifolia* (Desf.) Boiss.	s.n.	Egypt, Burg el-Arab (CAI)
30. *Neotorularia aculeolata* (Boiss.) Hedge & Léonard	5801	Iran, West of Jaz Murian (BR)
31. *Neotorularia torulosa* (Desf.) Hedge & Léonard	4662	Egypt, Dabaa (BM)
32. *Olimarabidopsis pumila* (Stephan) Al-Shehbaz, O'Kane & Price	171	Egypt, mountain of St. Catherine (B)
33. *Robeschia schimperi* (Boiss.) Schulz	170	Egypt, Mountains Sinai, between granitic rocks (B)
34. *Sisymbrium erysimoides* Desf.	19	Egypt, Gebel Elba, Wadi Drawina (SHG)
35. *Sisymbrium irio* L.	31	Egypt, S. Sinai, Deir el-Rahebat, Wadi Feiran, as weed in garden (SHG)
36. *Sisymbrium orientale* L.	11	Egypt, S. Sinai, Deir Feiran, Wadi Feiran (SHG)
37. *Sisymbrium polyceratum* L.	585	France, Asco, island of Corsica (WAG)
38. *Sisymbrium runcinatum* Lag. Ex DC.	2095	Spain, near Madrid (WAG)
39. *Sisymbrium septulatum* DC.	122	Egypt, mountains Sinai (L)

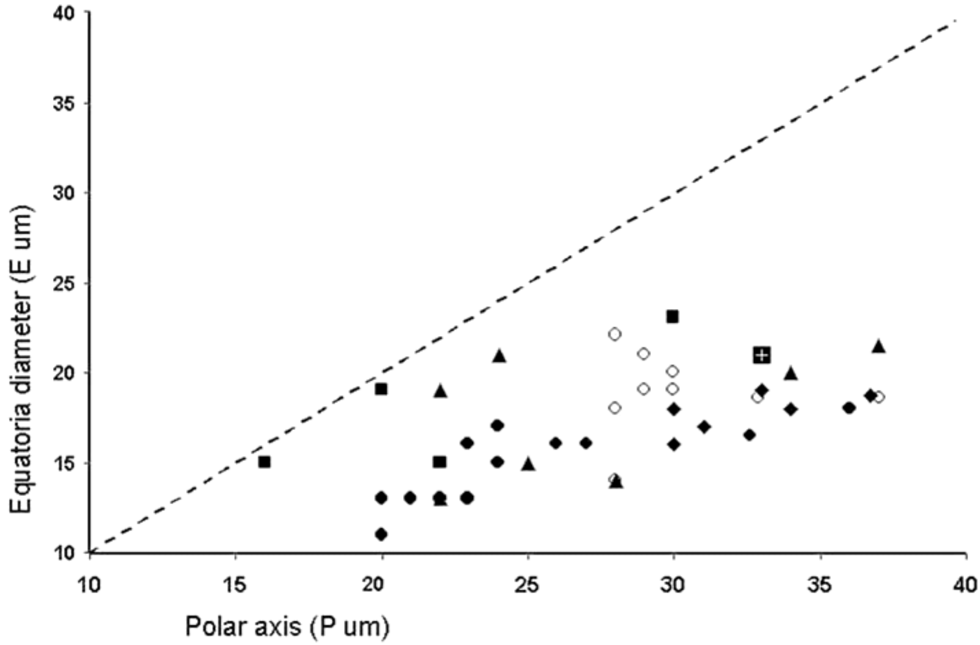


Fig. 4a. Pollen size-shape ◆ Arabideae ■ Euclidieae ▲ Hesperideae ⊞ Lunarieae ○ Matthioleae ● Sisymbrieae

Table 4.2. Pollen morphological data of Brassicaceae: Polar axis (P); Equatorial diameter (E); the ratio between the Polar and Equatorial (P/E); Pollen shape (Ps); Lumina size (L. ca.); Ornamentation types: Microreticulate (I); Reticulate (II); Coarsely reticulate (III).

Taxon	Polar axis (P µm)		Equatorial axis (E µm)		P/E µm	pollen shape	Lumina ca. (µm)		Ornamentation type
	Range	Mean	Range	Mean			Range	Mean	
1. Tribe Arabideae									
Arabis alpina sub sp. *caucasica*	(31-35)	33	(17-21)	19	1,74	Prolate	(1.2-2)	1,6	II
Arabis *nova*	(33-35)	34	(17-19)	18	1,9	Prolate	(2.7-3.2)	3,1	III
Nasturtium officinale	(27-33)	30	(16-20)	18	1,7	Prolate	(0.8-1.4)	1,1	II
Rorippa indica	(28-32)	30	(15-17)	16	1,88	Prolate	(0.9-1.3)	1,2	II
Rorippa integrifolia	(33-38)	36,7	(17-19)	18,7	1,96	Prolate	(1-1.6)	1,3	II
Rorippa palustris	(28-32)	31	(15-19)	17	1,8	Prolate	(1.2-1.6)	1,4	II
2. Tribe Euclidieae									
Anastatica hierochuntica	(25-34)	30	(21-26)	23	1,3	Subprolate	(1.2-2)	1,68	II
Neslia paniculata	(20-25)	22	(13-17)	15	1,47	Prolate	(0.7-1.5)	1,1	II
Ochthodium aegyptiacum	(18-25)	20	(18-19)	19	1,05	Prolate spheroidal	0.8-1.5	1,1	II
Schimpera arabica	(14-17)	16	(15-16)	15	1,07	Prolate spheroidal	0.8-1.6	1,23	II
3. Tribe Hesperideae									
Eremobium aegyptiacum subsp. *aegyptiacum*	(20-24)	22	(11-15)	13	1,69	Prolate	(0.7-1.5)	1,11	II
Erysimum repandum	(20-25)	22	(18-20)	19	1,16	Subprolate	(0.7-1.3)	0,98	I
Leptaleum filifolium	(21-27)	25	(13-15)	15	1,66	Prolate	(0.8-1.3)	1,1	II
Malcolmia africana	(26-31)	28	(12.-15)	14	2	Prolate	(1.5-2.5)	1,9	II
Malcolmia nana	(32-35)	34	(17-20)	20	1,7	Prolate	(1-1.5)	1,23	II
Malcolmia pygmaea	(33-40)	37	(19-23)	21,5	1,72	Prolate	(2.6-4)	3	III
4.Tribe Lunarieae									
Ricotia lunaria	(29-37)	33	(20-23)	21	1,57	Prolate	(2.7-4.2)	3,3	III

Table 4.2. continued

5. Tribe Matthioleae									
Diceratella eliptica	(30-34)	32,9	(16-19)	18,55	1,77	Prolate	(1-1.5)	1,35	II
Matthiola arabica	(25-30)	29	(17-20)	19	1,53	Prolate	(2.7-4.5)	3,4	III
Matthiola fruticulosa	(27-32)	30	(18-21)	20	1,5	Prolate	(2.5-4.5)	3,5	III
Matthiola longipetala subsp. *longipetala*	(28-30)	29	(20-22)	21	1,38	Prolate	(2.2-2.7)	2,4	III
Matthiola *parviflora*	(24-30)	28	(20-23)	22	1,27	Subprolate	(3.5-4.5)	3,9	III
Morettia canescens	(32-38)	37	(18-20)	18,6	1,99	Prolate	(1.3-2.5)	1,78	II
Morettia parviflora	(25-30)	28	(12.-15)	14	2	Prolate	(0.7-1)	0,8	I
Morettia philaeana	(29-33)	30	(18-23)	19	1,58	Prolate	(0.8-1.4)	1,1	II
Notoceras bicorne	(23-30)	28	(16-19)	18	1,55	Prolate	(0.7-1.5)	1,3	II
6. Tribe Sisymbrieae									
Crucihimalaya kneuckeri	(19-21)	20	(10-12.)	11	1,8	Prolate	(0.5-0.8)	0,59	I
Descurainia sophia	(19-21)	21	(11-14)	13	1,6	Prolate	(0.3-0.6)	0,37	I
Nasturtiopsis coronopifolia	(21-25)	24	(19-22)	21	1,14	Prolate spheroidal	(1.2-2.2)	1,71	II
Neotorularia aculeolata	(19-21.5)	20	(12-14)	13	1,54	Prolate	(0.8-1.2)	1,1	II
Neotorularia torulosa	(22-25)	23	(12-15)	13	1,77	Prolate	(0.5-1)	0,72	I
Olimarabidopsis pumila	(21-25)	22	(12-14)	13	1,69	Prolate	(0.5-1)	0,76	I
Robeschia schimperi	(23-28)	27	(14-17)	16	1,68	Prolate	(0.4-0.8)	0,59	I
Sisymbrium erysimoides	(33-37)	36	(16-19)	18	2	Prolate	(1-1.7)	1,3	II
Sisymbrium irio	(30-33)	32,6	(15-17)	16,5	1,98	Prolate	(1-1.3)	1,2	II
Sisymbrium orientale	(23-27)	24	(14-16)	15	1,6	Prolate	(1.1-2)	1,58	II
Sisymbrium polyceratum	(21-24)	23	(15-16)	16	1,44	Prolate	(1.1-1.8)	1,38	II
Sisymbrium runcinatum	(22-27)	26	(15-18)	16	1,6	Prolate	(1.3-2)	1,45	II
Sisymbrium septulatum	(23-27)	24	(15-18)	17	1,4	Prolate	(1-1.5)	1,3	II

4. 3. 3. Apertures

Pollen grains of all members of Brassicaceae are normally tricolpate. The colpi are usually widest at the equator and gradually narrowing towards the poles. The pollen grains are weakly aperturate in *Matthiola arabica* (Plate IV, 19).

4. 3. 4. Surface ornamentation

The basic ornamentation of the Brassicaceae pollen is reticulate with muri simplibaculate, straight or slightly sinuous. The largest lumina are at or near the equator and the size is gradually smaller towards each pole except in a few taxa. Lumina vary from 4-6 gonal, polygonal to irregular in shape.

Based on variation in diameter of the lumina, there are three different types of exine ornamentation

Type I (Plate VII, 40)

Exine is microreticulate, with lumina less than 1 µm in diameter. This type is present in *Erysimum repandum, Morettia parviflora, Crucihimalaya kneuckeri, Descurainia sophia, Neotorularia torulosa, Olimarabidopsis pumila and Robeschia schimperi* (Plate II, 12; IV, 24; V, 27-28; VI, 31-33). The lumina diameter is between 0.37-0.98 µm (table 1).

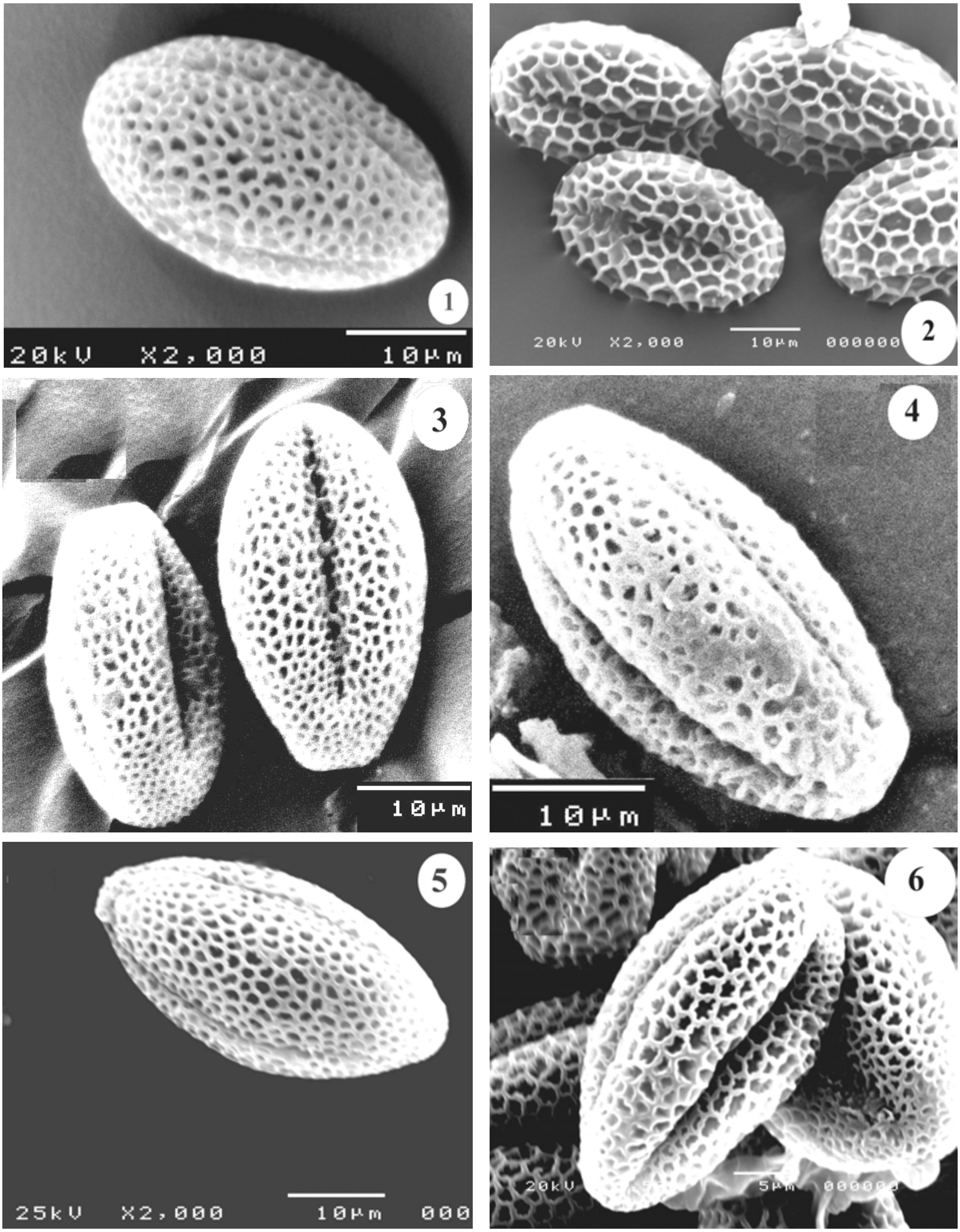
Type II (Plate VII, 41)

Exine is reticulate, with lumina between 1-2 µm in diameter. This type is present in all genera of the tribe Euclidieae and most genera of tribes Arabideae, Hesperideae, Matthioleae and Sisymbrieae but it is absent in the tribe Lunarieae, (plate I, 1, 3-6; II, 7-11; III, 13-15, 18; IV, 23; V, 25-26, 29-30; VI, 34-36; VII, 37-39). The lumina diameter is between 1.1-1.9 µm (table 1)

Type III (Plate VII, 42)

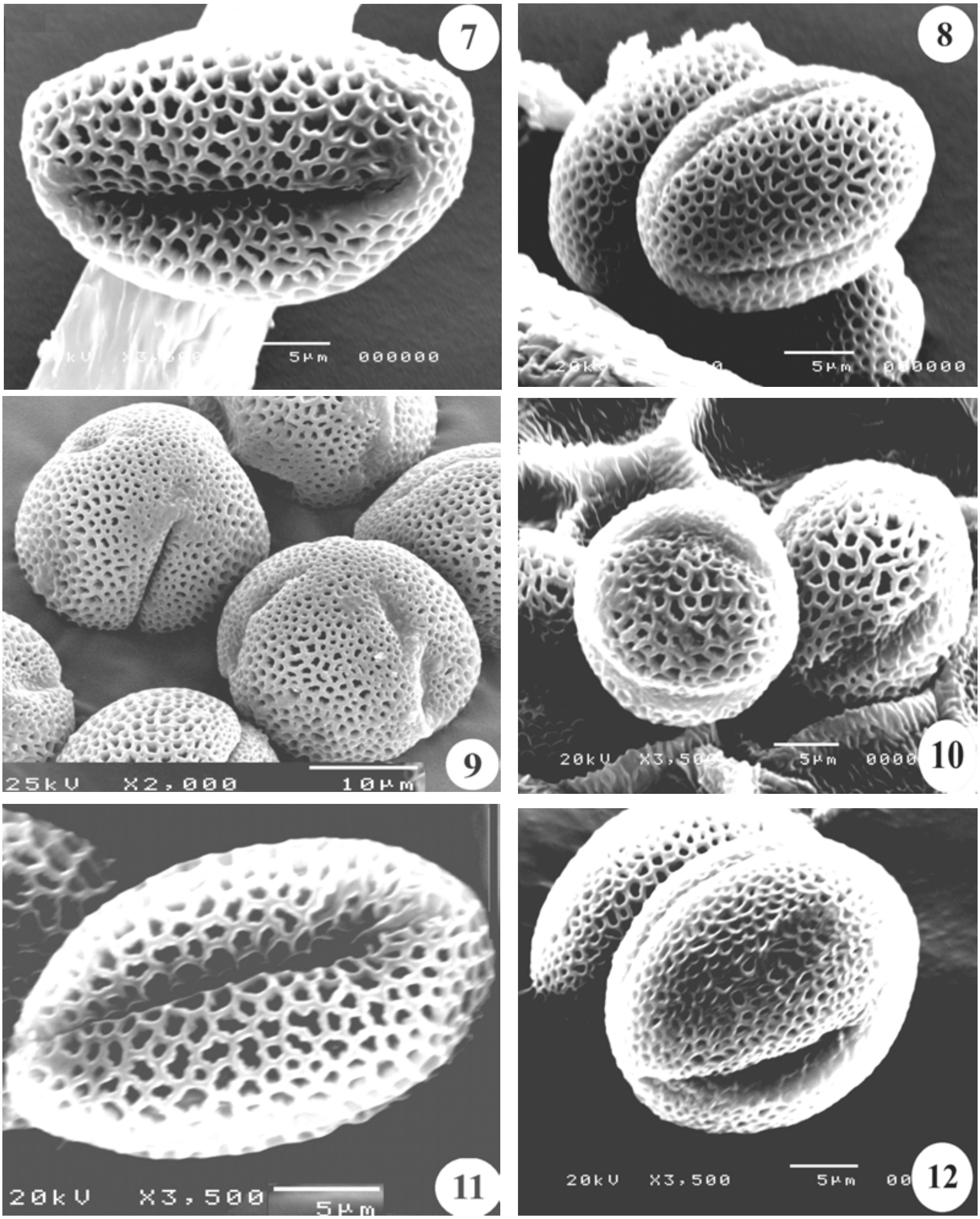
Exine is coarsely reticulate, with lumina more than 2 µm in diameter. This type is present only in *Arabis nova, Ricotia lunaria, Malcolmia pygmaea* and species of *Matthiola* (plate I, 2; III, 16-17; IV, 19-22). The lumina diameter is between 2.4-3.9 µm (table 1).

Plate I



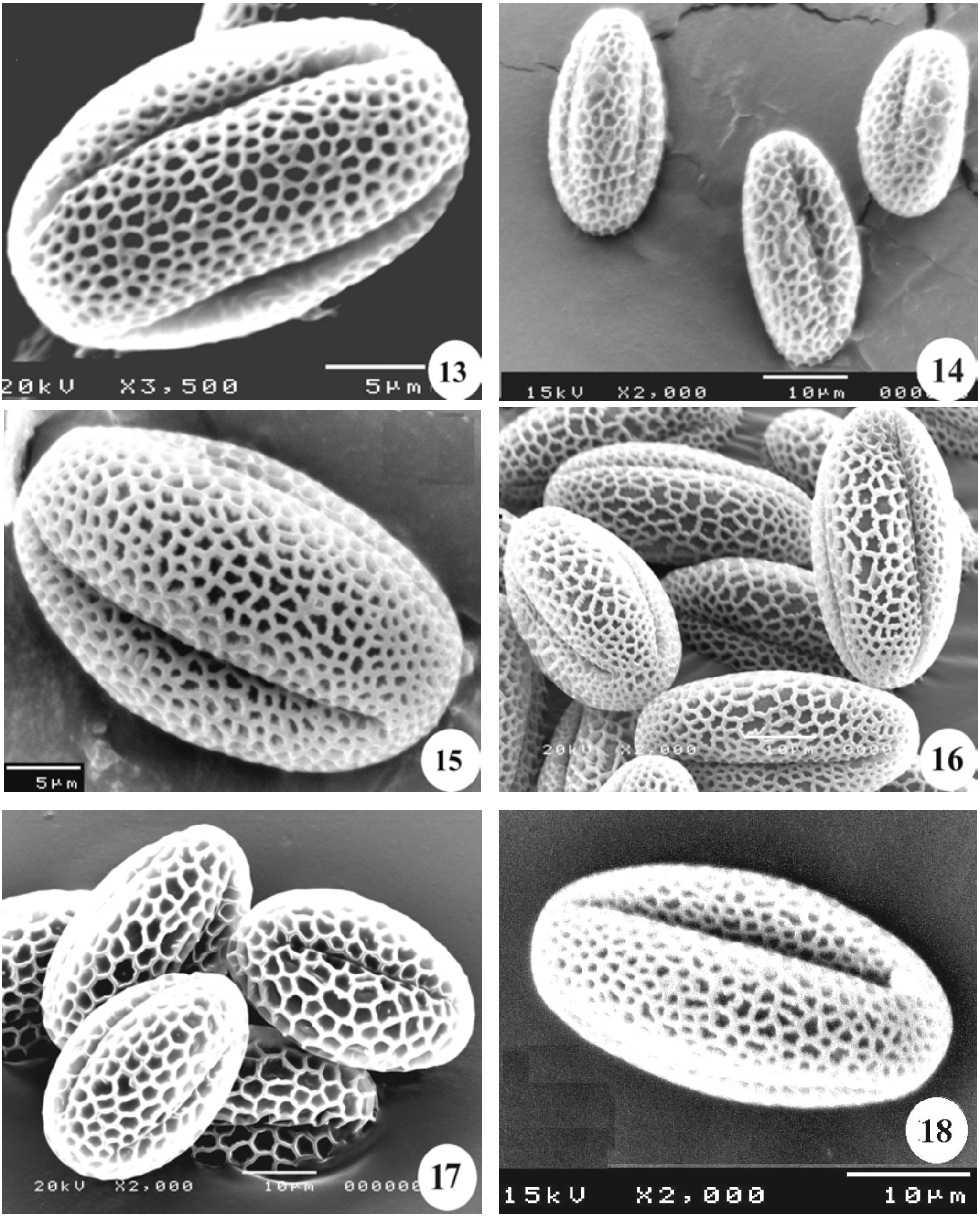
Figs. 4.1-6. SEM photographs of pollen grains. **1**. *Arabis alpina.* **2**. *Arabis nova.* **3**. *Nasturtium officinale.* **4**. *Rorippa indica.* **5**. *Rorippa integrifolia.* **6**. *Rorippa palustris.*

Plate II



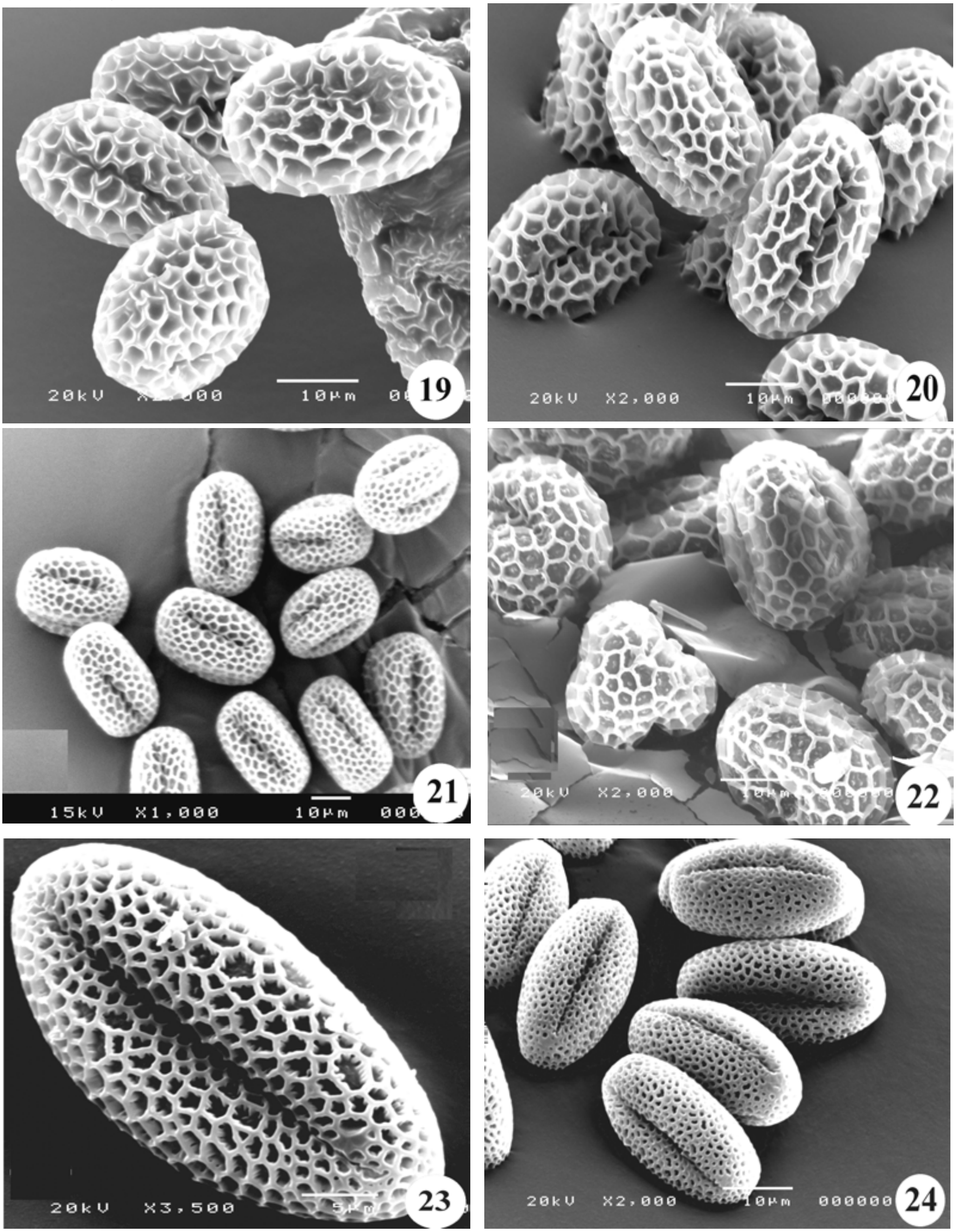
Figs. 4.7-12. SEM photographs of pollen grains. **7**. *Anastatica hierochuntica.* **8**. *Neslia paniculata.* **9**. *Ochthodium aegyptiacum.* **10**. *Schimpera arabica.* **11**. *Eremobium aegyptiacum.* **12**. *Erysimum repandum.*

Plate III



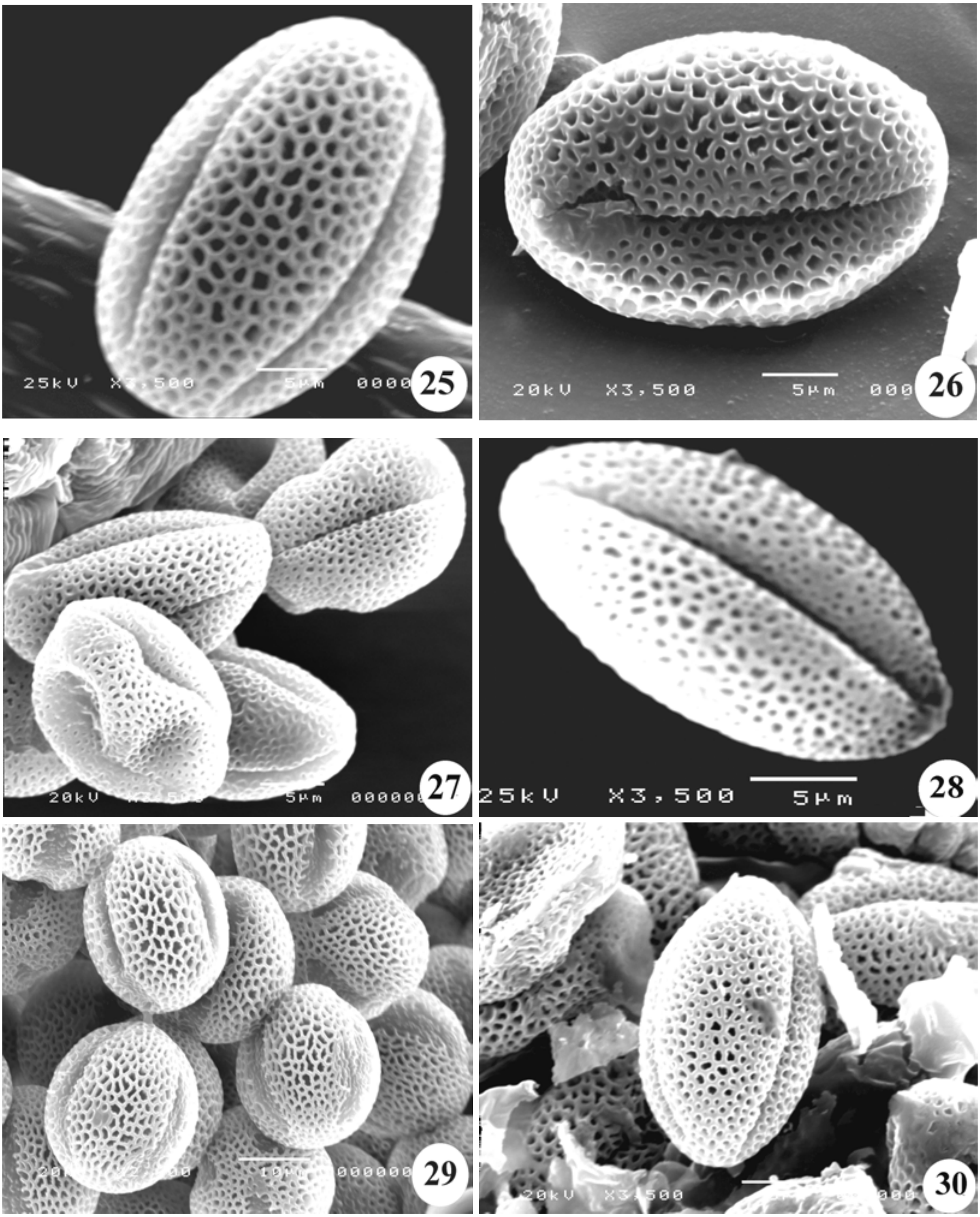
Figs. 4. 13-18. SEM photographs of pollen grains. **13**. *Leptaleum filifolium.* **14**. *Malcolmia africana.* **15**. *Malcolmia nana.* **16**. *Malcolmia pygmaea.* **17**. *Ricotia lunaria* **18**. *Diceratella elliptica.*

Plate IV



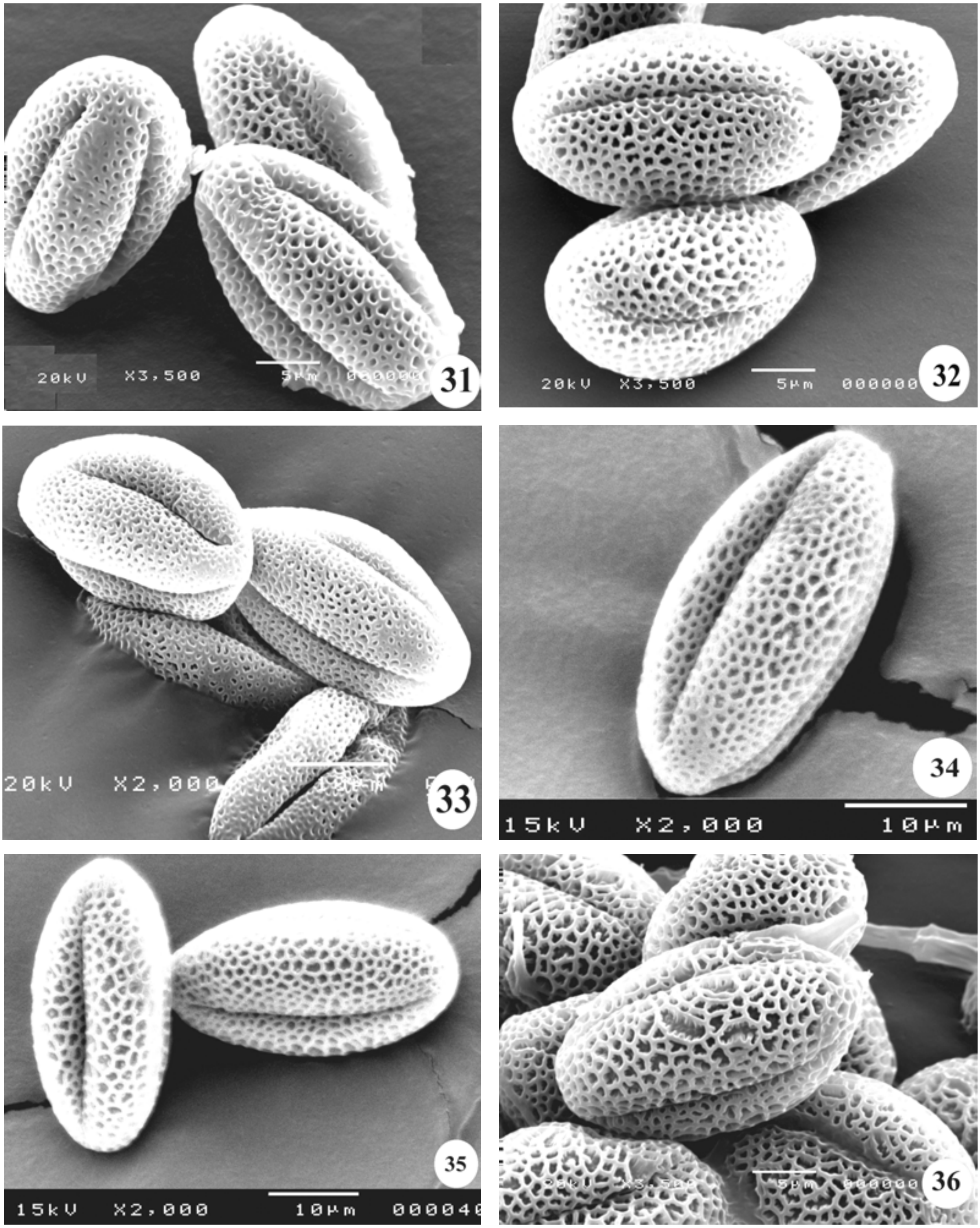
Figs. 4. 19-24. SEM photographs of pollen grains. **19**. *Matthiola arabica.* **20**. *Matthiola fruticulosa.* **21**. *Matthiola longipetala.* **22**. *Matthiola parviflora*. **23**. *Morettia canescens*. **24**. *Morettia parviflora.*

PlateV



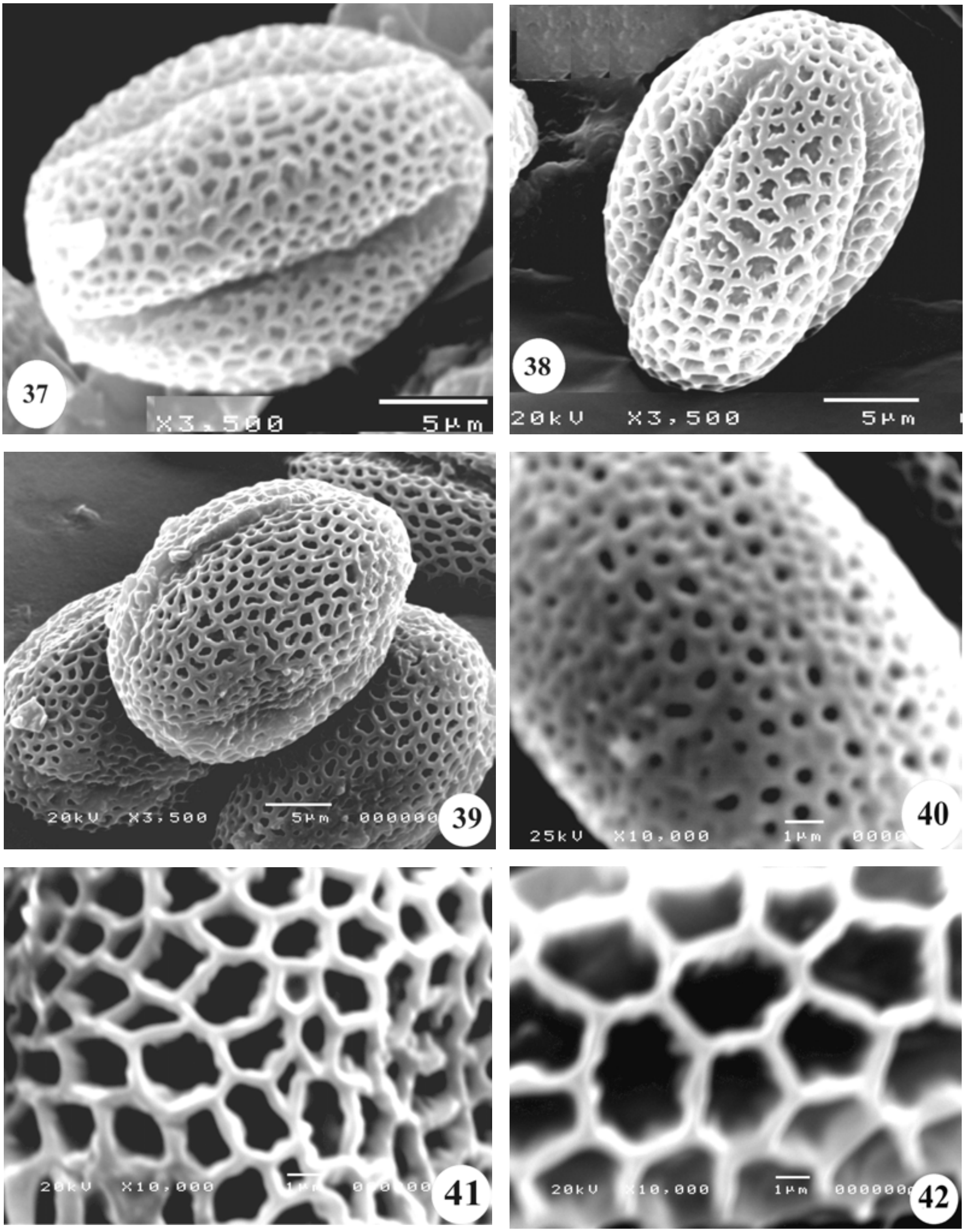
Figs. 4.25-30. SEM photographs of pollen grains. **25**. *M. philaeana.* **26**. *Notoceras bicorne.* **27**. *Crucihimalaya kneuckeri.* **28**. *Descurainia sophia.* **29**. *Nasturtiopsis coronopifolia.* **30**. *Neotorularia aculeolata.*

Plate VI



Figs. 4.31-36. SEM photographs of pollen grains. **31**. *Neotorularia torulosa.* **32**. *Olimarabidopsis pumila.* **33**. *Robeschia schimperi.* **34**. *Sisymbrium erysimoides.* **35**. *S. irio.* **36.** *Sisymbrium orientale.*

Plate VII



Figs. 4.37-42. SEM photographs of pollen grains. **37**. Sisymbrium polyceratum. **38**. Sisymbrium *runcinatum.* **39**. Sisymbrium *septulatum.* **40**. Type I. Microreticulate. **41**. Type II. Reticulate. **42**. Type III. Coarsely reticulate.

4. 4. DISCUSSION

This study confirms minor differences in pollen size, shape, apertures as well as significant variation in exine ornamentation in the pollen grains of the Brassicaceae.

The most common shape is prolate, and this type is present in genera of all tribes. A few crucifer grains are subprolate or prolate spheroidal. These results are congruent with the results of pollen shape of Lahham & Al-Eisawi, 1987 (prolate and subspheroidal); Anchev & Deneva, 1997 (prolate spheroidal, subprolate, prolate) and Rollins & Banerjee, 1979 (subprolate, prolate, spherical).

The shape of pollen grains varies more or less between genera within tribes but very rarely between species within the same genus.

All investigated taxa are tricolpate. However, in *Matthiola arabica* the colpi are less clear but also tricolpate. Minor variation in apertures has been reported in *Matthiola* species. Erdtman (1972), Rollins & Banerjee (1979), Jonsell (1979) and Lahham & Al-Eisawi (1987) reported non aperturate or slightly colpate pollen grains in a few *Matthiola* species. This variation together with other pollen characters is useful in distinguishing between closely related taxa such as *Matthiola, Morettia* and *Diceratella.* In *Morettia* and *Diceratella* the colpi are elongated nearly to the poles, but in *Matthiola* the colpi are weakly aperturate and not strongly formed. Lahham & Al-Eisawi (1987) indicate that *Ricotia lunaria*, *Matthiola longipetala*, *M. parviflora*, *M. livida*, *Anastatica hierochuntica* and *Neslia apiculata* are inaperturate, but we have seen only tricolpate grains in our samples of these taxa and we believe that their pollen samples may have been immature.

Exine ornamentation of pollen grains plays a significant role within the Brassicaceae. The exines vary mostly among genera within tribes and among species within the same genus.

Rollins & Banerjee (1979) indicated that the surface of crucifer pollen is reticulate and reported a strong reticular pattern of the muri with relatively large lumina in *Matthiola* and *Ricotia*. They also reported that the surface of *Heliophila* (tribe Heliophileae) is sparsely spinulose and very finely punctate with some scattered small holes and pits.

Anchev & Deneva (1997) indicated two types: The first type is reticulate with lumina equal to or exceeding the muri in size, this type is found in all tribes; the second type has perforated reticulate sculpture with lumina equal in size or smaller than the muri and this type is present in *Erysimum*.

Our results indicate that it is possible to distinguish three types. In the tribe Arabideae, exine ornamentation varies from coarsely reticulate (type III) in *Arabis nova* to reticulate (type II) in the rest of the species; the lumina are largest at the mesocolpium and decreasing in size towards the poles and the colpi but in *Arabis nova* the lumina are uniform in size. The size of lumina was found useful to distinguish between the species of *Arabis*. In *Arabis alpina* the lumina size is type II but in *A. nova* the lumina size is type III.

In the tribe Euclidieae, the exine ornamentation is represented only by type II; lumina with largest size in the mesocolpium and decreasing in size towards the poles and the colpi.

In the tribe Lunarieae, the exine ornamentation is coarsely reticulate (type III); lumina are uniform in size.

In the tribes Hesperideae and Matthioleae, there are three types of exine ornamentation. Type I is present in *Erysimum repandum* and *Morettia parviflora*; type III in *Malcolmia pygmaea, Matthiola arabica, M. fruticulosa, M. longipetala* and *M. parviflora*; type II in the rest of the genera; lumina with largest size in the mesocolpium and decreasing in size towards the poles and the colpi except in *Matthiola* species. The size of lumina was found useful to differentiate between different genera in tribe Matthioleae such as *Morettia, Matthiola* and *Diceratella*, it varies from coarsely reticulate in *Matthiola*, reticulate in *Diceratella* to microreticulate or reticulate in *Morettia*. The size of lumina was found useful also to distinguish between species within the same genus. In *Malcolmia,* the size varies from coarsely reticulate in *Malcolmia pygmaea* to reticulate in *M. africana* and *M. nana.* In *Morettia,* also the size of lumina varies from microreticulate in *M. parviflora* to reticulate in *M. canescens* and *M. philaeana.*

In the Sisymbrieae, types I & II occur. Type I is present in *Crucihimalaya kneuckeri, Descurainia sophia, Neotorularia torulosa, Olimarabidopsis pumila* and *Robeschia schimperi* while type II is present in *Neotorularia aculeolata* and species of *Sisymbrium*; lumina are decreasing in size from the equatorial area of mesocolpium towards the poles and the colpi. In *Neotorularia* the size of lumina varies from microreticulate in *N. torulosa* to reticulate in *N. aculeolata*.

The ornamentation types of pollen grains 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. Three tribes (Arabideae, Sisymbrieae and Hesperideae) that are the same as the tribes studied by us prove to be not monophyletic. This result agrees with our results based on the exine ornamentation types. This result agrees with our results that tribes show variation in the exine sculpture types. Their results show Brassiceae to be monophyletic. We did not study representatives of this tribe but El Naggar (1987) reported that all the species of this tribe are tricolpate and have the exine is reticulate; the lumina and muri size vary and provide a character of limited taxonomic value. Variation in pollen morphological type seems to be a good indication whether a tribe is natural or not. Based on our morphological results (Abdel Khalik et al. 2001 unpublished) their are congruence with pollen morphology and we would expect Euclidieae and Lunarieae to show up as monophyletic in a molecular investigation.

4. 5. CONCLUSIONS

Pollen grains of 39 species belonging to 6 tribes from the Brassicaceae were studied. The shape of pollen varies from prolate spheroidal, subprolate to prolate. The shape of pollen grains varies both among the genera but very rarely among the species within the same genus.

According to the number and position of apertures, the pollen grains belong to the trizonocolpate (weakly aperturate in *Matthiola arabica*), and have a reticulate exine ornamentation. Based on the lumina size, three different types were established.

Generally, these results indicate that Sisymbrieae, Matthioleae, Hesperideae and Arabideae are heterogeneous tribes because all three types of exine ornamentation are presented in all tribes. However, Euclidieae and Lunarieae are homogeneous because we found only one type of exine ornamentation among the genera of these tribes. These results agree with the results of Abdel Khalik et al. (2002, chapter 5) based on morphological data; Koch et al. (2001) based on morphological and molecular (Chs-and matK) data.

Exine ornamentation was found useful to differentiate among closely related genera such as *Matthiola, Morettia* and *Diceratella* and among species of *Arabis*, *Malcolmia, Morettia* and *Neotorularia*.

5.

NUMERICAL TAXONOMIC STUDY OF SOME TRIBES OF BRASSICACEAE FROM EGYPT

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ABSTRACT

A systematic study of 45 taxa belonging to 23 genera of tribes Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae of Brassicaceae from Egypt was conducted by means of numerical analysis based on sixty two morphological characters, including vegetative parts, pollen grains and seeds. On the basis of UPGMA clustering and PCO analysis, four main groups are recognised: Lunarieae, Euclidieae, Matthioleae and a mixed group. Representatives of these groups cluster together based on characters with high factor loading in the PCO analysis. The tribe Euclidieae is the most homogeneous group, and the tribe Arabideae is the most heterogeneous.

Key words: Brassicaceae, Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae, Sisymbrieae, Numerical taxonomy, Morphology, UPGMA cluster, PCO.

5. 1. 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 centres of distribution of the family are in the Irano-Turanian, Mediterranean, and Saharo-Sindian regions (Hedge, 1976).

Bentham & Hooker (1862) recognized 10 tribes based on fruit length and cotyledon / radicle characters. Prantl (1891) in the Pflanzenfamilien used the indumentum characters and recognized four tribes. Hayek (1911) used nectar glands and myrosin cells and recognized 10 tribes.

Schulz (1936) contributed enormously to our knowledge of the Brassicaceae on a world basis. He recognized 360 genera throughout the world and assigned these genera to 19 tribes depending on a number of characters, such as nectar glands, fruit septum, position of cotyledons relative to the radicle, fruit-length, and indumentum.

Janchen (1942) reduced the total number of Schulz's tribes from 19 to 15. He united Schulz's tribes Hesperideae and Matthioleae under Hesperideae because he did not consider the differences of incumbent (Hesperideae) versus accumbent (Matthioleae) radicles of sufficient importance to separate tribes. He also united Schulz's tribes Alysseae, Lunarieae and Drabeae under Alysseae, because he did not believe that the details of cell structure in the septum were adequate for recognition of 3 independent tribes, and also transferred some genera from tribes into new tribes.

Avetisian (1976, 1983) reduced Schulz's tribes to three tribes: Thelypodieae, Brassiceae and Sisymbrieae. Clemente & Hernandez-Bermejo (1980a, 1980b and 1980c) studied 145 taxa, belonging to 41 genera of the tribe Brassiceae growing in the Mediteranean region, based on characters of calyx, corolla and nectaries and divided this tribe into 7 groups.

Al-Shehbaz (1984) classified the family Brassicaceae of the southeastern United States into 7 tribes based on the morphological characters of fruit, sepals, stamens and the position of cotyledons relative to the radicle.

Taxonomically the Brassicaceae is a large and rather homogeneous family, and the problems of classification emerge at two levels: 1. On suprageneric level, the natural links within the family cause difficulties for the grouping of the genera into tribes and subtribes. 2. On infrageneric level, the taxonomic problems relate to the differentiation of the species within the group of closely related species especially in large genera (Anchev & Deneva, 1997).

In the flora of Egypt, Brassicaceae are one of the four largest plant families, represented by about 102 species belonging to 55 genera, assigned to 9 tribes (O.E. Schulz's system) (El Hadidi et al., 1988). Boulos (1999) treated 104 species belonging to 53 genera. Species of the tribes Lepideae, Brassiceae and Alysseae (63 species belonging to 32 genera) have been the subject of earlier studies (El Naggar, 1987, 1992, 1993; El Naggar & El Hadidi 1998). The remaining Brassicaeae, belonging to the tribes Arabideae, Euclideae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae (O.E. Schulz's system, 1936) count 39 species in 23 genera exhibiting great diversity. The members of these tribes are distributed over a wide range of habitats: weeds of farmland and waste places; desert subshrubs or herbs; they occur in Mediterranean coastal land; the oases; the mountains of Sinai and Elba; as well as inland and in maritime salt marshes.

The tribal classification of the Brassicaceae is problematic because the characters traditionally used at this rank are few in a number, usually only one or two morphological characters. These are variable even within genera, or they conflict with one another in their distribution patterns among genera and tribes and may not support natural groups.

The purpose of this study is to use numerical taxonomy to understand better the phenetic relationships between genera within tribe and tribes within the family. This study is based on a large number of characters (62) of vegetative parts, pollen grains and seeds, and uses UPGMA clustering and PCO analysis.

5. 2. MATERIALS AND METHODS

5.2.1. Plant material

The present study is largely based on herbarium material received on loan from B, BM, BR, E, K, KSU, L, LY, NMGM, OXF & FHO and W, and collections kept in the following herbaria; B, CAI, CAIM, WAG and Sohag University Herbarium (SHG, proposed abbreviation). In addition, fresh material of most of the taxa was studied, and field observations were made from

several localities of the Mediterranean region, and the Western desert, Eastern desert, Nile valley, Mountains of Sinai and Elba in Egypt.
In the analyses, species or subspecies constituted the OTU (Operational Taxonomic Unit), see table 5.1.
In order to broadly sample the variation, the OTU's consist of a number of collections (either herbarium specimens or fresh material or both) from different localities in Egypt. For some taxa, materials from Egypt were not available and specimens from other countries were used (OTU 1, 2, 13, 30, 34, 36, 43, 44).

5.2.2. Morphological characters observations

Table 5.2 shows the characters and character states scored for plant morphology, seed morphology, and pollen morphology, averaged for each OTU.
A total of 62 characters were measured on each specimen, comprising 8 quantitative and 54 qualitative characters. Fourteen of the qualitative characters were scored as binary and the rest were scored as multistate characters. The measurements for all specimens of a taxon were averaged into one OTU score for each of the characters. OTU scores for quantitative characters were averages of measurements of at least 20 specimens (where possible). Because herbarium specimens can not be considered to be a random sample of the species, we followed Wieringa (1999: 62-65) by calculating the mean of the minimum and maximum measurement. For some of the OTU's we lacked observations for some of the characters, and these omissions were coded as missing data (-999). The complete data matrix see table 5.3.

5.2.3. Data analysis

Two types of analyses were performed with NTSYS-pc 2.02k software (Applied Biostatistics Inc., Setauket, New York, USA).

Firstly, we performed a cluster analysis using average taxonomic distance and UPGMA clustering (procedures SIMINT, SAHN, and TREE). To reduce the effects of different scales of measurement for different characters, the values for each character were standardized with procedure STAND, according to the formula: y_I,STD = (y_i- AVGy_i)/STDy_i),
Where the default value in NTSYS-pc (STAND) for y_i = the value to be standardized, AVGy_i= the average of all values for the character, and STDy_i = the standard deviation. The cophenetic correlation coefficient between the distance matrix and the tree matrix was calculated to examine the goodness of fit of the cluster analysis to the distance matrix (procedures COPH and MXCOMP).

Secondly, we performed a principal coordinates analysis (PCO), using the product-moment correlation as a coefficient. The procedure SIMINT was used to calculate the distance matrix based on STAND data, the procedures EIGEN, PROJ, and MXPLOT to perform the PCO. We preferred a PCO rather than a PCA (Principal Components Analysis), because a PCO performs better on data sets with missing data (Rohlf, 1972).

Table 5.1. List of taxa used for the study, arranged by tribe according to Schulz (1936)

OTU No.	Taxon	Tribe	Origin	No. of individuals
1	*Arabis alpina* L. sub sp. *caucasica* (Willd.) Briq.	Arabideae	Israel, Lebanon	4
2	*Arabis nova* Vill.	Arabideae	Lebanon, Syria	5
3	*Nasturtium officinale* R.BR.	Arabideae	Egypt	4
4	*Rorippa indica* (L.) Hiern	Arabideae	Egypt	12
5	*Rorippa integrifolia* Boulos	Arabideae	Egypt	3
6	*Rorippa palustris* (L.) Besser	Arabideae	Egypt	4
7	*Anastatica hierochuntica* L.	Euclidieae	Egypt	21
8	*Neslia paniculata* (L.) Desv	Euclidieae	Egypt, Morocco	10
9	*Ochthodium aegyptiacum* (L.) DC.	Euclidieae	Egypt, Lebanon	12
10	*Schimpera arabica* Hochst & Steud.	Euclidieae	Egypt	7
11	*Eremobium aegyptiacum* (Spreng.) Asch. & Schweinf. subsp. *aegyptiacum*	Hesperideae	Egypt	25
12	*E. aegyptiacum* subsp. *lineare* (Delile) Abdel Khalik	Hesperideae	Egypt	17
13	*E. aegyptiacum* subsp. *longisiliquum* (Coss.) Maire	Hesperideae	Algeria, Morocco	13
14	*Erysimum repandum* L.	Hesperideae	Egypt, Turkey	7
15	*Leptaleum filifolium* (Willd.) DC.	Hesperideae	Egypt, Iran	13
16	*Malcolmia africana* (L.) R.Br.	Hesperideae	Egypt	15
17	*M. nana* (DC.) Boiss.	Hesperideae	Egypt	14
18	*M. pygmaea* (Del.) Boiss.	Hesperideae	Egypt	17
19	*Ricotia lunaria* (L.) DC.	Lunarieae	Egypt, Israel	25
20	*Diceratella eliptica* (DC.) Jonsell	Matthioleae	Egypt	15
21	*Matthiola arabica* Boiss.	Matthioleae	Egypt	25
22	M. fruticulosa (L.) Maire	Matthioleae	Egypt, Morocco	11
23	*M. longipetala* subsp. *bicornis* (Sibth.) Ball	Matthioleae	Egypt, Israel, Turkey	10
24	*M. longipetala* subsp. *hirta* (Conti) Greuter & Burdet	Matthioleae	Egypt	21
25	*M. longipetala* subsp. *kralikii* (Pomel) Maire	Matthioleae	Egypt	6
26	*M. longipetala* subsp. *livida* (Delile) Maire	Matthioleae	Egypt	27
27	*M. longipetala* (Vent.) DC. subsp. *longipetala*	Matthioleae	Egypt	15
28	*M. parviflora* (Schousboe) R.Br.	Matthioleae	Egypt, Morocco	17
29	*Morettia canescens* Boiss.	Matthioleae	Egypt	9
30	*M. parviflora* Boiss.	Matthioleae	Saudi Arabia	10
31	*M. philaeana* (Delile) DC.	Matthioleae	Egypt	25
32	*Notoceras bicorne* (Ait.) Caruel	Matthioleae	Egypt	6
33	*Crucihimalaya kneuckeri* (Bornm.) Al-Shehbaz, O'Kane & Price	Sisymbrieae	Egypt	2
34	*Descurainia sophia* (L.) Webb & Berth.	Sisymbrieae	Israel, Iran	4
35	*Nasturtiopsis coronopifolia* (Desf.) Boiss.	Sisymbrieae	Egypt	10
36	*Neotorularia aculeolata* (Boiss.) Hedge & Léonard	Sisymbrieae	Iran	4
37	*N. torulosa* (Desf.) Hedge & Léonard	Sisymbrieae	Egypt	12
38	*Olimarabidopsis pumila* (Stephan) Al-Shehbaz, O'Kane & Price	Sisymbrieae	Egypt	3
39	*Robeschia schimperi* (Boiss.) Schulz	Sisymbrieae	Egypt	8
40	*Sisymbrium erysimoides* Desf.	Sisymbrieae	Egypt	23
41	*S. irio* L.	Sisymbrieae	Egypt	30
42	*S. orientale* L.	Sisymbrieae	Egypt	15
43	*S. polyceratum* L.	Sisymbrieae	Italy	4
44	*S. runcinatum* Lag. ex DC.	Sisymbrieae	Syria, Jordan	3
45	*S. septulatum* DC.	Sisymbrieae	Egypt	8

Table 5.2. Characters and character states used in morphometric analysis of Brassicaceae

Character	**Character state**	**Code**	**Character**	**Character state**	**Code**
1. Life cycle	Annual		**11. Inflorescence characters**	Bracts present	1
	Annual or short lived perennial	2		Bracts sometimes present	2
	Perennial	3		Bracts absent	3
	Sub-shrubby	4	**12. Inflorescence position**		
2. Plant height (mean length in cm)				Terminal	1
3. Plant surface	Glabrous	1		Terminal and axillary	2
	Glabrous to sparsely hairy	2		Axillary	3
	Hairy	3	<u>**Flower characters**</u>		
4. Hair style	Simple	1	**13. Flowers number**	Solitary	1
	Simple and glandular	2		Solitary or in pairs	2
	Simple and vasculate	3		2 or 3	3
	Medifixed	4		More than 3	4
	Medifixed and 3-fid	5	**14. Flower pedicel**	Sessile	1
	2-4 fid	6		Pedicellate	2
	Simple and branched	7	**15. Sepal base**	Saccate at the base	1
	Branched	8		Not saccate at the base	2
	Simple, glandular and dendroid	9	**16. Sepal persistence at fruit maturity**		
	Simple, branched and stellate	10		Caducous	1
	Glandular, dendroid and stellate	11		Persistent	2
	Stellate and dendroid	12	**17. Sepal length (mean length in mm)**		
	Stellate	13	**18. Sepal patent**	Erect	1
5. Stem shapes	Erect	1		Erect to spreading	2
	Erect or ascending	2		Spreading	3
	Otherwise	3	**19. Petal length (mean length in mm)**		
<u>**Leaf characters**</u>			**20. Petal shape**	Linear to oblanceolate	1
6. Leaf structure	Simple	1		Linear to oblong	2
	Compound	2		Spathulate to oblong-obovate	3
7. Lower leaves arrangement				Oblong to spathulate	4
	Rosette-forming	1		Spathulate	5
	Not rosette	2		Obovate	6
8. Lower leaves	Simple, entire	1		Obovate to orbicular	7
	Otherwise	2		Obcordate	8
	Lobed or pinnatisect	3	**21. Petal apex**	Rounded	1
9. Cauline leaves	Simple, entire	1		Rounded and truncate	2
	Otherwise	2		Truncate	3
	Lobed or pinnatisect	3		Obtuse to slightly emarginate	4
10.Base of cauline leaves				Emarginate	5
	Auriculate	1	**22. Petal margin**	Entire	1
	Sessile or cunate into apetiole	2		Entire to slightly undulate	2
	Petiolate	3			

Table 5.2. continued

23. Petal colour	White	1
	Cream	2
	Yellow	3
	Lemon yellow	4
	Pink	5
	Pink to white	6
	Violet	7
	Violet to white or yellow	8
	Pink to violet or purple	9
24. Stamens number	6	1
	4 or 2	2
25. Filament length (mean length mm)		
26. Anther shapes	linear	1
	Linear to oblong	2
	Oblong	3
	Oblong to sagittate	4
	Sagittate	5
	Ovoid to sagittate	6
	Ovoid-oblong	7
	Ovoid	8
27. Pollen shape	Prolate spheroidal	1
	Subprolate	2
	Prolate	3
28. Exine sculpture	Fine reticulate	1
	Medium reticulate	2
	Coarse reticulate	3
29. Style shape	Style jointed with fruit	1
	Style not jointed with fruit	2
30. Stigma shape	Depressed	1
	Capitate to slightly depressed	2
	Capitate	3
	Connate	4
	Ovoid or capitate to bi-lobed	5
	Bi-lobed	6
	Decurrent	7
	Divergent	8
31. Lateral horns (Stigmatic horns)		
	Present	1
	Present or absent	2
	Absent	3
32. Length of lateral horns (mean length in mm)		
	Horizontal to slightly curved	1
	Horizontal or upcurved or deflexed	2
	Straight or upcurved	3
	Straight or strongly incurved	4
34. Appendages beside the lateral horns		
	Absent	1
	Present	2
35. Length of fruit pedicel (mean length in mm)		
36. Indumentum of fruit pedicel		
	Glabrous	1
	Glabrous to hairy	2
	Hairy	3
<u>Fruit characters</u>		
37. Fruit type	Siliqua	1
	Silicule	2
38. Fruit length (mean length in cm)		
40. Fruit dehiscent	Dehiscent	1
	Tardily dehiscent	2
	Indehiscent	3
41. Number of fruit locules	One	1
	Two	2
42. Number of seeds in fruit	1	1
	2	2
	3-8	3
	More than 8	4
43. Number of rows per locule		
	One	1
	Two	2
44. Fruit shape	Linear	1
	Linear-oblong	2
	Lenticular to elliptical	3
	Sub-globose	4
	Irregular ovoid	5
	Ovoid	6
45. Fruit patent	Erect	1
	Erect to spreading	2
	Spreading	3
	Appressed to the stem	4

Table 5.2. continued

46. Fruits curvature	Straight	1	**55. Seed colour**	Brown	1
	Straight to slightly curved	2		Light brown	2
	Curved	3		Yellow-brownish	3
	Straight or contorted	4		Orange-brown	4
47. Persistence of fruits	Deciduous	1		Red-brown	5
	Persistent	2	**56. Radicle**	Accumbent	1
48. Valve surface	Glabrous	1		Incumbent	2
	Glabrous to slightly hairs	2	**57. Epidermal cell patterns**	Isodiametric	1
	Hairy	3		Isodiametric or 4-5-6-polygonal	2
	Tuberculate	4		Isodiametric or polygonal	3
49. Valve shape	Winged or beaked	1		Polygonal	4
	Horned	2		4-5-6 gonal or elongate in one direction	5
	Wingless	3		Polygonal or elongate in one direction	6
50. Valve veines	0	1		Isodiametric, 4-5-6 gonal or elongate in one direction	7
	1	2	**58. Anticlinal walls**	Straight	1
	3	3		Straight to sinuous	2
51. Septum shape	Thick	1		Sinuous	3
	Thin (membranous)	2	**60. The sculpture of anticlinal boundaries**		
	Delicate or absent	3		Smooth	1
<u>Seed characters</u>				Smooth to folded	2
52. Seed shape	Oblong-ellipsoidal	1		Folded	3
	Oblong	2	**61. Outer periclinal cell walls**	Flat	1
	Oblong-ovoid	3		Flat to concave	2
	Ovoid to ellipsoid	4		Concave	3
	Ovoid	5		Flat to convex	4
	Rounded	6		Convex	5
	Suborbicular to ovoid or to elliptic	7		Domate	6
	Cordiform to ovoid	8	**62. Sculpture of periclinal cell walls**		
	Suborbicular	9		Smooth	1
	Orbicular	10		Smooth to folded	2
53. Seed wing	Wingless	1		Striate	3
	Narrow winged	2		Radiate to striate	4
	Wide winged	3		Micro-reticulate	5
54. Seed size (mm)	0.5-1 x 0.3-0.9	1		Macro-reticulate	6
	1-3 x 0.5-1.7	2		Micro-papillate	7
	3-8 x 2.5-7	3			

Table 5.3. Data matrix used in the numerical analysis of the Brassicaceae

OTU	species / character	1	2	3	4	5	6	7	8
1	*Arabis alpina* subsp. *caucasica*	3	18	3	7	1	1	1	2
2	*Arabis nova*	1	13	3	7	1	1	1	2
3	*Nasturtium officinale*	3	45	1	-999	3	2	2	3
4	*Rorippa indica*	2	33	2	1	2	1	2	3
5	*Rorippa integrifolia*	1	15	3	1	1	1	2	2
6	*Rorippa palustris*	2	30	2	1	2	1	2	2
7	*Anastatica hierochuntica*	1	8	3	12	3	1	2	1
8	*Neslia paniculata*	1	22	3	8	1	1	2	2
9	*Ochthodium aegyptiacum*	1	61	3	2	2	1	2	3
10	*Schimpera arabica*	1	13	3	1	2	1	1	2
11	*Eremobium aegyptiacum* subsp. *aegyptiacum*	2	30	3	13	3	1	2	1
12	*E. aegyptiacum* subsp. *lineare*	2	14	3	13	3	1	2	1
13	*E. aegyptiacum* subsp. *longisiliquum*	4	40	3	13	3	1	2	1
14	*Erysimum repandum*	1	21	3	5	1	1	2	2
15	*Leptaleum filifolium*	1	5,5	2	1	3	1	2	2
16	*Malcolmia africana*	1	17	3	10	1	1	2	2
17	*Malcolmia nana*	1	12	3	13	2	1	2	2
18	*Malcolmia pygmaea*	1	8,5	3	8	2	1	1	2
19	*Ricotia lunaria*	1	23	2	1	3	2	2	3
20	*Diceratella elliptica*	4	63	3	10	2	1	1	1
21	*Matthiola arabica*	3	58	3	11	2	1	1	1
22	*Matthiola fruticulosa*	3	23	3	10	2	1	1	1
23	*Matthiola longipetala* subsp. *bicornis*	1	25	3	11	3	1	1	2
24	*M. longipetala* subsp. *hirta*	1	14	3	9	3	1	1	2
25	*M. longipetala* subsp. *kralikii*	1	28	3	11	2	1	2	2
26	*M. longipetala* subsp. *livida*	1	33	3	11	1	1	2	2
27	*M. longipetala* subsp. *longipetala*	1	33	3	12	2	1	1	2
28	*Matthiola parviflora*	1	20	3	11	1	1	1	2
29	*Morettia canescens*	3	25	3	13	3	1	2	2
30	*Morettia parviflora*	3	20	3	12	3	1	2	1
31	*Morettia philaeana*	3	35	3	12	2	1	2	2
32	*Notoceras bicorne*	1	17	3	4	3	1	2	2
33	*Crucihimalaya kneuckeri*	1	19	3	12	2	1	1	3
34	*Descurainia sophia*	2	42	3	7	1	2	2	3
35	*Nasturtiopsis coronopifolia*	1	16	3	1	2	1	1	2
36	*Neotorularia aculeolata*	1	6	1	-999	3	1	1	3
37	*Neotorulria torulosa*	1	20	3	7	3	1	1	2
38	*Olimarabidopsis pumila*	1	15	3	6	2	1	1	2
39	*Robeschia schimperi*	1	6,5	3	8	2	2	2	3
40	*Sisymbrium erysimoides*	1	25	2	1	1	1	2	3
41	*S. irio*	1	29	2	1	1	1	2	3
42	*S. orientale*	1	38	3	1	1	1	1	3
43	*S. polyceratum*	1	30	2	1	2	1	1	3
44	*S. runcinatum*	1	18	3	3	2	1	1	3
45	*S. septulatum*	1	28	2	1	1	1	1	3

Table 5. 3. continued

9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
2	1	3	1	4	2	1	1	6	1	1,1	6	4	1	1	1	6,5	4
2	1	3	1	4	2	1	1	1,75	1	3	5	1	1	1	1	2,25	1
3	1	3	1	4	1	1	1	3,5	3	5,5	5	1	1	1	1	4,5	8
3	2	3	1	4	2	1	1	1,75	1	3,5	5	2	1	3	1	2,25	1
2	2	3	1	4	2	1	1	2	1	3,25	7	2	1	3	1	1,75	5
3	3	3	2	4	2	1	1	2	1	2	4	1	1	3	1	1,5	8
1	2	3	3	4	1	2	1	1,75	1	2,75	5	1	1	1	1	1,75	5
2	1	3	1	4	2	2	1	1,75	1	2,4	5	1	1	3	1	1,75	8
2	2	3	1	4	2	2	1	1,75	3	2,5	4	1	1	3	1	1,75	4
2	2	3	1	4	2	2	1	1,3	3	1,8	6	4	1	3	1	1,25	5
1	2	3	1	4	2	1	1	4	1	6	4	1	1	8	1	4	5
1	2	3	1	4	2	1	2	5	1	8	4	1	1	8	1	5	5
1	2	3	1	4	2	1	1	5	1	8	4	1	1	8	1	5	5
2	2	3	1	4	2	1	1	4,5	1	7	4	2	1	3	1	5	5
2	2	3	3	2	2	2	1	4,5	1	8,5	1	1	1	1	2	7,5	5
2	2	1	1	4	2	1	1	4,5	1	7	5	1	1	8	1	4,5	5
2	2	3	1	4	2	1	1	1,8	1	3,5	3	1	1	9	1	2,5	7
2	-999	3	1	4	2	1	1	3,5	1	8,5	6	2	1	7	1	5,5	5
1	3	3	1	4	2	1	1	6	1	13	8	5	1	6	1	5,5	5
1	3	3	1	4	2	2	1	17	1	29	3	1	1	1	1	7,5	2
1	2	3	1	4	2	1	1	9,5	1	18	2	1	1	1	1	5	3
1	2	3	1	4	2	1	1	9	1	17,5	2	1	2	8	1	4,5	4
2	2	3	1	4	1	1	1	8,5	1	16,5	4	1	1	9	1	4	4
2	2	3	1	4	1	1	1	6,5	1	17	6	4	1	9	1	4	5
2	2	3	1	4	1	1	1	6,5	1	14,5	3	1	2	8	1	3,5	3
2	2	3	1	4	1	1	1	8	1	16	1	1	2	8	1	4	3
2	2	3	1	4	1	1	1	8,5	1	18,5	2	1	2	9	1	6	4
2	2	3	1	4	1	1	1	6	1	9,5	3	1	1	9	1	5,5	5
2	2	1	2	4	2	2	1	4,5	1	7	5	1	1	6	1	2,25	2
1	3	1	2	4	2	2	1	2,7	1	4,5	4	1	1	1	1	2,5	5
2	2	1	2	4	2	2	2	5	1	9	5	1	1	1	1	3,5	2
2	2	3	2	4	2	2	1	1,25	1	1,75	4	1	1	3	1	1	5
2	2	2	1	4	2	2	1	1,25	1	2,5	5	1	1	7	1	1,75	5
3	2	3	1	4	2	2	1	1,8	2	1,7	5	1	1	3	1	2,5	6
2	2	3	1	4	2	2	1	1,75	2	2,75	6	1	1	3	1	2,1	8
2	2	3	1	4	2	2	1	1,75	2	3	4	1	1	5	1	1,75	8
2	2	3	1	4	2	2	1	2	2	3,5	4	3	1	1	1	2	5
2	1	3	1	4	2	2	1	1,75	1	2,25	5	1	1	3	1	1,75	3
3	3	3	1	4	2	2	1	2,5	1	3,5	4	1	1	6	1	3,5	7
2	3	3	1	4	2	2	1	1,75	2	2,25	5	1	1	3	1	1,6	5
2	2	3	1	4	2	2	1	2,1	2	3	2	1	1	3	1	2,2	5
2	3	3	1	4	2	2	1	4,5	2	8	3	2	1	3	1	5	5
2	2	1	3	3	2	2	1	1,5	2	1,75	4	1	1	2	1	1,2	5
2	2	1	1	1	2	2	1	2	2	2,75	3	1	1	3	1	2	5
3	3	3	1	4	2	2	1	5	2	10	6	1	1	4	1	6	4

Table 5. 3. continued

27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
3	2	1	2	3	-999	-999	1	1,2	3	1	5,5	0,2	1	2	4	1
3	3	1	1	3	-999	-999	1	1	1	1	3,5	0,1	1	2	4	1
3	2	1	3	3	-999	-999	1	8,5	1	1	1,25	0,22	1	2	4	2
3	2	1	4	3	-999	-999	1	2,5	1	1	1,45	0,2	1	2	4	2
3	2	1	4	3	-999	-999	1	4	3	1	0,3	0,15	1	2	4	2
3	2	1	3	3	-999	-999	1	4,5	1	1	0,6	0,25	1	2	4	2
2	2	1	3	3	-999	-999	1	-999	-999	2	0,5	0,35	3	2	2	1
3	2	1	3	3	-999	-999	1	6	1	2	0,3	0,24	3	2	2	1
1	2	2	6	3	-999	-999	1	5,5	1	2	0,35	0,275	3	2	2	1
1	2	2	6	3	-999	-999	1	3	1	2	0,22	0,15	3	1	1	1
3	2	1	8	3	-999	-999	1	3,5	3	1	3,25	0,1	1	2	4	1
-999	-999	1	8	3	-999	-999	1	3,2	3	1	1,8	0,2	1	2	3	1
-999	-999	1	8	3	-999	-999	1	4	3	1	5	0,12	1	2	4	1
2	1	1	6	3	-999	-999	1	2,5	3	1	4,1	0,12	2	2	4	1
3	2	2	4	3	-999	-999	1	4	2	1	1,5	0,2	2	2	4	2
3	2	2	5	3	-999	-999	1	2,5	3	1	4,25	0,12	1	2	4	1
3	2	1	5	3	-999	-999	1	3,5	3	1	1,75	0,1	1	2	4	1
3	3	1	6	3	-999	-999	1	1,3	3	1	2,5	0,1	1	2	4	1
3	3	1	5	3	-999	-999	1	9	3	2	2,1	0,9	1	1	3	1
3	2	2	5	3	-999	-999	1	4,5	3	1	4,2	0,15	2	2	4	1
3	3	1	5	3	-999	-999	1	3,5	3	1	3,6	0,12	1	2	4	1
3	3	2	6	2	2,75	3	1	1,25	3	1	5,5	0,12	2	2	4	1
-999	-999	2	6	1	6	4	1	1,5	3	1	4,75	0,13	2	2	4	1
-999	-999	2	6	1	4	3	1	1	3	1	4	0,18	2	2	4	1
-999	-999	2	6	1	3,2	2	1	1	3	1	4	0,12	2	2	4	1
-999	-999	2	6	1	3	1	1	1,2	3	1	5	0,15	2	2	4	1
3	3	2	6	1	5	1	1	1	3	1	4,5	0,12	2	2	4	1
2	3	2	6	1	4	3	2	1	3	1	4,5	0,15	2	2	4	1
3	2	1	8	3	-999	-999	1	3	3	1	1	0,15	2	2	4	1
3	1	1	6	3	-999	-999	1	3	3	1	1,5	0,1	2	2	4	1
3	2	1	8	3	-999	-999	1	2,5	3	1	1,25	0,2	2	2	4	1
3	2	1	3	3	-999	-999	1	1,75	3	1	0,6	0,2	2	2	3	1
3	1	1	3	3	-999	-999	1	7	3	1	3,75	0,05	1	2	4	1
3	1	1	3	3	-999	-999	1	14	2	1	2	0,06	1	2	4	1
1	2	1	5	3	-999	-999	1	7	3	1	1,1	0,13	1	2	4	2
3	2	1	6	3	-999	-999	1	2	1	1	2,25	0,1	1	2	4	1
3	1	1	3	3	-999	-999	1	1,25	2	1	1,4	0,15	1	2	4	1
3	1	1	3	3	-999	-999	1	4	3	1	2,25	0,1	1	2	4	1
3	1	1	1	3	-999	-999	1	1,5	3	1	2	0,1	1	2	4	1
3	2	1	6	3	-999	-999	1	3,5	2	1	3,25	0,1	1	2	4	1
3	2	1	6	3	-999	-999	1	8,5	2	1	2,75	0,1	1	2	4	1
3	2	1	6	3	-999	-999	1	6	2	1	8,8	0,15	2	2	4	1
3	2	1	5	3	-999	-999	1	1,3	1	1	1,4	0,15	1	2	4	1
3	2	1	6	3	-999	-999	1	1,5	3	1	2	0,15	2	2	4	1
3	2	1	6	3	-999	-999	1	5	1	1	4,25	0,15	2	2	4	1

Table 5. 3. continued

44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
2	1	1	2	1	3	2	2	9	3	2	2	1	3	2	3	1	6	2
1	2	1	2	1	3	2	2	3	1	1	2	1	2	2	1	3	6	4
2	1	2	2	1	3	2	2	5	2	1	1	1	5	1	1	3	1	6
2	2	1	2	1	3	2	2	5	2	1	5	1	3	2	1	2	2	5
1	3	3	2	1	3	2	2	4	1	1	4	1	5	2	1	2	4	3
2	2	2	2	1	3	1	2	8	1	1	1	1	2	2	1	2	2	5
6	4	1	2	3	1	1	1	5	1	2	1	1	1	1	3	2	4	2
4	2	1	1	4	3	2	1	7	1	2	1	2	4	2	2	2	3	2
5	2	1	2	5	3	1	1	3	1	2	1	2	6	3	1	2	2	5
4	4	3	2	5	3	1	1	3	1	2	1	2	5	2	2	2	4	5
1	1	2	2	3	3	2	2	2	2	2	3	1	2	1	1	1	4	2
2	1	1	2	3	3	2	2	7	3	2	5	1	5	1	1	1	4	7
1	1	1	2	3	3	2	2	2	2	2	1	1	2	2	1	2	2	2
1	3	2	2	3	3	2	2	2	1	2	3	2	2	1	1	2	6	4
1	2	1	2	3	3	2	1	3	1	1	3	2	4	2	3	1	6	3
1	3	2	2	3	3	2	2	2	1	2	1	2	3	2	1	1	4	2
1	2	2	2	3	3	2	2	1	1	1	3	2	7	2	1	2	4	3
1	1	2	2	1	3	2	2	5	1	1	3	2	7	1	1	2	4	3
3	2	1	2	1	3	1	3	10	1	3	1	1	3	2	3	1	4	7
1	3	2	2	3	3	2	1	7	2	2	2	1	7	1	1	1	4	2
1	3	2	2	3	3	2	1	2	2	2	1	1	5	1	1	2	5	2
1	3	2	2	3	3	2	2	2	3	2	1	1	7	1	1	2	4	3
1	3	2	2	3	3	2	1	2	3	2	1	1	3	2	1	2	4	3
2	2	1	2	3	3	2	1	2	3	2	1	1	3	2	1	2	2	2
2	3	2	1	3	3	2	1	3	2	2	3	1	2	1	1	1	4	2
1	2	2	2	3	3	2	1	2	2	1	1	1	2	2	1	2	2	2
1	2	4	2	3	3	2	1	3	2	2	3	1	2	2	1	2	1	2
1	2	2	2	3	3	2	1	3	2	2	1	1	7	1	1	1	2	7
1	4	1	2	3	3	3	2	5	1	2	2	1	2	1	1	3	5	1
1	2	3	2	3	3	2	2	5	1	2	2	1	2	2	1	1	6	4
1	1	2	2	3	3	2	2	5	1	2	1	1	2	1	1	1	5	1
2	4	2	2	3	2	2	2	6	1	2	1	1	7	2	1	2	5	3
1	3	2	2	1	3	2	2	2	1	1	1	2	3	2	1	3	2	5
1	3	2	2	2	3	2	2	2	1	2	5	2	2	2	1	3	2	5
2	3	2	2	1	3	2	2	1	1	1	1	2	5	2	1	2	4	7
1	2	2	2	2	3	1	2	2	1	2	1	2	3	3	3	1	6	2
1	2	4	2	2	3	2	1	2	1	2	1	2	2	1	1	1	5	2
1	2	3	2	3	3	2	2	2	1	1	1	2	3	1	1	2	6	1
1	1	2	2	3	3	2	2	2	1	2	1	2	2	2	1	2	6	3
1	3	1	2	1	3	2	2	2	1	2	3	2	3	2	3	2	6	4
1	1	2	2	1	3	3	2	1	1	1	3	2	2	1	1	1	4	5
1	3	1	2	2	3	3	1	3	1	2	4	2	2	2	1	2	4	5
1	4	3	2	2	3	3	1	2	1	1	1	2	6	2	3	1	4	2
1	4	2	2	3	3	2	1	2	1	2	3	2	4	3	3	2	6	2
1	2	2	2	1	3	3	2	3	1	2	1	2	3	2	2	1	6	2

5.3. RESULTS

5.3.1. Cluster analysis

Figure 5.1 shows the UPGMA phenogram comprising all OTU's in the present study. The cophenetic correlation of distance matrix and tree matrix was 0.85, indicating a good fit of the phenogram to the distance matrix (see Rohlf, 1993).

Six branches and clusters can be distinguished: 1) A branch with *Ricotia lunaria* (Lunarieae). This branch shows the largest distance from all other branches, 2) A branch with *Leptaleum filifolium* (tribe Hesperideae), 3) A cluster consisting of OTU's of *Anastatica hierochuntica, Neslia paniculata, Ochthodium aegyptiacum,* and *Schimpera arabica* (tribe Euclidieae), 4) A branch with *Nasturtium officinale*, 5) A cluster comprising *Matthiola parviflora, M. longiptala, M. fruticulosa, M. arabica* and *Diceratella elliptica* (tribe Matthioleae), and 6) A cluster is divided into two subgroups: an *Arabis alpina* subgroup, and a subgroup with a mixture of genera from the tribes Matthioleae, Arabideae, Hesperideae and Sisymbrieae. Within this subgroup we can distinguish species of the same genus cluster together such as *Morettia, Rorippa* and *Sisymbrium,* while some species from different genera cluster within other genera such as *Erysimum* within *Malcolmia* and *Morettia* within *Eremobium*.

5.3.2. Principal coordinates analysis (PCO)

The plot of 45 OTU's on the first three principal coordinates axes is shown in Fig. 5.2, 3, 4. These axes explain 34.34 % of the total observed variation. Plots 1/2, 1/3 and 2/3 together show four groups.

On the first axis (15.5 % of the total variation) a segregation is demonstrated between three groups. 1) group of 20. *Diceratella elliptica,* 21. *Matthiola arabica,* 22. *M. fruticulosa,* 23-27. *M. longipetala* and 28. *M. parviflora* (tribe Matthioleae). 2) group of 11. *Eremobium aegyptiacum* subsp. *aegyptiacum*,12. *E. aegyptiacum* subsp. *lineare* and 13. *E. aegyptiacum* subsp. *longisiliquum*. 3) group of 19. *Ricotia lunaria* (tribe Lunarieae) nested within the tribe Euclidieae (7-10). The main characters explaining this separation (characters with high factor loading > 0.6) are (1) petal length, (2) sepal length, (3) hair shape, (4) seed wings, (5) lateral horns, (6) fruit pedicel indumentum, and (7) fruit length (Table 5.4).

The second principal coordinates axis (10.77 % of the total variation) reveals a split between two groups. 1) Group of 19. *Ricotia lunaria* (tribe Lunarieae) nested within 7. *Anastatica hierochuntica,* 8. *Neslia paniculata,* 9. *Ochthodium aegyptiacum,* and 10.

Schimpera arabica (tribe Euclidieae). 2) Group of genera from the tribes Arabideae, Hesperideae, Sisymbrieae and *Morettia* species from the tribe Matthioleae. This separation is based on mainly (1) fruit type, (2) number of seeds in fruit, (3) fruit shape, (4) fruit dehiscence, (5) pollen shape, (6) valve veines (Table 5.4).

Along the third axis (8.1 % of the total variation) shows a separation between 1) a *Ricotia lunaria* (tribe Lunarieae). 2) a group of the tribe Euclidieae (7-10), and almost all taxa of the mixed group of the tribes Matthioleae, Arabideae, Hesperideae and Sisymbrieae, based on septum shapes.

Table 5.4. Morphological characters showing highest factor loading on the first three Principal coordinates axes

Characters	Principal coordinates		
	1	2	3
	Factor loading		
1. Life cycle	0.34	0.09	0.37
2. Plant height	0.24	0.01	0.06
3. Plant surface	0.43	-0.18	-0.26
4. Hair shape	0.71	-0.04	-0.03
5. Stem shape	0.06	-0.3	0.17
6. Leaf structure	-0.28	0.01	0.49
7. Lower leaves arrangement	-0.19	-0.03	0.18
8. Lower leaves	-0.58	0.25	-0.03
9. Cauline leaves	-0.42	0.38	-0.09
10. Base of cauline leaves	-0.01	0.01	0.11
11. Inflorescence characters	0.05	-0.17	0.29
12. Inflorescence position	-0.21	-0.14	-0.29
13. Flower number	0.17	-0.09	0.4
14. Flower pedicel	-0.48	0.31	0.1
15. Sepal base	-0.54	-0.02	-0.49
16. Sepal persistence	0.14	-0.01	0.19
17. Sepal length	0.8	-0.1	0.16
18. Sepal patent	-0.54	-0.1	-0.19
19. Petal length	0.81	-0.15	0.1
20. Petal shape	-0.47	-0.19	0.5
21. Petal apex	-0.13	-0.37	0.4
22. Petal margin	0.58	-0.06	-0.22
23. Petal colour	0.55	-0.07	0.11
24. Stamens number	-0.08	0.04	-0.18
25. Filament length	0.58	0.03	0.32
26. Anther shapes	-0.45	-0.04	0.1
27. Pollen shapes	0.21	0.6	0.2

Table 5.4. continued

Characters	Principal coordinates		
	1	2	3
	Factor loading		
28. Exine sculpture of pollen	0.41	-0.29	0.23
29. Style shape	0.54	-0.41	-0.29
30. Stigma shape	0.43	-0.1	-0.04
31. Lateral horns	-0.7	0.2	0.17
32. Length of lateral horns	0.04	-0.08	0.03
33. Patent of lateral horns	-0.17	-0.24	0.3
34. Appendages beside the lateral horns	0.23	-0.11	-0.001
35. Length of fruit pedicel	-0.48	0.02	0.38
36. Indumentum of fruit pedicel	0.61	0.08	0.1
37. Fruits type	-0.37	-0.85	0.01
38. Fruit length	0.61	0.23	0.06
39. Fruit width	-0.22	-0.57	0.54
40. Fruit dehiscence	0.11	-0.7	-0.49
41. Number of fruit locules	0.26	0.56	-0.31
42. Number of seeds in fruit	0.35	0.84	0.12
43. Number of seed rows in each locule	-0.31	0.2	0.22
44. Fruit shape	-0.36	-0.83	0.0003
45. Fruit patent	-0.14	-0.27	-0.46
46. Fruit curving	0.08	0.21	-0.34
47. Persistence of fruits	-0.07	0.22	0.18
48. Valves surface	0.27	-0.57	-0.49
49. Valves shapes	0.13	0.44	0.15
50. Valves veines	0.19	0.6	-0.18
51. Septum shape	-0.29	0.35	0.67
52. Seed shape	-0.08	-0.34	0.55
53. Seed wings	0.71	-0.15	0.33
54. Seed size	0.2	-0.52	0.18
55. Seed colour	0.01	0.36	0.1
56. Radicle	-0.57	0.22	-0.43
57. Epidermal cell patterns	0.05	-0.16	0.002
58. Anticlinal walls	-0.4	-0.06	-0.2
59. Relief of cell boundaries	-0.41	-0.26	-0.09
60. Sculpture of anticlinal boundaries	-0.17	0.09	-0.03
61. Outer periclinal cell walls	-0.2	0.18	-0.16
62. Sculpture of periclinal cell walls	-0.31	-0.13	0.46
Percentage per **PCO**	15.47	10.77	8.1
Percentage total variation for the first three principal coordinates amount 34.34%			

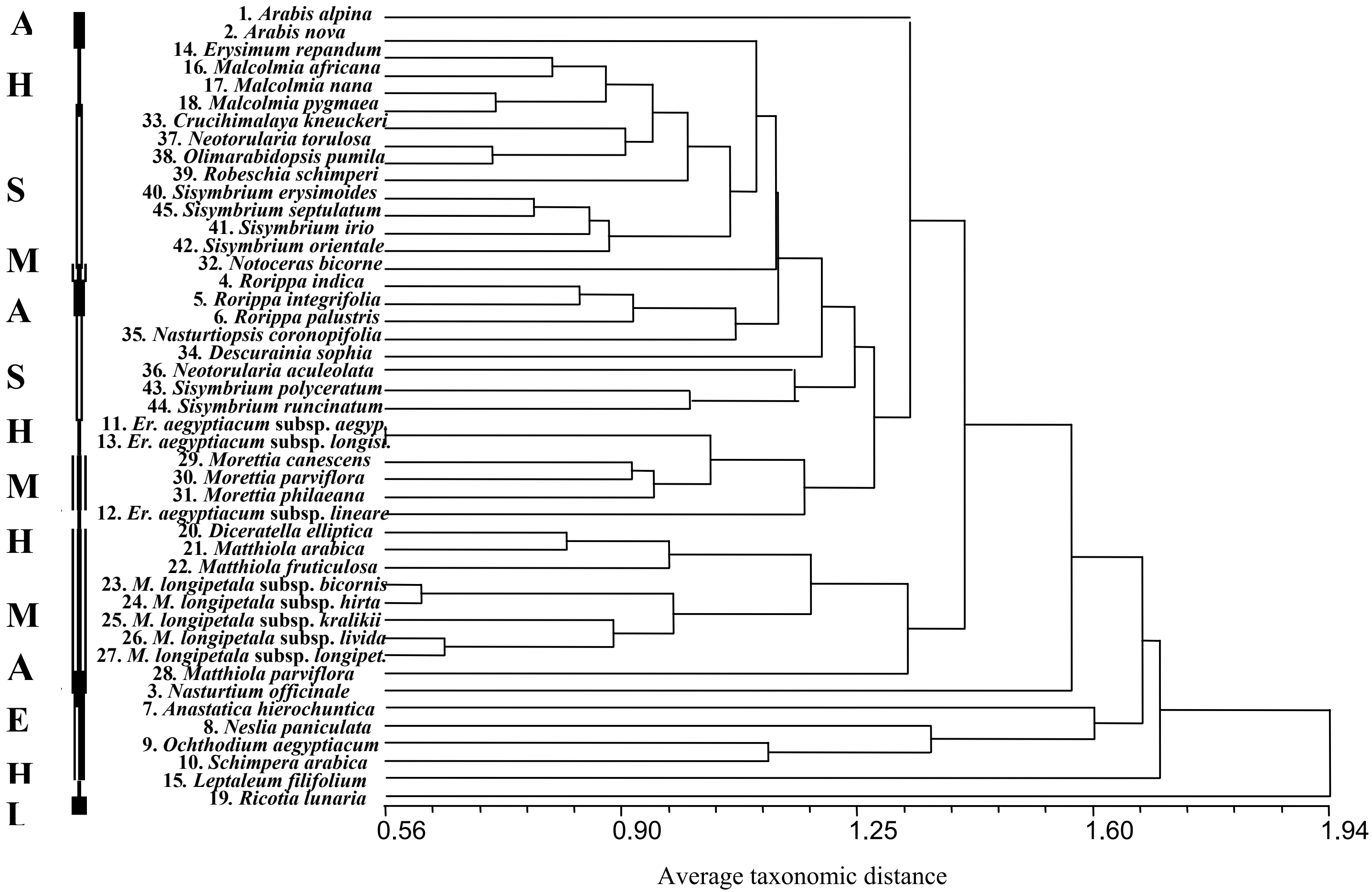

Fig. 5.1. Phenogram of the 45 studied taxa, clustering with the UPGMA method: Arabideae, **A**; Euclidieae, **E**; Hesperideae, **H**; Lunarieae, **L**; Matthioleae, **M**; Sisymbrieae, **S**.

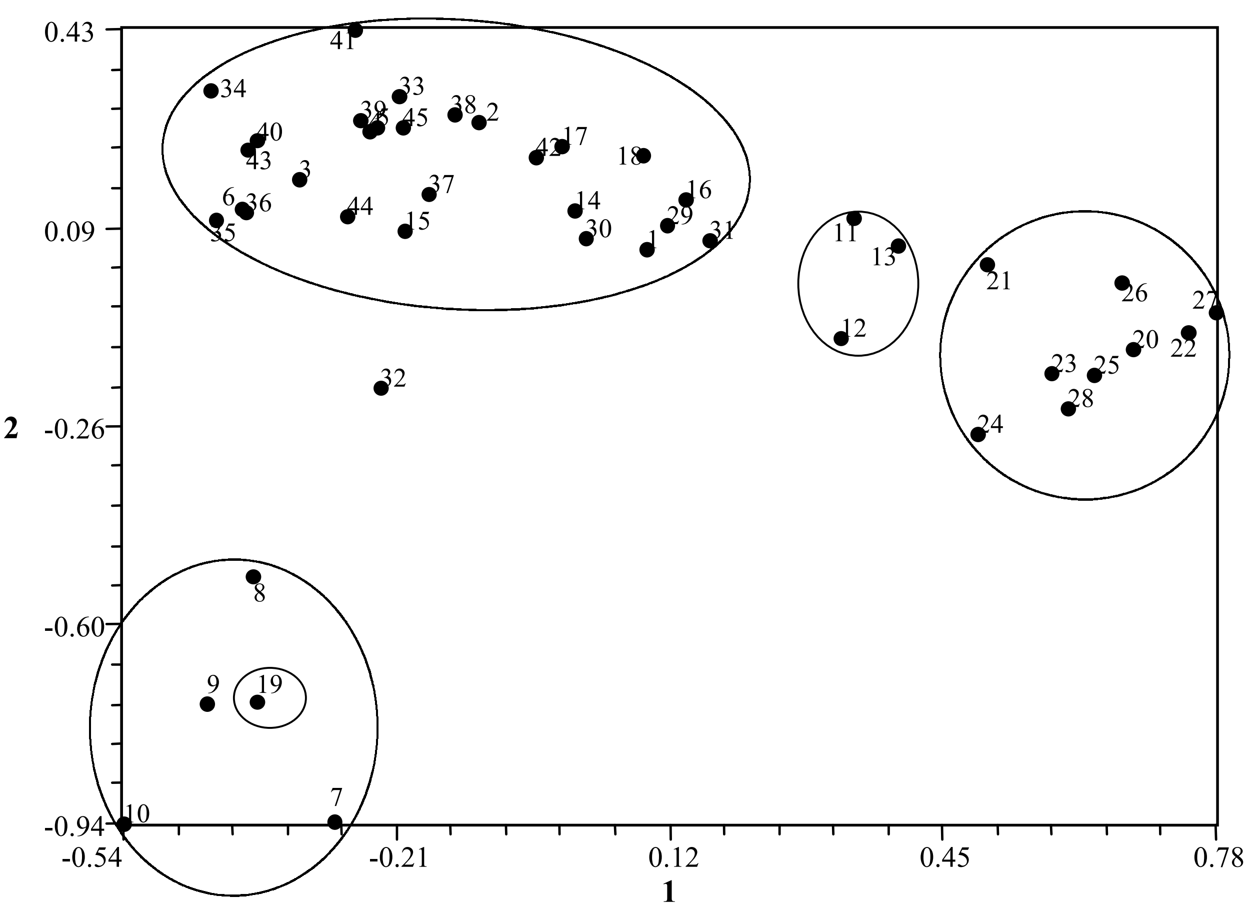

Fig. 5.2. Scatterplot of the 45 OTUs plotted against the the first principal coordinate by the second principal coordinate

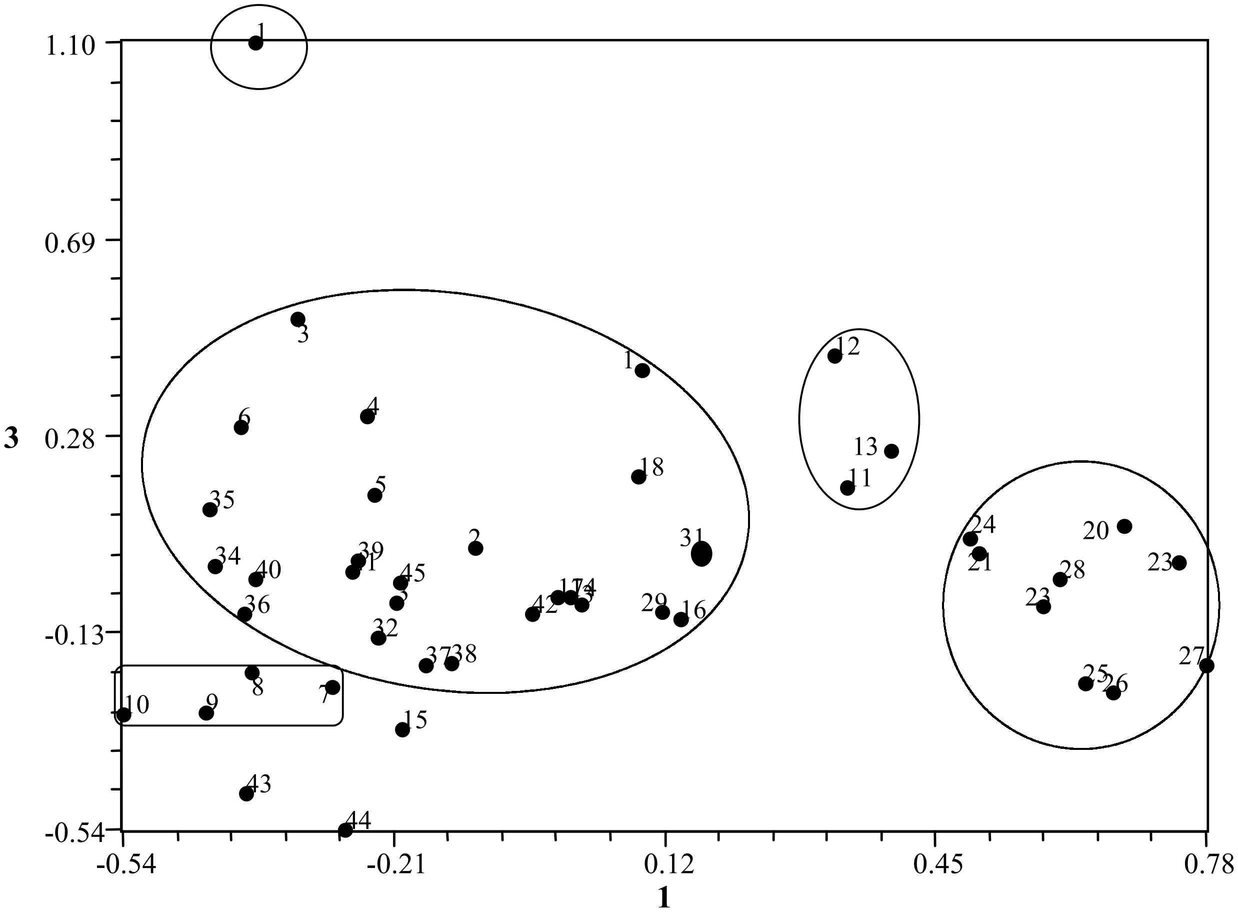

Fig.5.3. Scatterplot of the 45 OTUs plotted against the the first principal coordinate by the third principal coordinate

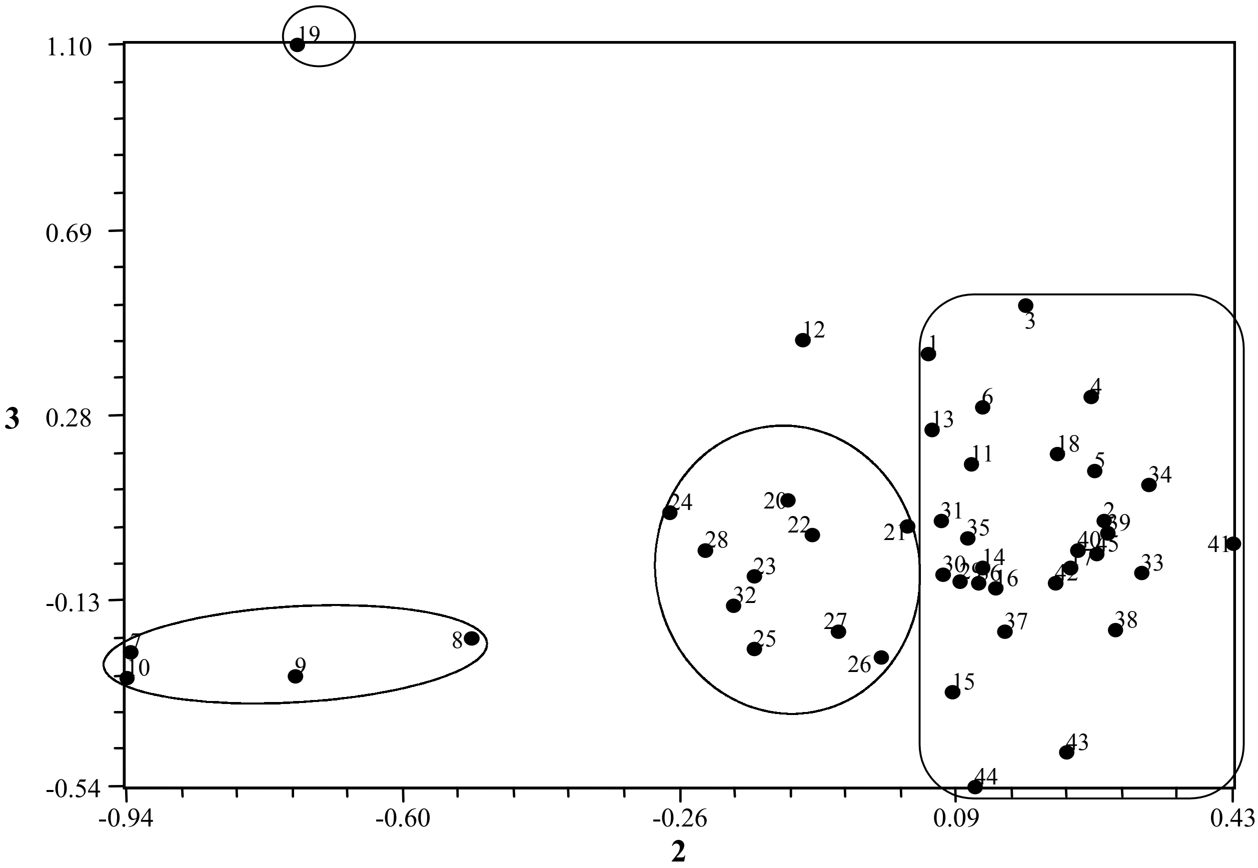

Fig. 5.4. Scatterplot of the 45 OTUs plotted against the the second principal coordinate by the third principal coordinate

5.4. DISCUSSION

Taxonomy must largely rely on morphological characters to circumscribe taxa. Problems in classification arise when taxa display a large amount of variability, due to phenotypic plasticity (van den Berg & Groendijk-Wilders, 1999).

In the Brassicaceae, several authors have tried to provide a natural system to divide this family into tribes (Hayek, 1911; Schulz, 1936; Janchen, 1942; Al-Shehbaz, 1984). These studies were based on a small number of morphological characters such as fruit shape, position of the embryo and cotyledons. In the present study a large number of characters was scored and numerical methods (UPGMA and PCO) were applied to study the relationships between tribes and estimate the level of variation within and between tribes.

UPGMA gives insight into degree of similarity among the OTU's and whether they form groups/clusters and gives an indication of the level of variation within and between tribes.

PCO reflects which characters are important on the axes, and indicates the significant characters based on the highest factor loading (Table 5.3). Therefore it becomes clear which characters cause the separation between groups and can be useful to distinguish taxa.

Generally, our results show congruence between the UPGMA clustering and PCO analyses, in suggesting four groups:

5.4.1. Tribe Euclidieae group

Janchen (1942) distributed the genera of Euclidieae among different tribes. El Naggar (1993) investigated 22 species from tribe Lepidieae and some other genera, including Euclidieae genera, and concluded that tribe Euclidieae seems to be a polyphyletic group. However, Schulz (1936) treated these genera as a good tribe based on the fruit characters.

The results of both cluster and principal coordinates analysis confirmed that the tribe Euclidieae as a well distinguished group, characterised by: (1) fruit asilicula, (2) fruit indehiscent, (3) low number of seeds, (4) pollen shapes prolate spheroidal, prolate to subprolate and medium exine sculpture.

5.4.2. Tribe Lunarieae group

Janchen (1942) united Schulz's tribes Alysseae, Lunarieae and Drabeae under Alysseae. Schulz (1936) separated Lunarieae from Alysseae mainly on the basis of simple, branched or stellate trichomes and the septum of the fruit. He placed *Ricotia* in the former having simple or branched trichomes and a delicate or absent fruit septum. El Naggar & El Hadidi (1998) studied the genera of the tribe Alysseae and *Ricotia* in Egypt based on the micro- and macro-morphological characters of the genera, and concluded that *Ricotia lunaria* (Lunariineae) is distinct from Alyssineae, and there is a small phenetic gap between the tribe Alysseae and the non Alysseae (*Ricotia*).

According to cluster and principal coordinates analysis, *Ricotia lunaria* (Lunarieae) shows the largest distance from all other groups, and is distinct from the others by the characters of septum (delicate or absent), petals shape (obcordate shape), petals apex (emarginate), and fruit width (9 mm). This result agrees with those of Schulz.

5.4.3. Tribe Matthioleae group

Janchen (1942) treated tribes Hesperideae and Matthioleae under one tribe Hesperideae. Schulz (1936) considered tribe Matthioleae as a separate tribe. In our results, both cluster and principal coordinates analysis show that the group of *Diceratella elliptica, Matthiola arabica, M. fruticulosa, M. parviflora, M. longipetala* and its subspecies (subsp. *longipetala*, subsp. *kralikii*, subsp. *hirta*, subsp. *bicornis* and subsp. *livida* (tribe Matthioleae) can be almost separated from the rest of the groups. The OTU's of this group are rather homogeneous. In comparison with other tribes Matthioleae have long petals and sepals; simple, glandular, dendroid and stellate hairs; winged seeds; fruit with lateral horns and long fruits (4.5-5.5 cm). Within this group *Diceratella elliptica* clusters with *Matthiola arabica*, based on the shape of fruit (without horns), while the other *Matthiola* species have horns. However, other representatives of the tribe Matthioleae, like *Morettia* and *Notoceras* cluster in the mixed group. On the other hand if axes 1+2 are combined, *Notoceras bicorne* is separated from the mixed group and the Matthioleae group as well, but in the second axis of the PCO (Fig. 5.4) the species *Notoceras bicorne* clusters within the tribe Matthioleae (see below).

5.4.4. The mixed group

Janchen (1942) presented a phylogenetic network and indicated close relationships of Sisymbrieae with Arabideae and Lepidieae. Zunk et al. (1993) and Price et al. (1994) have shown that the boundaries between the tribes Lepidieae, Lunarieae, Sisymbrieae, Euclidieae, and Alysseae are highly artificial.

The results from previous studies of phylogenetic relationships (Galloway et al., 1998; Koch et al., 1999, 2000, 2001) demonstrated a close relationship among the tribes Sisymbrieae, Lepidieae and Arabideae.

Mitchell & Heenan (2000) presented phylogenetic relationships of some species from New Zealand Brassicaceae (ITS sequence) and indicated that the tribes Arabideae, Lepidieae and Sisymbrieae are polyphyletic.

The present results show some degree of similarity among the taxa of tribes Hesperideae, Sisymbrieae and Arabideae based on fruit type, fruit shape, number of seeds in fruit, fruit dehiscence, pollen shape and valve veines, and there is a close relationship between these tribes.

The Arabideae were divided by Hayek (1911) into seven subtribes and he placed *Arabidopsis, Arabis turrita, Cardaminopsis, Cardamine* and *Barbarea* into subtribe Cardamininae and placed *Arabis* and *Aubrieta* in subtribe Arabidinae.

Koch et al. (2000) investigated 28 species from the genera *Arabidopsis* and *Arabis*, and related taxa from tribe Arabideae, based on Chalcone synthase (Chs) and Alcohol dehydrogenase (Adh) loci and they confirmed that the genus *Arabis* is polyphyletic. Les (1994) separated *Nasturtium* as a genus very distinct from *Rorippa* based on the sequence of chloroplast DNA (rbcL), and indicated that *Nasturtium* is most closely related to the cosmopolitan genus *Cardamine* L.

Our UPGMA results show that the tribe Arabideae is separated into four branches: (1) *Nasturtium officinale* which separates from *Rorippa* based on the leaf structure, reticulate seed coats, hollow stem and fiberous rooting below, this result agrees with results of Les (1994), (2) a branch with *Arabis alpina*, (3) a branch with *Arabis nova,* (4) a branch combining *Rorippa indica, R. integrifolia* and *R. palustralis*. We consider the tribe Arabideae as the most heterogeneous of the tribes because we found the taxa from this tribe interspersed with taxa from tribes Sisymbrieae and Hesperideae.

In the tribe Hesperideae, there is some separation between species from different genera clustering within other genera such as *Erysimum* within *Malcolmia,* based on the radicle type and petals length, and *Morettia* species within *Eremobium* based mainly on the radicle type, but this character varies within the tribe. In the PCO analysis *Eremobium aegyptacum* (11, 12, 13) is rather well separated in the first axis (Fig. 5.2, 3), but the second axis is not separated (Fig. 5.4).

In the tribe Sisymbrieae, there is some degree of similarity among species such as a cluster of *Sisymbrium erysimoides, S. septulatum, S. irio* and *S. orientale* together mainly on the type of inflorescence (ebracteate) and another cluster of *Sisymbrium polyceratum, S. runcinatum* and *Neotorularia aculeolata* together based on petal length. *Descurainia sophia* and *Robeschia schimperi* are interspersed between different clusters.

In the tribe Matthioleae, the genus *Morettia* clusters within the genus *Eremobium* (Fig. 5.1), basically on the number of seeds in fruit, fruit type, fruit shape, fruit dehiscence and pollen shape. All species of *Morettia* cluster together within this subgroup. However, it does not cluster within tribe Matthioleae, which is based on the length of petals and sepals, simple, glandular, dendroid and stellate hairs, winged seeds, fruit with lateral horns and long fruits, while the genus *Morettia* has short sepals and petals, without glandular hairs, seed wings and lateral horns. The genus *Notoceras* clusters within the mixed group in UPGMA, but in PCO analysis it clusters within the tribe Matthioleae (Fig. 5.4), and clusters within the mixed group

(Fig. 5.3), because with the members of the tribe Matthioleae it shares (1) fruit type, (2) fruit dehiscence, and (3) fruit shape, while it shares (1) number of rows per locule, (2) number of seeds in fruit, (3) exine sculpture of pollen grains, (4) types of hairs, and (5) length of petals with other tribes.

5.5. CONCLUSIONS

The UPGMA and PCO analysis can be used to study the morphological variation within the tribe and the tribes within the family to determine the discontinuities between genera and tribes. Our results indicate that there is much separation between tribes Lunarieae, Euclidieae and all species of *Matthiola* and *Diceratella* of the Matthioleae, which seem to be distinct groups. However, there is also some degree of similarity among certain taxa of tribes Hesperideae, Sisymbrieae and Arabideae. We consider the tribe Arabideae the most heterogeneous of the tribes because we found the taxa from this tribe interspersed with taxa from tribes Sisymbrieae and Hesperideae.

We will reinvestigate these tribes with molecular data. This will enable a comparison of morphological results with molecular results.

6.

PHYLOGENETIC ANALYSIS OF BRASSICACEAE BASED ON PLASTID *MATK* SEQUENCES

(IMPLICATIONS FOR TAXONOMY OF BRASSICACEAE IN EGYPT)

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ABSTRACT

Phylogenetic relationships of 83 species of Brassicaceae belonging to 39 genera of the tribes Brassiceae, Alysseae, Arabideae, Euclidieae, Hesperideae, Lepidieae, Lunarieae, Matthioleae and Sisymbrieae, including 44 species belonging to 28 genera from Egypt were investigated using nucleotide sequences variation of the chloroplast *matK* gene to assess relationships among genera within tribes and tribes within the family. The topology of the trees from Parsimony Analysis, and Maximum Likelihood analysis are largely in agreement. The analysis indicates that the tribes Arabideae, Sisymbrieae, Hesperideae, and Lepidieae are polyphyletic. Our results support the association of *Ricotia lunaria* with *Maresia* and *Eremobium* rather than with *Alyssum* and *Lobularia*, as was suggested by previous authors. *Capsella* and *Neslia* are originally placed in tribe Lepidieae, but our data show that these two genera are closely related to *Arabidopsis* and *Olimarabidopsis*. Furthermore, our results support a monophyletic *Maresia* (*M. nana, M. pygmaea*), and suggest that species of this genus are not closely related to *Malcolmia* (*M. africana*). There are close relations among *Anastatica, Morettia, Diceratella*, and *Notoceras*; and among the members of *Matthiola, Leptaleum, Malcolmia,* and *Neotorularia torulosa.* Moreover, our results show that *Sisymbrium* taxa are closely related to *Octhodium* and they represent a monophyletic group. However, the *Nasturtium*/*Cardamine* clade is separated from a clade of *Rorippa*, and these results are in agreement with previous published (ITS and noncoding chloroplast analyses). Besides, our results showed that *Rorippa integrifolia* is very close to *Nasturtiopsis coronopifolia*, and this species may be a hybrid between *Rorippa* and *Nasurtiopsis.* Our phylogenetic analysis is mostly supporting the classification of genera in the system of Janchen with some modifications.

Key words: Brassicaceae, phylogenetic analysis, *mat*K.

6.1. INTRODUCTION

Brassicaceae comprise approximately 340 genera and more than 3350 species in almost 10 defined tribes, distributed throughout the world, chiefly in temperate regions of the northern hemisphere (Al-Shehbaz, 1984). The major centres of distribution of the family are in the Irano-Turanian, Mediterranean, and Saharo-Sindian regions (Hedge, 1976). It forms a strongly supported monophyletic group nested within the clade of mustard oil glucosides containing families, which can be treated as an expanded order Capparales based on the molecular sequences (*rbc*L) and morphological trait comparisons (Rodman et al. 1993, 1997).

Brassicaceae are morphologically rather homogeneous and systematically complex. The problems of classification emerge at two levels 1. On the suprageneric level, the natural links within the family cause difficulties for the grouping of the genera into tribes and subtribes. 2.

On the infrageneric level, the taxonomic problems relate to the differentiation of species within groups of closely related species, especially in large genera (Anchev & Deneva, 1997).

The tribal classification of the Brassicaceae is problematic because the characters traditionally used at this rank are few in a number, usually only one or two morphological characters. These are variable even within genera, or they conflict with one another in their distribution patterns among genera and tribes and may not support natural groups.

Bentham and Hooker (1862) recognized 10 tribes based on fruit length and cotyledon/radicle characters. Prantl (1891) in the Pflanzenfamilien used the indumentum characters and recognized four tribes. Hayek (1911) used nectar glands and myrosin cells and recognized 10 tribes. Schulz (1936) recognized 360 genera throughout the world and assigned these genera to 19 tribes based on nectar glands, fruit septum, position of cotyledons relative to the radicle, fruit-length, and indumentum. Janchen (1942) reduced the number of Schulz's tribes from 19 to 15. He united Schulz's tribes Hesperideae and Matthioleae under Hesperideae because he did not consider the differences of incumbent (Hesperideae) versus accumbent (Matthioleae) radicles of sufficient importance to separate tribes. He also united Schulz's tribes Alysseae, Lunarieae and Drabeae in Alysseae, because he did not believe that the details of cell structure in the septum were adequate for recognition of 3 independent tribes, and also transferred some genera from tribes into new tribes. Avetisian (1976, 1983) reduced Schulz's tribes to three tribes: Thelypodieae, Brassiceae and Sisymbrieae. Clement and Hernandez-Bermejo (1980a, 1980b and 1980c) studied 145 taxa, belonging to 41 genera of the tribe Brassiceae growing in the Mediterranean region, and divided this tribe into 7 groups based on characters of calyx, corolla and nectaries. Al-Shehbaz (1984) classified the family Brassicaceae of the southeastern United States into 7 tribes based on the morphological characters of fruit, sepals, stamens and the position of cotyledons relative to the radicle.

In the flora of Egypt, Brassicaceae are one of the four largest plant 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 (63 species belonging to 32 genera) have been the subject of earlier studies (El Naggar, 1987, 1992, 1993; El Naggar & El Hadidi, 1998). The remaining Brassicaeae, belonging to the tribes Arabideae, Euclideae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae (O.E. Schulz's system, 1936) count 39 species in 23 genera exhibiting great diversity and are studied in the present work.

Price et al. (1994); Abdel Kalik et al., this thesis, suggested that tribal and generic classifications of the Brassicaceae based on morphological characters need to be revised using molecular data.

A first analysis using plastid DNA markers demonstrated that tribal relationships might be highly artificial (Price et al. 1994). They studied 8 taxa from 4 tribes by using *rbc*L sequences variation, and 5 tribes (19 taxa) were considered using chloroplast DNA restriction site variation. They demonstrated that the tribe Thylypodieae is close to Sisymbrieae and Brassiceae to some taxa from Lepidieae, and that the tribes Arabideae and Sisymbrieae are highly artificial. Galloway et al. (1998) and Koch et al. (1999, 2000, 2001) demonstrated a close relationship among the tribes Sisymbrieae, Lepidieae and Arabideae.

Miyashita et al. (1998) investigated a different set of 13 crucifers concentrating on tribe Arabideae and the genera *Arabidopsis* and *Arabis*. They concluded that *Arabidopsis* is not monophyletic and proposed that *Arabidopsis* should be split into several genera.

Mitchell & Heenan (2000) presented phylogenetic relationships of some species from New Zealand Brassicaceae (ITS sequence) and indicated that the tribes Arabideae, Lepidieae and Sisymbrieae are polyphyletic. Koch et al. (1999) showed that some taxa from tribe Lepidieae are closer related to the taxa from tribe Arabideae than to tribe Lepidieae. Zunk et al. (1999) studied some taxa from Lepidieae based on chloroplast DNA and supported the classification of genera in the Hayek (1919) system. Mummenhoff et al. (2001) sequenced the chloroplast DNA from 73 species of Lepidium and found that only a few of the taxa delimited in the traditional systems represented monophyletic lineages, and they proposed three main lineages, one of them including almost all *Lepidium* species.

Koch et al. (2000) investigated 28 species from the genera *Arabidopsis* and *Arabis*, and related taxa from tribe Arabideae, based on Chalcone synthase (*Chs*) and Alcohol dehydrogenase (*Adh*) loci and they confirmed that the genus *Arabis* is polyphyletic. Les (1994) separated *Nasturtium* as a genus very distinct from *Rorippa* based on the sequence of chloroplast DNA (*rbc*L), and indicated that *Nasturtium* is most closely related to the cosmopolitan genus *Cardamine* L.

The chloroplast *matK* gene encodes a maturase and is located within the *trn*K intron (Neuhaus & Link, 1987). It evolves nearly two to three times faster than *rbc*L (Johnson & Soltis, 1994, 1995; Steele & Vilgalys, 1994). *MatK* sequences have been used successfully to resolve inter- and infrafamilial phylogenetic relationships at the ordinal (Cuenoud et al., 2002), tribal and subtribal level (Hilu & Alice, 2001; Koch et al., 2001). The *matK* is a popular choice for plant systematic studies in intergeneric relationships (Johnson et al., 1996; Mort et al., 2001; Cameron et al., 2001), and it has been found to resolve phylogenetic relationships at varietal, specific, and subgeneric level (Johnson & Soltis, 1994, 1995; Hilu & Liang, 1997; Gravendeel et al., 2001).

The aim of this study was: (1) to investigate the phylogenetic relationships within the family, (2) to evaluate taxonomic status of taditional tribes (sensu previous authors) in Egypt based on chloroplast DNA sequences.

6.2. MATERIAL AND METHODS

6.2.1. Plant material

A total of 83 species belonging to 39 genera of tribes Brassiceae, Alysseae, Arabideae, Euclidieae, Hesperideae, Lepidieae, Lunarieae, Matthioleae and Sisymbrieae of Brassicaceae, including 44 species belonging to 28 genera from Egypt were investigated. Brassicaceae from outside of Egypt, and from the tribes to which the Egyptian taxa belong, have been included to give a broader context for relationships of the Egyptian genera and to make the phylogenetic reconstruction more effective. For some taxa, material from Egypt was not available and specimens from other countries were used. Sources of plant material are listed in Table 6.1. Some samples were collected in botanical gardens, some in the field, and a number of samples were taken from herbarium specimens. Thirty-nine Egyptian species were sequenced and an additional 44 sequences were obtained from GenBank. *Aethionema grandiflora* served as outgroup. This species has already been shown on the molecular level to be only distantly related to other crucifers (Zunk et al., 1996; Galloway, Malmberg, and Price, 1998; Koch et al., 1999, 2001). In addition we used two taxa from the Saxifragaceae as outgroups in order to confirm that *Aethionema grandiflora* is appropriate as outgroup. Traditionally *Aethionema* is placed in tribe Lepidieae (Hayek, 1911; Schulz, 1936; Janchen, 1942).

6.2.2. DNA extraction, amplification, and sequencing

Extraction. Total genomic DNA was extracted from fresh leaves, herbarium specimens, or silica-gel dried leaves (0.1–0.5 g) using the modified CTAB extraction protocol of Doyle & Doyle (1987). With addition of one extra centrifugation step (13,000 rpm for 1 min) and decanting of the supernatant prior to the addition of 2.5 volumes of cold ethanol in order to remove undissolved particles.

Amplification was performed in a volume of 50 µL containing 5–20 ng genomic DNA, 0.5 µM of each primer, 200 µM of each dNTP, 4 µM $MgCl_2$, 16 mM $(NH_4)_2SO_4$, 67 mM Tris-HCl, 0.1% Tween-20, and 2 units Taq Polymerase. The first 650 bp of the *matK* gene were amplified with primers trnK-710F (5'- CGCACTATGTGTCATTTCAGAACTC-3') and *matK*-495R (5'- CTTGGTTCAAACCCTACGTTACCG-3') (Koch et al. 2001). The profile for 28 cycles of amplification was: 1 min at 94°C, 1 min at 50°C and 2 min at 72°C, followed by one cycle of 10 min at 72°C. After visual inspection on a 1%-agarose gel, fragments were cleaned using Quiaquick™ columns following the manufacturer's protocol and eluted in 30 µL Nanopure™ water.

Sequencing. Cleaned fragments were sequenced using fluorescent dye-labelled ddNTPs using the ABI PRISM™ Dye Terminator Cycle Sequencing Ready Reaction Kit from Perkin Elmer according to the manufacturer's instructions. Sequencing reactions were purified over Sephadex and analysed on an ABI PRISM® 3700 DNA Analyzer (96 capillaries) at Greenomics™.

Sequence Alignment

Sequences were assembled, edited and aligned using the LaserGene™ package (DNASTAR Madison, Wisconsin). The CLUSTAL option was used for initial alignment, which was followed by manual adjustment. The data alignments are available from the first author upon request: e-mail:Kadry.ElsayedAbdelKhalik@wur.nl.

6.2.3. Phylogenetic analysis

Phylogenetic analysis was carried out using both a maximum Parsimony and a Bayesian/Maximum likelihood analyses. Parsimony analyses and tests for clade support were performed using PAUP* 4.0b10 PPC/Altivec (Sowfford, 2001) running on a G4 Power Macintosh computer. Bayesian/Maximum likelihood-based phylogenetic analysis was performed using Mr. Bayes 2.0 (Huelsenbeck & Ronquist, 2001) running on a pentium III PC.

Maximum Parsimony

Heuristic searches involved TBR branch swapping, MULPARS, and COLLAPSE branches when maximum length is zero. Starting trees were generated by 10 cycles of random addition sequence (RAS) holding 2 trees at each step.

Jackknife analysis was carried out using PAUP* with settings so as to emulate Parsimony Jackknifer (Farris et al., 1996), i.e., percentage of characters deleted in each replicate = 37, 'fast' stepwise addition and "Jac" resampling method used.

Bayesian analyses

Bayesian phylogenetic analyses (aiming for stationarity of log-likelihood of trees after running a Markov chain) were performed using the GTR model (Yang 1994). Model parameters were not defined prior to the analyses but in stead were estimated as part of the analysis. All Bayesian analyses were initiated with random starting trees and were run for 2×10^6 generations. The Markov chains were sampled at intervals of 100 generations resulting in 20,000 trees, from which a 50% majority rule consensus tree was calculated.

6.3. RESULTS

Phylogenetic analysis

The final *matK* alignment used in this study contained 83 sequences (including the outgroup *Aethionema*), 44 taxa of which were obtained from GenBank (see table 6.1). After excluding parts of the alignment for which for many taxa data was missing, 482 nucleotide positions were retained corresponding to position 1-463 of the *matK* gene sequence. A deletion of two amino acids was observed at nucleotide positions 262–267 for all included species of *Sisymbrium* and for *Rorippa integrifolia*, *Ochtodium aegypticum*, *Neotorularia aculeolata*, *Nasturtiopsis coronopifolia, Brassica nigra*, *Sinapis alba* and *Arabis blepharopsis*. Indel (6 bp) was coded as a binary character and added to the matrix. The final data set therefore contained 483 characters of which 247 were variable, 143 (including indels) of which were parsimony informative.

Maximum parsimony

Jackknife analysis showed moderate to high supporting for the main clades (see fig 6.1), the relation among of them remains unresolved. Heuristic search yielded 46817 equally most parsimonious trees (MPTs) of 520 steps long, all originating from a single tree island. Consistency index (CI) and Retention index (RI) of these trees were 0.64 and 0.75 respectively. Their semistrict consensus tree supplemented with jackknife values (only values higher than 50% are shown) is presented in fig 6.2. One of the 46817 MPTs is shown in phylogram style in fig 6.3, in which it is clear that *Notoceras bicorne* has an unusually long branch. After translation of this sequence the resulting amino acid sequence contained several stop-codons indicating that this part of the *Notoceras bicorne matK* sequence is most likely non-functional, hence explaining the high number of nucleotide substitutions and therefore the long branch length. The heuristic and jackknife search was repeated exluding the *Notoceras bicorne* sequence, but this did not produce different topologies. Therefore we conclude that the topologies found including *Notoceras* are not influenced by long branch attraction arte facts.

Maximum likelihood analysis (Bayesian anayses)

After running the Markov chain for 2×10^6 generations it appeared that stationarity of the log-likelihood values (-541.81) had already been reached after appr. 500 generations. These first 500 “burn-in” samples were removed after which from the remaing 19,500 trees the 50% majority-rule consensus tree was calculated (fig 6.4). The GTR model parameters (relative rates of the six different substitution types) at stationarity were: rCT = 1.56, rCG = 1.07, rAT = 0.30, rAG = 1.75, rAC = 1,92 (rGT was set to 1.0).

The topology of the 50 % majority rule consensus tree is largely in agreement with the parsimony tree.

Table 6.1. List of species analysed.

Taxon	Source/ Voucher	Origin	GenBank no.
1. *Aethionema grandiflora* L.	s.n.	Germany, Botanic Garden Jena	AF144354
2. *Alliaria petiolata* L.	Koch s.n.	Germany, Jena, Thüringen	AF144363
3. *Alyssum simplix* Rudolphi	Lippert 21834	Morocco, Oujda, 5 km W El Aioun	
4. *Anastatica hierochuntica* L.	Abdel Khalik 35 (WAG)	the Netherlands,Wageningen Botanical Gardens	
5. *Arabidopsis halleri* (L.) O'Kane and Al-Shehbaz	Koch s.n.	Germany, NRW, Blankenrode	AF144341
6. *Arabidopsis lyrata* (L.) O'Kane and Al-Shehbaz	Savoleinen	Sweden, SWE94	AF144331
7. *Arabidopsis lyrata* (L.) O'Kane and Al-Shehbaz	Koch s.n.	Germany, Bavaria, Neuhaus, Pfaffenhofen	AF144336
8. *Arabidopsis lyrata* (L.) O'Kane and Al-Shehbaz	Mitchel-Olds	USA, MA, Birkshire City, Bash-Bish	AF144342
9. *Arabidopsis thaliana* (L.) Hayek	Koch s.n.	Germany, Lower Saxony, Hagen a.T.W	AF144348
10. *Arabis alpina* L.	s.n.	Kenya, Mt. Kenya, Teleky valley, Botanical Garden	AF144328
11. *Arabis alpina* L. sub sp. *caucasica* (Willd.) Briq.	Koch s.n.	Germany, Pottenstein near Bayreuth, Bavaria.	AF144329
12. *Arabis blepharophylla* Hook. et Arn.	Bishop	USA, CA, Sonoma City, Bodega Marine Lab.	AF144353
13. *Arabis divaricarpa* A. Nels.	Roy	USA, COL, Gunnison City, Gold Creek	AF144351
14. *Arabis drummondii* A. Gray	Stotz	USA, WY, Teton City, near Jenny Lake	AF144343
15. *Arabis hirsuta* (L.) Scop.	Koch s.n.	Germany, NRW, Lengerich	AF144338
16. *Arabis pumila* Jacq.	s.n.	Germany, Jena, Botanical Garden	AF144340
17. *Arabis lignifera* A. Nels.	Marler	USA, UT, Rich City	AF144344
18. *Arabis lyallii* S. Wats.	Mitchel-Olds	USA, MT, Walton Lake	AF144332
19. *Arabis nova* Vill.	Danin et al. 48. 014 (B).	Syria, Golan, Odem forest, near Masaada	
20. *Arabis parishii* S. Wats.	Marler	USA, CA, San Bernadino City, San Bernadino Mts	AF144349
21. *Arabis procurrens* Waldstein et Kit.	s.n.	Germany, Jena, Botanical Garden	AF144339
22. *Arabis turrita* L.	s.n.	Germany, Botanical Garden Berlin-Dahlem	AF144347
23. *Aubrieta deltoidea* (L.) DC.	s.n.	Germany, Botanical Garden Jena	AF144352
24. *Barbarea vulgaris* R. Br.	Koch s.n.	Germany, Lower Saxony, Hasbergen	AF144330
25. *Brassica nigra* (L.) Koch	Seegeler 3404 (WAG)	the Netherlands,Wageningen botanical gardens	
26. *Capsella bursa-pastoris* (L.) Medik.	Abdel Khalik 36 (WAG)	Wageningen	
27. *Capsella rubella* Reuter	Hurka 774	Germany, University Osnabrück	AF144334
28. *Cardamine amara* L.	Koch s.n.	Germany, Lower Saxony, Hagen a.T.W.	AF144337
29. *Cardamine penzesii*	Marhold	Bulgaria, near Jasna Poljana, Black Sea coast	AF144364
30. *Cardamine rivularis* Schur.	Marhold	Bulgaria, Zeleznica, Mt. Vitosa	AF144365
31. *Cochlearia danica* L.	Koch s.n.	Germany, Lower Saxony, Borkum	AF174531

Table 6.1. continued

Taxon	Source/ Voucher	Origin	GenBank no.
32. *Cochlearia pyrenaica* L.	Koch s.n.	Germany, NRW, Alme	AF144357
33. *Crucihimalaya kneuckeri* (Bornm.) Al-Shehbaz, O'Kane & Price	Podlech 49785 (CAI)	Egypt, Sinai, E slopes of Gebel Catherine	
34. *Crucihimalya himalaica (Edgeworth)* Al-Shehbaz, O'Kane & Price	s.n.	Japan, Sendai, Miyagi University, Sendai Arabidopsis Seed Center	AF144356
35. *Crucihimalya wallichii* (J.D. Hooker & Thompson) Al-Shehbaz, O'Kane & Price	s.n.	Japan, Sendai, Miyagi University, Sendai Arabidopsis Seed Center	AF144367
36. *Descurainia sophia* (L.) Webb & Berth.	5978/2	Morocco, Timahdite (BM)	
37. *Diceratella eliptica* (DC.) Jonsell	Abdel Khalik 17 (SHG)	Egypt, Gebel Elba, Wadi el Shallal	
38. *Eremobium aegyptiacum* (Spreng.) Asch. & Schweinf. subsp. *aegyptiacum*	Abdel Khalik 29 (SHG)	Egypt, El Arish area beside the Airport, N. Sinai	
39. *Erysimum repandum* L.	Vasak s. n (BR)	Turkey, Antalya, near Doyran	
40. *Fourraea alpina* (L.) Greut. & Burd.	Koch s.n.	Germany, Jena, Thüringen	AF144335
41. *Halimolobus perplexa* (Henderson) Rollins	Mitchel-Olds	USA, ID, Adams City	AF144346
42. *Inopsidium abulense* (Pau.) Rothm.	Gomez-Campo 604-68	Spain, Madrid, Avila	AF144368
43. *Inopsidium prolongoi* (Boiss.) Batt.	Gomez-Campo 2234-73	Spain, Madrid, Cadiz	AF144369
44. *Lepidium campestre* L.	Koch s.n.	Germany, NRW, Brochterbech	AF144359
45. *Leptaleum filifolium* (Willd.) DC.	Bouharmont 27296 (BR)	Syria, Maaloula	
46. *Lobularia maritima* L.	Jongkind & Nieuwenhuis 4241 (WAG)	Spain, Alicante, Sierra de Bernia	
47. *Malcolmia africana* (L.) R.Br.	Abdel Khalik 2 (SHG)	Egypt, Deir el Rahba, Wadi el Arbain, S. Sinai	
48. *Malcolmia nana* (DC.) Boiss.	Abdel Khalik 28 (SHG)	Egypt, El Arish-Rafah road, 23 km from El Arish	
49. *Malcolmia pygmaea* (Del.) Boiss.	Abdel Khalik 22 (SHG)	Egypt, 26 km, Sidi Krer, Alex.-Matruh coastal road	
50. *Matthiola arabica* Boiss.	Abdel Khalik 12 (SHG)	Egypt, Wadi el Arbaien, S. Sinai	
51. *Matthiola fruticulosa* (L.) Maire	S. Jury 14495 (BM)	Morocco, road to Ouarzazate, Kourkouda	
52. *Matthiola incana* (L.) R. Br.	s.n.	Germany, Botanical Garden Jena	AF144361
53. *Matthiola longipetala* (Vent.) DC. subsp. *longipetala*	Abdel Khalik 25 (SHG)	Egypt, 28 km before Matruh, Alexandria-Matruh Road	
54. *Matthiola parviflora* (Schousboe) R.Br.	Lewalle 12516 (BR)	Morocco, Tazrourt	
55. *Microthlapsi perfoliatum* (L.) F. Meyer	Koch	Germany, Lower Saxony, Bad Later	AF144362
56. *Morettia canescens* Boiss.	Abdel Khalik 10 (SHG)	Egypt, Wadi Feiran, S. Sinai	
57. *Morettia parviflora* Boiss.	Ghazanfar 1753 (BR)	Oman, Wadi Mistal, Ghubrah Bowl	

Table 6.1. continued

Taxon	Source/ Voucher	Origin	GenBank no.
58. *Morettia philaeana* (Delile) DC.	Abdel Khalik 3 (SHG)	Egypt, 35 km from Qena at the road Qena-Safaga	
59. *Nasturtiopsis coronopifolia* (Desf.) Boiss.	Danin et al. 27024 (B)	Israel, south Negev, Nahal Paran	
60. *Nasturtium officinale* R.BR.	Leeuwenberg 9950 (WAG)	Cameroun, Manengouba Mts.	
61. *Neotorularia aculeolata* (Boiss.) Hedge & Léonard	Léonard 5801 (BR)	Iran, West of Jaz Murian	
62. *Neotorularia torulosa* (Desf.) Hedge & Léonard	Bouharmont 27393 (BR)	Syria, Palmyra	
63. *Neslia paniculata* (L.) Desv.	Gavin Stark 1095 (NMGM)	Morocco, Taza	
64. *Notoceras bicorne* (Ait.) Caruel	Al-Farhan 10162 (KSU)	Saudi Arabia, Riyadh	
65. *Ochthodium aegyptiacum* (L.) DC.	Danin et al. 44. 015 (B)	Syria, Golan, Qazrin	
66. *Olimarabidopsis cabulica* (J.D. Hooker & Thompson) Al-Shehbaz, O'Kane & Price	s.n.	Japan, Sendai, Miyagi University, Sendai Arabidopsis Seed Center	AF144358
67. *Olimarabidopsis pumila* (Stephan) Al-Shehbaz, O'Kane & Price	CS 3701 (ABRC)	Ohio State University	AF144345
68. *Ricotia lunaria* (L.) DC.	Danin et al. 45. 004 (B)	Syria, Golan, Park forest	
69. *Robeschia schimperi* (Boiss.) Schulz	Schimper 170 (B)	Egypt, Mountains Sinai, between granitic rocks	
70. *Rorippa amphibia* (L.) Besser	Koch s.n.	Germany, NRW, Worringer Bruch near Cologne	AF174530
71. *Rorippa indica* (L.) Hiern	Fawzy s.n. (SHG)	Egypt, Qena, El Mahrosa island	
72. *Rorippa integrifolia* Boulos	Abdel Khalik 9 (SHG)	Egypt, Middle of Sinai, about 5 km before Ras Sedr	
73. *Rorippa palustris* (L.) Besser	Koch s.n.	Germany, Hagen a.T.W., Lower Saxony	AF144355
74. *Schimpera arabica* Hochst & Steud.	Batanouny s. n.(CAI)	Saudi Arabia, As Summan	
75. *Sinapis alba* L.	From EMBL database		X04826
76. *Sisymbrium erysimoides* Desf.	Abdel Khalik s.n. (WAG)	the Netherlands, Wageningen Botanical Gardens	
77. *Sisymbrium irio* L.	SENDAI Arabidopsis Seed Center, JOS 18	Japan, Sendai, Miyagi University	AF144366
78. *Sisymbrium orientale* L.	Abdel Khalik 11 (SHG)	Egypt, S. Sinai, Deir Feiran, Wadi Feiran	
79. *Sisymbrium polyceratum* L.	Sam Segal 585+ (WAG)	Fance, Asco, Island of Cornica	
80. *Sisymbrium runcinatum* Lag. ex DC.	Gavin Stark 267 (NMGM)	Morocco, Qsar Es Sour	
81. *Sisymbrium septulatum* DC.	Täckholm et al. s. n (CAI)	Egypt, S. Sinai, Wadi Ferieh	
82. *Thlaspi arvense* L.	Koch s.n.	Germany, Lower Saxony, Hagen a.T.W	AF144360
83. *Turritis glabra* L.	Koch s.n.	Germany, NRW, Niedersteinbeck	AF144333

Within this analysis (figs. 6.2, 6.4), genera of Brassicaceae are found in nine separate clades. These include (with their jackknife support between brachets): (1) *Arabidopsis, Turritis, Olimarabidopsis, Neslia, Capsella, Erysimum repandum, Arabis, Halimolobus* and *Crucihimalaya* (64%); (2) *Lepidium, Cardamine, Barbarea, Nasturtium officinale, Rorippa indica, R. palustaris, R. amphibia, Descurainia sophia,* and *Robeschia schimperi* (<50%); (3) Species of *Matthiola, Leptaleum, Malcolmia africana*, and *Neotorularia torulosa* (61%); (4) *Arabis species and Aubrieta* (84%); (5) *Fourraea*, *Sinapis alpa, Brassica nigra, Nasturtiopsis coronopifolia, Rorippa integrifolia, Neotorularia aculeolata, Octhodium*, all species of *Sisymbrium,* and *Schimpera arabica* (54%); (6) *Thlaspi* and *Alliaria* (71%); (7) *Cochlearia* and *Inopsidium* (71%); (8) *Anastatica, Diceratella*, all species of *Morettia, Notoceras*, *Lobularia* (<50%); (9) *Eremobium, Ricotia, Malcolmia nana, M. pygmaea* (93%). *Microthlaspi, Alyssum simplix*, and *Arabis turrita* form separate clades with low (<50%) support.
The Egyptian genera (44 taxa) are indicated in bold font.

6.4. DISCUSSION

1. Phylogenetic relationships among Brassicaceae tribes

Since the first comprehensive treatments of the Brassicaceae, this family has been divided into various tribes (see table 6.2). Although there is no doubt about the monophyly of the whole family (Rodman et al. 1998), the tribal subdivision of the family has been investigated for numerous examples such as tribes Lepidieae, Lunarieae, Sisymbrieae, Euclidieae, Arabideae, and Alysseae, and is shown to be highly artificial (Zunk et al. 1993; Price et al. 1994; Abdel Khalik et al., 2002, this thesis), and often the subtribal grouping of genera does not reflect phylogenetic relationships (Koch et al. 1999).
Our phylogenetic studies demonstrated close relationships among the tribes Sisymbrieae, Lepidieae and Arabideae, because we found taxa from tribe Lepidieae (*Capsella, Neslia,* and *Thlaspi*) joined with members of tribes Arabideae and Sisymbrieae, and these results agree with previous results (Galloway et al., 1998; Koch et al., 1999; Koch et al., 2000, 2001). We found close relationships between Alysseae and Hesperideae, because we showed *Ricotia* and *Lobularia* are interspersed with members of Hesperideae (see figs. 6.2, 6.4).
The members of the tribe Brassiceae are combined in one clade (90%), and this clade is combined with *Rorippa integrifolia, Nasturtiopsis,* and *Neotorularia aculeolata* with high support (81%). These results are congruent with those of Koch et al. (2001) in combining members of Brassiceae with members of the tribes Sisymbrieae and Arabideae. The polyploidization within Brassiceae (Lagercrantz, 1998) is the major force for speciation within this group.

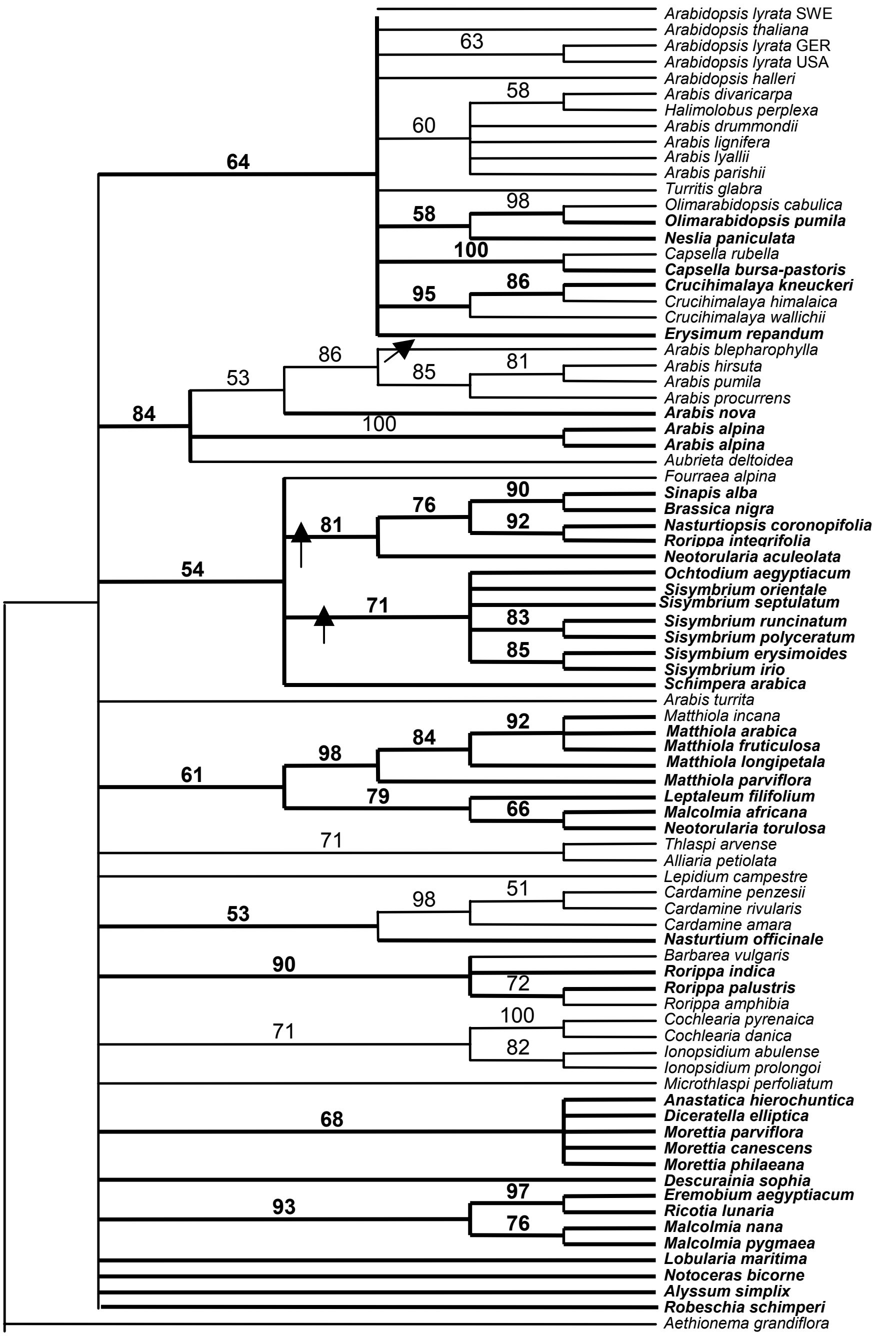

Fig. 6.1. Jackknife tree of the Brassicaceae *matK* data set. Percentage value > 50% are indicated above branches for 10,000 replicates. Arrows refer to the distribution of indel (2-amino acids) on the clades in which it is found.

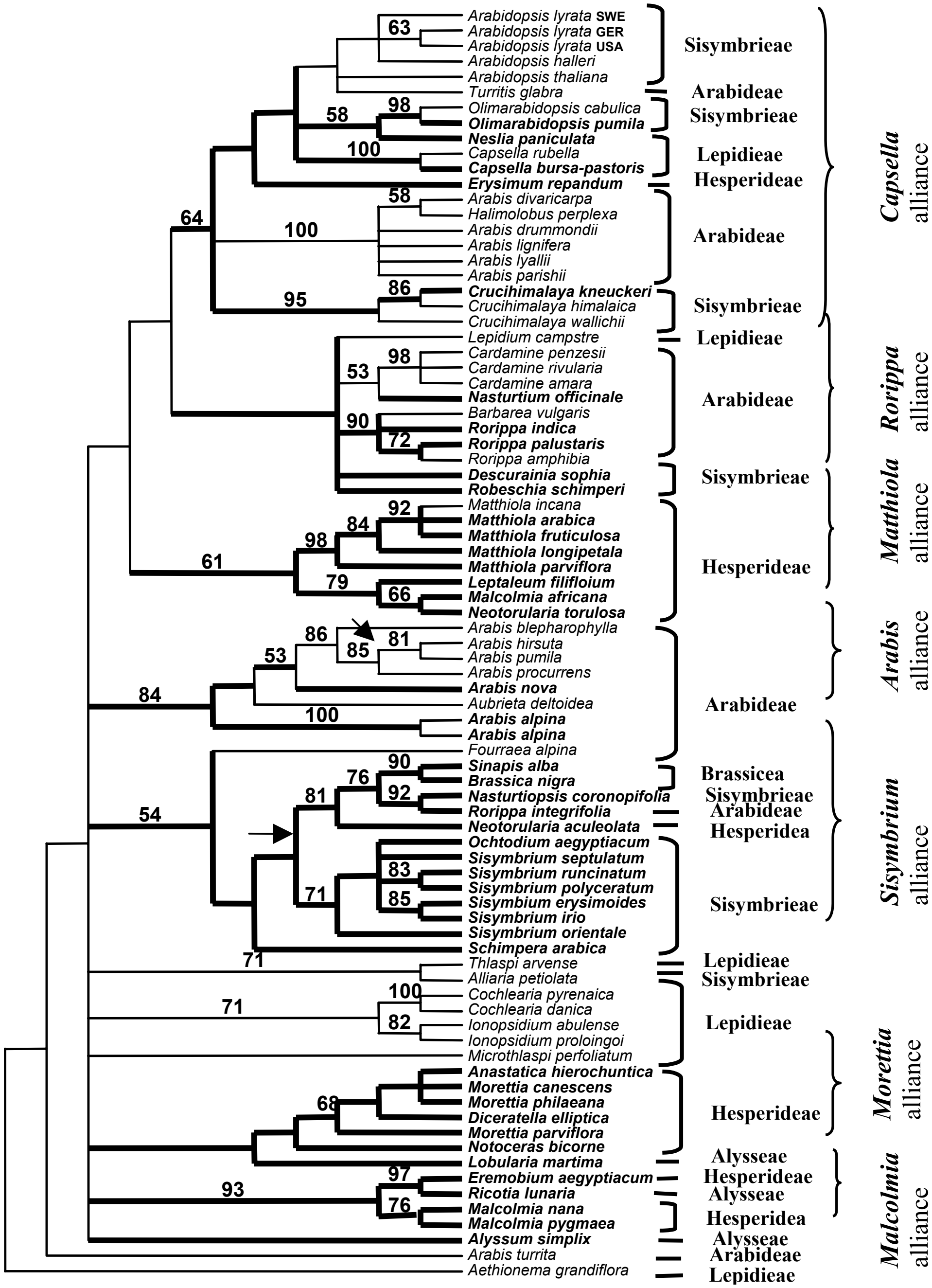

Fig. 6.2. Semistrict consensus of 46817 most parsimonious trees of length 520 (CI= 0.64, RI= 0.75) for Brassicaceae *matK,* jackknife percentages (10,000 replicatess) above 50% are indicated above branches. Tribal level assignments according to Janchen (1942), genus alliances are indicated between brackets.

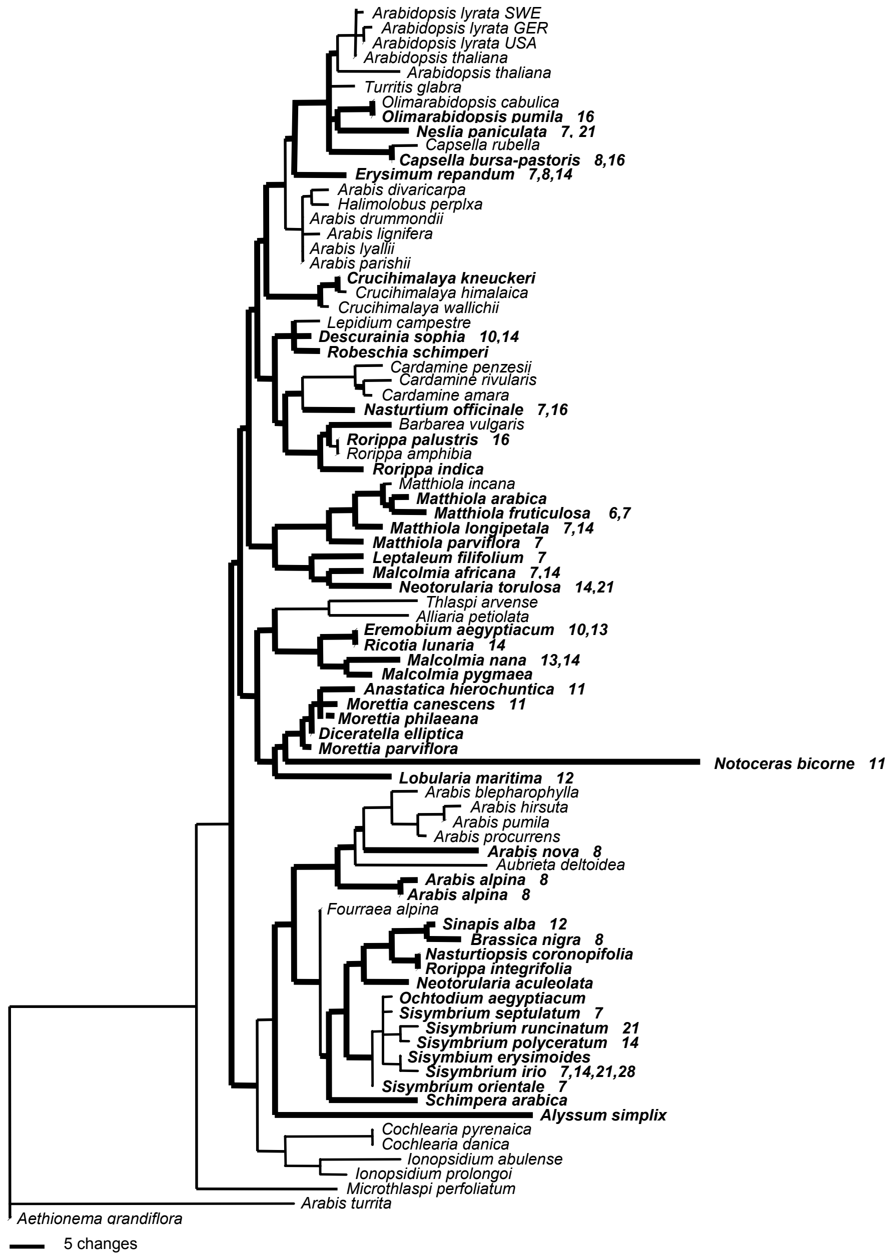

Fig. 6.3. One of 46817 most parsimonious trees (L= 520, CI=0.64, RI= 0.75) for Brassicaceae derived from the analysis of *matK,* to show branch lengths (number of nucleotides substitutions) for all taxa (included *Notoceras bicorne*), and chromosome numbers are indicated after species names.

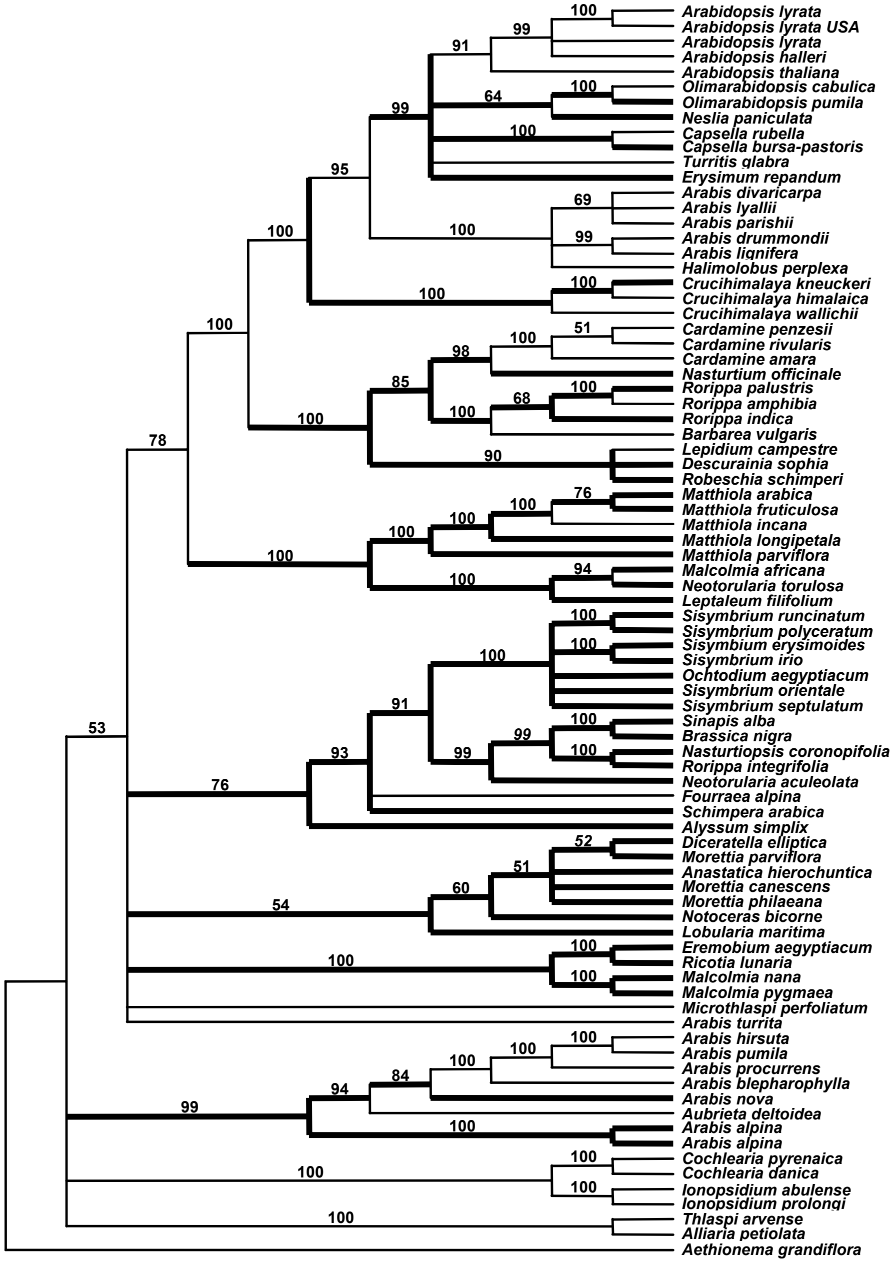

Fig.6.4. Majority rule consensus tree of 19,500 trees resulting from the Bayesian analysis of Brassicaceae *matK* data. Numbers indicated above branches represent the posterior probability that the taxa in the corresponding subtree form a clade.

The tribe Sisymbrieae as treated traditionally consists of at least three major lineages: (1) *Arabidopsis, Olimarabidopsis* and *Crucihimalaya*, (2) *Descurainia* and *Robeschia,* (3) *Octhodium, Schimpera,* and *Sisymbrium*, in addition to taxa interspersed within another tribes such as *Nasturtiopsis* and *Allaria*. Our results do not support monophyly of Sisymbrieae, and these results are congruent with previous results which have shown this tribe to be polyphyletic (Mitchell & Heenan, 2000).

The tribe Arabideae was divided by Hayek (1911) into seven subtribes and he put *Arabidopsis, Arabis turrita, Cardaminopsis* (*Arabidopsis lyrata, A. halleri, A. suecica*), *Cardamine, Barbarea* into the subtribe *Cardamininae,* and merged *Arabis, Aubrieta* into the subtribe Arabidinae.

Our results disagree with this, because we found *Arabidopsis, Cardaminopsis,* and part of *Arabis* together in one clade; *Cardamine, Nasturtium, Rorippa, Barbarea* in another clade; the rest of *Arabis* in another clade; and *Arabis turrita* in a separate clade. Janchen (1942) placed *Arabidopsis* in subtribe Arabidopsidinae of Sisymbrieae, and put *Cardamine, Rorippa, Barbarea*, and *Nasturtium* in subtribe Cardamininae, and this agrees with our results. On the other hand, he placed all species of *Arabis, Aubrieta, Cardaminopsis* in subtribe Arabidinae, but this is not congruent with our results. Koch et al. (2000) investigated 28 taxa from *Arabis* and *Arabidopsis,* and related taxa from Arabideae based on Chs and Adh, and they confirmed that *Arabis* is polyphyletic, and our results are congruent with these results and suggest that Arabideae is polyphyletic.

The tribe Hesperideae is distributed within three clades: (1) *Matthiola, Leptaleum, Malcolmia africana, Neotorularia torulosa*, (2) *Anastatica, Morettia, Notoceras*, (3) *Eremobium, Malcolmia pygmaea, M. nana*; and some taxa interspersed within other tribes like *Erysimum*, and *Neotorularia aculeolata.*

The members of the tribe Brassiceae are combined in one clade (90%), and this clade is combined with *Rorippa integrifolia, Nasturtiopsis,* and *Neotorularia aculeolata* with high support (81%). These results are congruent with those of Koch et al. (2001) in combining members of Brassiceae with members of the tribes Sisymbrieae and Arabideae. The polyploidization within Brassiceae (Lagercrantz, 1998) is the major force for speciation within this group.

The tribe Sisymbrieae as treated traditionally consists of at least three major lineages: (1) *Arabidopsis, Olimarabidopsis* and *Crucihimalaya*, (2) *Descurainia* and *Robeschia,* (3) *Octhodium, Schimpera,* and *Sisymbrium*, in addition to taxa interspersed within another tribes such as *Nasturtiopsis* and *Allaria*. Our results do not support monophyly of Sisymbrieae, and these results are congruent with previous results which have shown this tribe to be polyphyletic (Mitchell & Heenan, 2000).

The tribe Arabideae was divided by Hayek (1911) into seven subtribes and he put *Arabidopsis, Arabis turrita, Cardaminopsis* (*Arabidopsis lyrata, A. halleri, A. suecica*), *Cardamine, Barbarea* into the subtribe *Cardamininae,* and merged *Arabis, Aubrieta* into the subtribe Arabidinae.

Our results disagree with this, because we found *Arabidopsis, Cardaminopsis,* and part of *Arabis* together in one clade; *Cardamine, Nasturtium, Rorippa, Barbarea* in another clade; the rest of *Arabis* in another clade; and *Arabis turrita* in a separate clade. Janchen (1942) placed *Arabidopsis* in subtribe Arabidopsidinae of Sisymbrieae, and put *Cardamine, Rorippa, Barbarea*, and *Nasturtium* in subtribe Cardamininae, and this agrees with our results. On the other hand, he placed all species of *Arabis, Aubrieta, Cardaminopsis* in subtribe Arabidinae, but this is not congruent with our results. Koch et al. (2000) investigated 28 taxa from *Arabis* and *Arabidopsis,* and related taxa from Arabideae based on Chs and Adh, and they confirmed that *Arabis* is polyphyletic, and our results are congruent with these results and suggest that Arabideae is polyphyletic.

The tribe Hesperideae is distributed within three clades: (1) Matthiola, Leptaleum, Malcolmia africana, Neotorularia torulosa, (2) Anastatica, Morettia, Notoceras, (3) Eremobium, Malcolmia pygmaea, M. nana; and some taxa interspersed within other tribes like Erysimum, and Neotorularia aculeolata. Janchen (1942) placed Matthiola and Notoceras in the subtribe Matthiolinae, and merged Leptaleum, Malcolmia, Maresia (Malcolmia nana, M. pygmaea), Malcolmia, Erysimum, Eremobium, Torularia (Neotorularia), Morettia (Hesperis) in the subtribe Hesperidinae; and placed Anastatica in subtribe Euclidinae. Schulz (1936) divided these taxa over three tribes, placing Matthiola, Morettia, Notoceras in tribe Matthioleae, and Malcolmia, Maresia, Leptaleum, Erymobium in the tribe Hesperideae, and Anastatica with other taxa in tribe Euclideae, based on the fruit type and position of radicle/cotyledons. Our results contradict these traditional treatments (Schulz, 1936) and are congruent with treatments suggested by Janchen (1942), and suggest that the tribe Hesperideae is polyphyletic.

Within the tribe Lepideae, our results show that the representative taxa from this tribe are separated in one clade or with other genera from other tribes: *Cochlearia* and *Inopsidium* (71%); *Thlaspi, Micothlaspi, Lepidium, Capsella, Neslia* are distributed with other genera. Our results agree with previous phylogenetic analyses which showed that Lepideae as treated traditionally, consists of at least three major lineages (Bowmann et al., 1999; Zunk et al., 1999; Mitchell & Heenan, 2000; Koch et al., 2001). Within this analysis *Capsella* is closely related to *Olimarabidopsis* (*Arabidopsis*) and *Arabis*, which is also closely related to *Neslia* and this result is congruent with phylogenetic results of (Zunk et al., 1999; Yang et al., 1999; Koch et al., 2000).

Lobularia, Ricotia, and *Alyssum* are the only representatives of the Alysseae included in this study. *Lobularia* is nested with members from tribe Hesperideae but with low support. *Ricotia* is included with other members from Hesperideae with high support, while *Alyssium* forms a separate clade. *Alyssum* and *Lobularia* were placed in tribe Alysseae (Hayek, 1919; Schulz, 1936; Janchen, 1942), and *Ricotia* in tribe Alysseae by Hayek (1919) and Janchen (1942), and in tribe Lunarieae by Schulz (1936). Our phylogenetic results do not agree with the classification proposed by them, but this should be tested by inclusion of additional species representative of the tribe Alysseae.

2. Relationships among the major alliances (clades) in Egyptian Brassicaceae

To avoid confusion with traditional tribal classification (see table 6.2), genera are assigned to our tree as genus alliances. Within this analysis Egyptian genera of Brassicaceae are found in 7 separate clades (alliances). The name of genus alliance was chosen based on the high jackknife support value for the genus (fig. 6.2.).

1. *Capsella* alliance

This alliance consists of *Neslia, Capsella, Olimarabidopsis, Crucihimalaya* and *Erysimum repandum*. Within this clade taxa share the following characters: embryo type incumbent, covered with branched hairs. Taxa have been placed within different tribes by various authors (see table 6.2), *Neslia* and *Capsella* were placed in the tribe Lepidieae by (Hayek, 1919; Janchen, 1942); *Erysimum* in tribe Hesperideae (Schulz, 1936; Janchen, 1942), while *Olimarabidopsis* and *Crucihimalaya* in the tribe Sisymbrieae (Schulz, 1936; Janchen, 1942). The results from previous studies of phylogenetic relationships based on ITS (Yang et al. 1998); nuclear gene Adc (Galloway et al., 1998); *matK* and *Chs* genes (Koch et al., 2001) demonstrated a close relationship between *Capsella* and *Arabidopsis, Crucihimalaya,* and *Olimarabidopsis*. However, Zunk et al. (1999), based on chloroplast DNA, showed that *Neslia*, *Capsella* and *Camelina* form a monophyletic group with very high support (96%). Moreover, based on ITS and *rbc*L genes Koch & Al-Shehbaz (2000) showed close relationships among *Capsella, Arabidopsis, Yinshana, Barbarea* and *Cardamine* (97%). Jang et al. (1999), based on mitochondrial gene NADH, investigated the relationships among *Capsella bursa-pastoris, Arabidopsis thaliana, Cardamine scutata*, and *Rorippa indica* (45%). Our phylogenetic analyses are in agreement with theirs, and support these views.

Table 6.2. Tribal and subtribal classification of studied genera according to Hayek (1911), Schulz (1936), and Janchen (1942) relative to the genus alliances identified in our phylogeny.

Genus	**Current analysis Genus alliance**	**Hayek (1911)**	**Schulz (1936)**	**Janchen (1942)**
Arabis	***Arabis***	Arabideae/Arabidinae	Arabideae	Arabideae/Arabidinae
Nasturtium		Arabideae/ Cardamininae	Arabideae	Arabideae/ Cardamininae
Rorippa	***Rorippa***	Arabideae/Cardamininae	Arabideae	Arabideae/Cardamininae
Descurainia		Arabideae/Sisymbriinae	Sisymbrieae/Descurainiinae	Sisymbrieae/Descurainiinae
Robeschia		Arabideae/Sisymbriinae	Sisymbrieae/Descurainiinae	Sisymbrieae/Sisymbriinae
Crucihimalaya		Arabideae/Cardamininae	Sisymbrieae/Arabidopsidinae	Sisymbrieae/Arabidopsidinae
Olimarabidopsis		Arabideae/Cardamininae	Sisymbrieae/Arabidopsidinae	Sisymbrieae/Arabidopsidinae
Neslia	***Crucihimalaya***	Lepidieae/Capsellinae	Euclidieae	Lepidieae/Capsellinae
Capsella		Lepidieae/Capsellinae	Lepidieae/Capsellinae	Lepidieae/Capsellinae
Erysimum		Arabideae/Erysiminae	Hesperideae	Hesperideae/Hesperidinae
Nasturtiopsis		Arabideae/Sisymbriinae	Sisymbrieae/Brayinae	Sisymbrieae/Sisymbriinae
Rorippa		Arabideae/Cardamininae	Arabideae	Arabideae/Cardamininae
Neotorularia		Arabideae/Sisymbriinae	Sisymbrieae/Brayinae	Hesperideae /Hesperidinae
Brassica		Brassiceae/Brassicinae	Brassiceae/Brassicinae	Brassiceae/Brassicinae
Sinapis		Brassiceae/Brassicinae	Brassiceae/Brassicinae	Brassiceae/Brassicinae
Sisymbrium		Arabideae/Sisymbriinae	Sisymbrieae/Sisymbriinae	Sisymbrieae/Sisymbriinae
Ochthodium	***Sisymbrium***	Arabideae/ Buniadinae	Euclidieae	Sisymbrieae/Buniadinae
Schimpera		Arabideae/ Buniadinae	Euclidieae	Sisymbrieae/Buniadinae
Leptaleum		Alysseae/Brayinae	Hesperideae	Hesperideae/Hesperidinae
Malcolmia		Alysseae/Hesperidinae	Hesperideae	Hesperideae/Hesperidinae
Matthiola	***Matthiola***	Alysseae/Hesperidinae	Matthioleae	Hesperideae/Matthiolinae
Neotorularia		Arabideae/Sisymbriinae	Sisymbrieae/Brayinae	Hesperideae /Hesperidinae
Anastatica		Alysseae/Euclidiinae	Euclidieae	Hesperideae/Euclidiinae
Morettia		Alysseae/Hesperidinae	Matthioleae	Hesperideae/Hesperidinae
Notoceras	***Morettia***	Alysseae/Hesperidinae	Matthioleae	Hesperideae/Matthiolinae
Diceratella		Alysseae/Hesperidinae	Matthioleae	Hesperideae/Matthiolinae
Lobularia		Alysseae/Alyssinae	Alysseae	Alysseae/Alyssinae
Ricotia		Alysseae/Lunariineae	Lunarieae	Alysseae/Lunariinae
Eremobium	***Malcolmia***	Alysseae/Hesperidinae	Hesperideae	Hesperideae/Hesperidinae
Malcolmia (*Maresia*)	(***Maresia***)	Alysseae/Hesperidinae	Hesperideae	Hesperideae/Hesperidinae
Aethionema		Lepidieae/Iberidinae	Lepidieae/Thlaspidinae	Lepidieae/Thlaspidinae
Lepidium		Lepidieae/Lepidiinae	Lepidieae/Lepidiinae	Lepidieae/Thlaspidinae
Alyssum		Alysseae/Alyssinae	Alysseae	Alysseae/Alyssinae
Thlaspi		Lepidieae/Thlaspidinae	Lepidieae/Thlaspidinae	Lepidieae/Thlaspidinae
Cochlearia		Lepidieae/Thlaspidinae	Lepidieae/Cochleariinae	Lepidieae/Cochleariinae
Inopsidium		Lepidieae/Thlaspidinae	Lepidieae/Thlaspidinae	Lepidieae/Thlaspidinae
Arabidopsis		Arabideae/Cardamininae	Sisymbrieae/Arabidopsidinae	Sisymbrieae/Arabidopsidinae
Alliaria		Arabideae/Arabidinae	Sisymbrieae/ Alliariinae	Sisymbrieae/ Alliariinae
Cardaminopsis		Arabideae/Cardamininae	Arabideae	Arabideae/Arabidinae
Barbarea		Arabideae/Cardamininae	Arabideae	Arabideae/Cardamininae
Cardamine		Arabideae/Cardamininae	Arabideae	Arabideae/Cardamininae
Aubrieta		Arabideae/Arabidinae	Arabideae	Arabideae/Arabidinae

2. *Rorippa* alliance

This alliance consists of *Rorippa, Nasturtium, Descurainia* and *Robeschia*. *Nasturtium* and *Rorippa* are placed in tribe Arabideae (see table 6.2), while *Descurainia* and *Robeschia* are placed in tribe Sisymbrieae (Schulz, 1936; Janchen, 1942), and in tribe Arabideae (Hayek, 1919). *Rorippa* and *Nasturtium* share the embryo type (accumbent), indumentum of simple hairs, fruit with two rows of seeds in each locule; *Descurainia* and *Robeschia* share their incumbent embryo, indumentum of branched hairs, pinnatisect leaves, linear fruit, and one row of seeds in each locule. Within this clade, *Nasturtium* is separated from *Rorippa,* therefore our results do not support the incorporation of *Nasturtium* within *Rorippa*. In the tree the *Nasturtium officinale* form a support clade together with *Cardamine* taxa. This clade is separated from the *Rorippa* and *Barbarea* clade. Our findings are in agreement with the previous phylogenetic analysis based on ITS (Franzke et al., 1998; Yang et al., 1999), and *rbc*L analysis (Les, 1994) where *Nasturtium officinale* is grouped together with *Cardamine* taxa, and was separated from *Rorippa indica*, *R. amphibia*, *R. palustris* and from *Barbarea.*

Moreover, all members of alliance for monophyletic group (figs. 6.2, 6.4), and these results also agree with the phylogenetic analysis based on ITS (Franzke et al., 1998) where *Nasturtium, Rorippa, Cardamine* and *Dentaria* form a monophyletic group with support 66%. In addition, phylogenetic analysis based on *rbc*L (Price et al., 1994) showed that *Barbarea vulgaris, Sisymbrella aspera* and *Descurainia* form a monophyletic group with very high support of 100%.

3. *Matthiola* alliance

This alliance consists of *Matthiola, Malcolmia africana, Neotorularia torulosa* and *Leptaleum*. Our molecular data showed that these genera form a monophyletic group. Within this alliance there are two monophyletic groups: (1) all *Matthiola* species (98%), (2) *Leptaleum, Malcolmia africana, Neotorularia torulosa* (79%).

The classification system of Janchen (1942) is in agreement that all taxa in this alliance belong to the tribe Hesperideae. However, these taxa had been placed in different tribes by Hayek (1919) and Schulz (1936) (see table 6.2).

3a. *Matthiola* clade

The all taxa of this clade share several characters that may support a close relationship: accumbent embryo type, long petals, fruit horns, pollen with coarsely reticulate ornamentation, chromosome number (2n= 14, Manton, 1932).

3b. Mixed clade (*Leptaleum, Malcolmia africana, Neotorularia torulosa*)

All taxa share the embryo type (incumbent). However, the chromosome numbers are: *Leptaleum*, 2n=14, *Neotorularia torulosa*, 2n= 28, 42 (Polatschek, 1971), *Malcolmia africana*, 2n=14 (Podlech & Dieterle, 1969), 2n=28 (Manton, 1932). Stork & Wüest (1978), studied the seed coat and epidermal slime bodies morphology of species from *Malcolmia* by SEM, and they found that rather uniform between *Malcolmia africana* and *Torularia* spp., but there are great differences between this group and *Eremobium* and *Maresia* (*M. nana, M. pygmaea*). Based on fatty acids distribution, *Malcolmia africana* and *Torularia torulosa* form a distinct group (Kebber & Stork, 1983).

Our results are congruent with the classification proposed by the previous authors, especially with Janchen (1942) and Al-Shehbaz (1984) in sinking the tribe Matthioleae into Hesperideae. Our results are in agreement with Janchen in dividing this tribe into subtribes; *Matthiola* species (subtribe Matthiolinae), *Leptaleum, Malcolmia africana, Neotorularia torulosa* (subtribe Hesperidinae).

4. *Arabis* alliance (*Arabis alpina, A. nova*)

The molecular data support the recognition of the Egyptian species of *Arabis*. Morphological and cytological characters support the monophyly of this genus (84%) include the following: plant covered with simple and branched hairs, accumbent embryo type, leaves basal in a rosette, upper leaves sessile, amplexicaul, petals white, stigma depressed, fruit siliqua, linear-oblong, dehiscent, and unique base chromosome number 2n=16 (Burdet, 1969).

Arabis was traditionally classified in Arabideae (Hayek, 1919; Schulz, 1936; Janchen, 1942). According to Al-Shehbaz (1988a) *Arabis* has more than 180 species, distributed in the temperate areas of the northern hemisphere, while *Arabis alpina* and *A. glabra* occur in the high mountains of tropical East Africa. In Egypt *Arabis nova* is found distributed in the mountains of Sinai. Our phylogenetic analyses are in agreement with morphological analysis for supporting this clade.

5. *Sisymbrium* alliance

This alliance includes *Sisymbrium, Octhodium, Sinapis, Brassica, Nasturtiopsis, Rorippa integrifolia, Neotorularia aculeolata,* and *Schimpera.*

The monophyly is supported by deletion of two amino acids (6-bp) at nucleotide positions 262–267. Previous studies (Johnson and Soltis, 1994, 1995; Plunkett et al., 1996, Soltis and Soltis, 1998; Mort et al., 2001) indicate that indels in *matK* are often phylogenetically informative. Comparison of the taxonomic distribution of indels to the results of our phylogenetic analysis suggests that these indels are phylogenetically informative for this group. Within this alliance, there are two subclades with strong support and separate clade with *Schimpera.*

5a. *Sisymbrium* clade (*Sisymbrium, Octhodium*)

The position of *Octhodium* with *Sisymbrium* as alliance in our tree is somewhat surprising because they have been classified by a previous author (Schulz, 1936) into tribes Euclidieae (fruit silicula, indehiscent) and Sisymbrieae (fruit siliqua, dehiscent), respectively. Recent molecular analysis in Brassicaceae demonstrated that species of different genera with widely different fruit types are closely related (Price et al., 1994; Zunk et al., 1999; Koch et al., 2000; Mummenhoff et al., 2001). Phylogenetic analysis indicates that this group is monophyletic, also supported by a 6-bp deletion. Some other morphological evidence supporting the inclusion of *Octhodium* and *Sisymbrium* in one clade, all taxa are characterized by the same embryo type (seeds with incumbent radicle/cotyledons), and the type of hairs (both of them sparsely covered with simple hairs). Our results are congruent with classification proposed by (Janchen, 1942) who placed both genera in Sisymbrieae, but in two subtribes.

5b. Mixed clade (*Sinapis, Brassica, Nasturtiopsis, Rorippa integrifolia, Neotorularia aculeolata*)

Our molecular data clearly demonstrated that these genera form a monophyletic group with a jackknife support of 81%, and high posterior probability 99. This clade shares a 6-bp deletion. Within this clade there are two monophyletic groups: *Sinapis* and *Brassica*; *Rorippa integrifolia* and *Nasturtiopsis*, and the single species *Neotorularia aculeolata*.

The classification systems of Hayek (1919), Schulz (1936), and Janchen (1942) all agree that *Sinapis* and *Brassica* belong to tribe Brassiceae. However, they placed *Rorippa, Nasturtiopsis* and *Neotorularia* in different tribes (see table 6.2).

Previous analysis based on the nuclear gene Adc (1220 bp) showed close relationships between two cultivated *Brassica* species, *Sisymbrium altissimum, Stanleya pinnata, Thlaspi arvense*, and *Thellungiella*, and a ndhF data set (780 bp) (Galloway et al., 1998) showed the same result. Moreover, Price et al. (1994) based on chloroplast DNA (*rbc*L) analysis, indicated that the genus *Brassica* is a highly unnatural group in its current delimitation, and they showed close relationships between *Brassica nigra, Eruca sativa, Sisymbrium altissimum, Stanleya pinnata, Thlaspi arvense,* and *Thellungiella* (82%). Koch et al. (2001) used molecular data from *matK* and *Chs* genes and showed that *Sinapis alba*, *Raphanus sativus* and *Sisymbrium irio* form a monophyletic group with very high support (99%). Kowalski et al., 1994; Lagercrantz et al., 1995; Lagercrantz, 1998 showed that diploid genomes of *Brassica* contain three copies of a basic genome similar in size to the *A. thaliana* genome, and that chromosome evolution in Brassicaceae seems to involve an exceptionally high rate of chromosomal rearrangements. Furthermore, the polyploidization is the major force for speciation within this group. Our results agree with previous results in forming a monophyletic group from traditional tribe

Brassiceae and from both the tribe Arabideae (*Rorippa integrifolia*) and the tribe Sisymbreae (*Neotorularia aculeolata* and *Nasturtiopsis*).

Within this analysis, the endemic species *Rorippa integrifolia* is separated from the rest of *Rorippa* and cluster together with *Nasturtiopsis.* The primary difference between *Rorippa integrifolia* and *Nasturtiopsis* is that *Rorippa* belongs to tribe Arabideae (See table 6.2) with accumbent (radicle/cotyledons) type, while *Nasturtiopsis* which is placed in tribe Sisymbrieae, with incumbent type. However, there are some morphological characters that also support the common ancestry of *Rorippa* and *Nasturtiopsis*, because both taxa are characterised by: (1) sandy and stony soil habitat, (2) basal leaves rosette, (3) upper leaves narrow and sessile, (4) indumentum of sparsely simple hairs, (5) small yellow petals, (6) stigma capitate or slightly 2-lobed, (7) fruit straight to slightly curved, glabrous, (8) seeds in two rows in each locule, (9) the same seed coat type (Abdel Khalik & van der Maesen, 2002), and both taxa are native to the Old World (the Mediterranean area), *R. integrifolia* (Egypt) and *Nasturtiopsis* (North Africa, Syria, Israel, Saudi Arabia). Because there is strong support by high jackknife value and posterior probability in our analysis tree, there is a general impression that *Rorippa integrifolia* is somewhat intermediate between *Rorippa* and *Nasturtiopsis,* so it may be possible that *Rorippa integrifolia* is a hybrid between *Rorippa* and *Nasurtiopsis*.

Schimpera arbica is placed in three different tribes, Euclideae (Schulz, 1936); Arabideae (Hayek, 1919); Sisymbrieae (Janchen, 1942).

In this analysis *Schimpera* is separated with other members from tribe Sisymbrieae (Janchen, 1942), but within this clade it separated from the rest of group supported by deletion of (9 bp) at positions 259–267, which is unique to this genus and this is confirmed by its morphology: fruit a silicule, indehiscent, forming a horizontal beak.

6. *Morettia* alliance

This alliance consists of *Morettia, Anastatica, Diceratella, Notoceras,* and *Lobularia.*

These genera share a number of characters: (1) embryo type accumbent (radicle/cotyledon), (2) fruit indehiscent or tardily dehiscent, (3) plant covered with branched and stellate hairs except *Notoceras,* and *Lobularia* (bipartite hairs). Based on morphological characters, these genera are traditionally classified in tribe Alysseae (Haeyk, 1919); Hesperideae and Alysseae (Janchen, 1942); or in three tribes (Schulz, 1936). The genus *Morettia* was described by De Candolle and placed together with the genus *Anastatica* in tribe Anastaticeae. The chromosome numbers for these taxa are known for *Morettia canescens* (2n=22, Reese, 1957; Humphries et al., 1978), *Anastatica hierochuntica* (2n=22, Reese, 1957), and *Notoceras bicorne* (2n=22, Reese, 1957). Our molecular data confirm this grouping. Indeed these genera are very similar in a number of morphological characters with the exception of *Lobularia* and our phylogenetic analysis suggests that this similarity is due to common ancestry.

7. *Malcolmia* (*Maresia*) alliance

This alliance includes *Malcolmia nana, M. pygmaea, Eremobium,* and *Ricotia*.

The position of *Ricotia* with *Eremobium* and *two Malcolmia* (*Maresia*) species is somewhat surprising because they have been classified by previous authors into tribes Lunarieae and Hesperideae (Schulz, 1936); Alysseae and Hesperideae (Janchen 91942) respectively. However, Hayek (1919) placed all together in the tribe Alysseae in two subtribes. Based on morphology, there are a lot of differences among these taxa: In *Ricotia*, leaves trifoliate or pinnate, flower large, limb emarginate or obcordate, fruiting pedicels deflexed, fruit strongly flattened, septum delicate or absent, seeds orbicular (Abdel Khalik & van der Maesen, 2002), pollen grains are coarsely reticulate ornamentation (Abdel Khalik et al., 2002 in press), chromosome number 2n=28 (Manton, 1932). In *Eremobium*, leaves are linear to oblong, flower small, limb of petals entire, fruiting pedicels erect, septum present, thin and hyaline, fruit siliqua linear, terete, seeds ellipsoid, pollen grains are reticulate ornamentation, chromosome number 2n=20 (Reese, 1957), 2n=26 (Kerber & Stork, 1983). In *Malcolmia nana* and *M. pygmaea*, leaves oblong-obovate, entire to pinnatifid, flower small, fruiting pedicels erect to spreading, septum present, thin, fruit lineae, terete to smooth, seeds ovoid to oblong, pollen reticulate to coarsely reticulate sculpturing, chromosome number *M. nana* 2n=26 (Titz, 1969); 2n=28 (Aryavand, 1977). On the other hand both *Eremobium* and *Ricotia* share accumbent embryos. Stork (1972) studied 37 taxa from *Malcolmia* based on anatomy of seed coat using stain techniques, and according to the swelling, form, and structure of the columns, she divided these taxa into groups: (1) *Malcolmia africana* and *Torularia* group (2) *Malcolmia littorea* and *Maresia (M. nana, M. pygmaea*) groups (3) *Erymobium aegyptiacum* group. Kerber & Stork (1983) studied the seed fatty acids and the absence/presence of Sinapin and p-Hydroxybenzylglucosinolate, of *Malcolmia, Torularia, Maresia* and *Eremobium.* They showed that Sinapin is present in all taxa; p-Hydroxybenzyglucosinolate only in *Malcolmia africana*. Based on fatty acids they divided these taxa into four groups: (1) group of *Malcolmia africana* and *Torularia torulosa,* (2) group of *Malcolmia maritima* and *M. crenulata* with long chain of fatty acids, (3) group of *Malcolmia littorea, M. ramosissma* and *Maresia* (*M. nana, M. pygmaea*) are between 1 and 2, (4) *Erymobium aegyptiacum* group which is completely different from the rest of groups. Based on anatomical analysis (Dvořák, 1972) suggested that *Eremobium* is derived from *Maresia*. He grouped *Malcolmia aficana* and taxa around it together in the genus *Fedtschenkoa*, based on chromosome number (2n=14). He also pointed out that anatomical structures of the fruit of *Malcolmia scorpioides* and *Torularia contortuplicata* are very similar.

Abdel Khalik & van der Maesen (2002) investigated the seed surface of all these taxa and showed that in *Eremobium* this is flat to convex; with smooth to fine folded periclinal cell wall; *Malcolmia pygmaea* and *M. nana* flat to convex; striate periclinal cell wall; *Malcolmia africana* flat to convex with flat central portion; fine to coarse folded; *Neotorularia torulosa* convex; smooth to fine folded. Based on the previous studies, our phylogenetic analysis strongly supports this grouping with Jackknife value of 96%, and 100 posterior probability which agrees with Hayek's classification (1919), and it shows the monophyly of the group of *Malcolmia nana* and *M. pygmaea* which confirms that the two species do not belong to *Malcolmia* but belong to *Maresia*.

6.5. CONCLUSIONS AND OUTLOOK

1. Supra generic level (tribal level)

The present molecular data helped us to understand better the relationships among genera and tribes in Brassicaceae, as suggested by our morphological studies (Abdel Khalik et al., 2002, this thesis).

Our phylogenetic analysis demonstrated close relationships among tribes Arabideae, Sisymbrieae, and Lepideae and confirmed that Arabideae, Hesperideae, Sisymbrieae, and Lepideae are polyphyletic tribes.

Our analyses reveal that the boundaries among tribes Lepidieae, Lunarieae, Arabideae, Sisymbrieae, Euclidieae, Mattahioleae, Alysseae, and Hesperidieae are highly artificial, because the chacters traditionally used this rank are few in number and do not support natural groups, and these results are in agreement with Zunk et al. (1993), Price et al. (1994), Koch et al. (2001), Abdel Khalik et al. (2002, this thesis).

2. Infra generic level

Phylogenetic analysis of *matK* data helped to resolve a number of old disputes about the relationships of some enigmatic taxa, because *matK* is maternally inherited (Mort et al., 2001). Our results showed that *Malcolmia* (*M. africana*) and *Maresia* (*M. nana, M. pygmaea*) are separated from each other. There are close relations between *Anastatica, Morettia, Diceratella*, and *Notoceras*; and also between *Matthiola, Leptaleum, Malcolmia,* and *Neotorularia torulosa*. Furthermore, *Ricotia* is closely related to *Eremobium* and *Maresia* (*M. nana, M. pygmaea*) rather than with *Alyssum* and *Lobularia*, as was suggested by previous authors. Our results demonstrate that the tribe Lepidieae (*Neslia, Capsella*) is interspersed with taxa from Sisymbrieae and Hesperideae. Moreover, our results showed that *Rorippa integrifolia* is very close to *Nasturtiopsis coronopifolia*, and this species may be a hybrid between *Rorippa* and *Nasurtiopsis.* On the other hand, the results do not support the incorporation of *Nasturtium officinale* within *Rorippa*, and these results are in agreement with the previous results (Les, 1994; Franzke et al., 1998). Furthermore, relationships within some taxa are often less resolved (*Rorippa* and *Neotorularia*) apparently due to low number of characters, low number of species in each. In order to provide sufficient phylogenetic information to resolve relationships among *Rorippa* and *Neotorularia*, more taxa and more characters such as AFLP should be used.

7.

SUMMARY AND CONCLUSIONS

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SUMMARY AND CONCLUSIONS

The present work deals with a systematic investigation of 45 taxa belonging to 23 genera of the tribes Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae and Sisymbrieae of the family Brassicaceae from Egypt. This work is largely based on herbarium material received on loan from B, BM, BR, E, HUJ, K, KSU, L, LY, NMGM, OXF & FHO and W, and collections kept in the following herbaria: B, CAI, CAIM, WAG and Sohag University Herbarium (SHG, proposed abbreviation). In addition, fresh material of most of the taxa was studied and field observations were made from several localities of the Mediterranean region, Western desert, Eastern desert, Nile valley, and the mountains of Sinai and Elba in Egypt.

Taxa of six tribes have been studied by using different biosystematical methods.

Chapter 1 describes the family as a whole, presenting a historical review, its phytogeography, uses and economic importance, an outline of the thesis, aims and general objectives.

Chapter 2 deals with a full discussion for all morphological characters; and gives a systematic treatment, based on macro-morphological characters such as habit, leaf, flower, fruit, seed and, embryo and micro-characters of trichomes. An artificial key applies the most reliable characters for the distinction of the genera.

In the systematic treatment 45 taxa are recognized, presenting up-to-date nomenclature, literature citations, type specimens and their locations, synonyms, specimens examined, and distribution maps.

Some taxonomic and nomenclature problems in *Rorippa, Neslia, Eremobium, Malcolmia, Matthiola, Arabidopsis* and *Neotorularia* are discussed and changes proposed.

Eremobium aegyptiacum subsp. *longisiliquum* and *Matthiola longipetala* subsp. *kralikii* are recorded from Egypt for the first time.

Nasturtium indicum is transferred to *Rorippa*; in Egypt, the number of species in *Nasturtium* is reduced from two to one.

In the genus *Neslia*, *N. apiculata* is treated as variety of *N. paniculata*. The number of species in this genus is reduced from two to one: *Neslia paniculata* with two varieties, *N. paniculata* var. *paniculata* and var. *apiculata*.

In the genus *Eremobium*, *E. diffusum* is considered a synonym of *E. aegyptiacum* subsp. *lineare*; the number of species in *Eremobium* is reduced from two to one. *Eremobium aegyptiacum* is represented by three infraspecific taxa: *E. aegyptiacum* subsp. *aegyptiacum*, subsp. *lineare* and subsp. *longisiliquum*.

In the genus *Matthiola*, *M. elliptica* is transferred from this genus to the genus *Diceratella*; *M. livida* is considered as infraspecific taxon of *M. longipetala*. The number of species in *Matthiola* is reduced from 6 to 4. *Matthiola longipetala* is represented by five infraspecific taxa, *M. longipetala* subsp. *bicornis*, subsp. *hirta*, subsp. *kralikii*, subsp. *livida* and subsp. *longipetala*.

Chapter 3 presents macro-morphological characters of the seeds such as seed shape, colour, size, position of the radicle, and micro-morphological characters (by SEM examination) of the epidermal cell shape, anticlinal boundaries, the outer periclinal cell wall and relief of outer cell walls. Three types of basic anticlinal cell wall boundaries are recognized, and six different shapes of the outer periclinal cell wall are described. A key for the identification of the investigated taxa based on seed characters is provided.

Chapter 4 deals with morphological characters of the pollen grains using light microscope (LM) and scanning electron microscope (SEM). In general the pollen morphology varies within a narrow range. The pollen grains are tricolpate. The shape varies from prolate spheroidal, subprolate to prolate. Three pollen types can be distinguished based on the size of lumina. The exine ornamentation of pollen grains varies between genera within tribes and between species within the same genus. The exine ornamentation of pollen was found useful to distinguish between closely related genera such as *Matthiola, Morettia* and *Diceratella,* and between species in the same genus such as *Arabis, Morettia, Malcolmia* and *Neotorularia*. Our results suggest that the tribes Sisymbrieae, Matthioleae, Hesperideae and Arabideae are heterogeneous because all three types of exine ornamentation are found among the genera of these tribes. However, the tribes Euclidieae and Lunarieae are homogeneous because we found only one type of exine ornamentation among the genera.

Chapter 5 deals with the systematics of the tribes of the Brassicaceae, by means of numerical analysis based on sixty-two morphological characters, including vegetative parts, flowers, fruits, pollen grains and seeds. Morphological characters have been analyzed using two types of analyses: firstly, we performed a cluster analysis using average taxonomic distance and UPGMA clustering (procedures SIMINT, SAHN, and TREE). Secondly, we performed a principal coordinates analysis (PCO), using the product-moment correlation as a coefficient. The procedures STAND and SIMINT were used to calculate the distance matrix, the procedures EIGEN, PROJ, and MXPLOT to perform the PCO. Four main groups are recognised: Lunarieae, Euclidieae, Matthioleae and a mixed group. Representatives of these groups cluster together based on characters with high factor loading in the PCO analysis. The tribe Euclidieae is the most homogeneous group, and the tribe Arabideae is the most heterogeneous and probably of polyphyletic origin.

Chapter 6 deals with phylogenetic relationships of 83 species belonging to 39 genera of tribes Brassiceae, Alysseae, Arabideae, Euclidieae, Hesperideae, Lepidieae, Lunarieae, Matthioleae and Sisymbrieae. In total 44 species belonging to 28 genera from Egypt were investigated using nucleotide sequence variation of the chloroplast *matK* gene to assess relationships among genera within tribe and tribes within the family. The topology of Parsimony analysis, and

Maximum Likelihood trees are largely in agreement. The analysis indicates that the tribes Arabideae, Sisymbrieae, Hesperideae, and Lepidieae are polyphyletic. Our results support the association of *Ricotia lunaria* with *Maresia* and *Eremobium* rather than with *Alyssum* and *Lobularia*, as was suggested by previous authors. *Capsella* and *Neslia* were originally placed in Lepidieae, but our data show that these two genera are closely related to *Arabidopsis* and *Olimarabidopsis*. Furthermore, our results support a monophyletic *Maresia* (*M. nana, M. pygmaea*), and suggest that species of this genus are not closely related to *Malcolmia* (*M. africana*). There are close relations among *Anastatica, Morettia, Diceratella*, and *Notoceras*; and among the members of *Matthiola, Leptaleum, Malcolmia,* and *Neotorularia torulosa.* Moreover, our results show that *Sisymbrium* taxa are closely related to *Octhodium* and they represent a monophyletic group. However, the *Nasturtium*/*Cardamine* clade is separated from a clade of *Rorippa*, and these results are in agreement with data on ITS and noncoding chloroplast sequence. Besides, our results showed that *Rorippa integrifolia* is very close to *Nasturtiopsis coronopifolia*, and this species may be a hybrid between *Rorippa* and *Nasurtiopsis.* Our phylogenetic analysis provides general support for the classification of genera in the system of Janchen with some modifications.

GENERAL CONCLUSIONS

1. Although there is no doubt about the monophyly of the whole family, the boundaries among tribes in the Brassicaceae are highly artificial, and even subtribal grouping of genera often does not reflect the phylogenetic relationships (Koch et al., 1999), because the number of characters used by previous authors is very small. Only two or three characters are used: cotyledon/radicle position, type of indumentum, type and position of nectaries, fruit length, and these characters are variable within genera.
2. Although the morphology of the traditional tribes Euclidieae and Lunarieae is most homogenous, the phylogenetic analysis of these tribes shows that the taxa of these tribes are interspersed with members of other tribes.
3. Based on molecular studies, species from different genera with widely different fruit types were shown to be closely related e.g. *Octhodium* fits with *Sisymbrium, Neslia* with *Olimarabidopsis*, and *Ricotia* with *Eremobium,* and these results are congruent with previous molecular results by Galloway, et al. 1998; Koch et al., 1999; Zunk et al., 1999.
4. Both morphology and molecular analysis suggest that Sisymbrieae, Arabideae, and Hesperideae including Matthioleae are polyphyletic tribes.
5. Seed morphology and ornamentation of pollen grains were found useful to distinguish between closely related genera and between species in the same genus.
6. The genera *Sisymbrium, Morettia,* and *Matthiola* are monophyletic.

7. Our results support a monophyletic *Maresia* (*M. nana, M. pygmaea*), and suggest that species of this genus are not closely related to *Malcolmia* (*M. africana*).
8. *Rorippa integrifolia* is very close to *Nasturtiopsis coronopifolia*, and this species may be a hybrid between *Rorippa* and *Nasurtiopsis.*
9. *Nasturtium* is separated from *Rorippa,* therefore our results do not support the incorporation of *Nasturtium* within *Rorippa*, which has been suggested by previous authors (Al-Shehbaz, 1988; Jonsell, 1988; and Rollins, 1993), and these results are in agreement with the previous phylogenetic analysis based on ITS (Yang et al., 1999).

SAMENVATTING EN CONCLUSIES

Deze studie betreft een systematisch onderzoek van 45 taxa behorende tot 23 genera van de tribus Arabideae, Euclidieae, Hesperideae, Lunarieae, Matthioleae en Sisymbrieae van de familie Brassicaceae uit Egypte. De gegevens zijn grotendeels gebaseerd op herbariummateriaal geleend uit B, BM, BR, E, HUJ, K, KSU, L, LY, NMGM, OXF & FHO en W, en op collecties bestudeerd in B, CAI, CAIM, WAG en Sohag Universiteit (voorgesteld acroniem SHG). Bovendien is vers materiaal verzameld van 1998 tot 2000 en bestudeerd van de meeste taxa, aangevuld met veldgegevens. De auteur bezocht in Egypte verschillende plaatsen langs de Middellandse Zee, in de Westelijke en Oostelijke woestijnen, de Nijlvallei, en de bergen van Sinai en Elba.

Taxa van zes tribus zijn bestudeerd vanuit verschillende biosystematische benaderingen.

Hoofdstuk 1 beschrijft de familie als geheel, met een historisch overzicht in de taxonomie, de plantengeografie, gebruik en economisch belang, een overzicht van het proefschrift en het doel van de studie.

Hoofdstuk 2 geeft een beschrijving van alle morfologische kenmerken en behandelt de taxa systematisch, gebaseerd op macromorfologische kenmerken zoals van habitus, blad, bloem, vrucht, zaad en embryo, en micromorfologische kenmerken van de haren. Een kunstmatige sleutel gebruikt de meest betrouwbare kenmerken voor het onderscheid van de genera.

In het taxonomische gedeelte worden 45 taxa onderscheiden, met recente nomenclatuur, opgave van literatuurgegevens, type-exemplaren en hun plaats-gegevens, synoniemen, lijsten van bestudeerde exemplaren en verspreidingskaartjes.

Een aantal taxonomische en nomenclatuurproblemen in *Rorippa, Neslia, Eremobium, Malcolmia, Matthiola, Arabidopsis* en *Neotorularia* worden besproken en veranderingen voorgesteld.

Eremobium aegyptiacum subsp. *longisiliquum* en *Matthiola longipetala* subsp. *kralikii* zijn voor het eerst in Egypte gerapporteerd.

Nasturtium indicum wordt overgeplaatst naar *Rorippa*; in Egypte wordt daardoor het aantal soorten in *Nasturtium* teruggebracht van twee naar één.

Neslia apiculata wordt als variëteit van *N. paniculata* opgevat. Het aantal soorten in dit genus wordt in Egypte ook van twee tot één soort gereduceerd; *N. paniculata* met twee variëteiten; var. *paniculata* en var. *apiculata.*

Eremobium diffusum wordt beschouwd als synoniem van *E. aegyptiacum* subsp. *lineare*; het aantal soorten in Egypte loopt daardoor terug tot één. *E. aegyptiacum* heeft wel drie infraspecifische taxa: subsp. *aegyptiacum,* subsp. *lineare* en subsp. *longisiliquum.*

Mantilla ecliptica wordt overgezet naar het genus *Diceratella*, *M. livida* wordt beschouwd als infraspecifisch taxon van *Matthiola longipetala*, zodat het aantal soorten in dat genus terugloopt van 6 naar 4. *M. longipetala* heeft in Egypte 5 ondersoorten; subsp. *longipetala,* subsp. *bicornis,* subsp. *hirta*, subsp. *kralikii,* en subsp. *livida*.

Hoofdstuk 3 presenteert macromorfologische kenmerken van het zaad, zoals vorm, kleur, grootte, vorm van de kiemwortel; en micromorfologische kenmerken (bestudeerd met een elektronenmicroscoop)(SEM) van de vorm van de epidermiscel, celwanden, de buitenste periclinale celwand en het reliëf van de buitenste cellen. Er worden drie types van de basale anticlinale celwand onderscheiden, en zes verschillende vormen van buitenste periclinaalwand worden beschreven. Een sleutel gebaseerd op zaadkenmerken kan de onderzochte taxa op naam brengen.

Hoofdstuk 4 verschaft pollenmorfologische kenmerken na onderzoek met licht- en elektronenmicroscoop. In het algemeen varieert de pollenmorfologie binnen nauwe grenzen. De pollenkorrels zijn tricolpaat. De vorm gaat van sferisch, via subprolaat naar prolaat. Naar gelang van de afmeting van de lumina kunnen drie pollentypes worden onderscheiden. De exinestructuur van het pollen varieert tussen genera binnen de tribus en tussen de soorten binnen een genus. Nauw verwante genera zoals *Matthiola, Morettia* en *Diceratella*, en soorten binnen bijvoorbeeld de genera *Arabis, Morettia, Malcolmia* en *Neotorularia* kunnen mede aan de hand van de exinestructuur worden onderscheiden. Onze resultaten suggereren dat de tribus Sisymbrieae, Matthioleae, Hesperideae and Arabideae heterogeen zijn omdat alle drie exinevormen bij genera van deze tribus aanwezig zijn. Daarentegen zijn Euclidideae en Lunarieae homogeen omdat hun genera slechts een exinetype te zien geven.

Hoofdstuk 5 behandelt de systematiek van de tribus van de Brassicaceae via numerieke analyse gebaseerd op 62 morfologische kenmerken, waaronder vegetatieve delen, bloemen, vrucht, pollenkorrels en zaden. Morfologische kenmerken zijn geanalyseerd met twee methoden: ten eerste voerden we een clusteranalyse uit met UPGMA clustering (procedures SIMINT, SAHN en TREE). Ten tweede gebruikten we een Principale Coördinaten Analyse (PCO). De procedures STAND en SIMINT werden benut om de product-moment correlatie matrix te berekenen, de procedures EIGEN, PROJ en MXPLOT werden gebruikt om de PCO uit te voeren. Vier hoofdgroepen konden worden onderscheiden: Lunarieae, Euclidieae, Matthioleae en een gemengde groep. Vertegenwoordigers van deze groepen clusteren samen gebaseerd op kenmerken met een hoge factorlading in de Principale Coördinaten Analyse. Het tribus Euclidieae is de meest homogene groep, het tribus Arabideae is de meest heterogene en waarschijnlijk van polyfyletische oorsprong.

Hoofdstuk 6 beschrijft de fylogenetische verwantschappen van 83 soorten uit 39 genera van de tribus Brassiceae, Alysseae, Arabideae, Euclidieae, Hesperideae, Lepidieae en Sisymbrieae. Daarvan werden 44 soorten uit 39 genera voorkomend in Egypte onderzocht door middel van nucleotidevolgorden van het *matK* gen van de chloroplasten, om verwantschappen te bepalen tussen genera binnen een tribus en tussen tribus binnen de familie. De topologie van de

Jackknife, parsimonieanalyse en Maximum Likelyhood dendrogrammen komen grotendeels overeen. De analyse geeft aan dat de tribus Arabideae, Sisymbrieae, Hesperideae en Lepidieae polyfyletisch zijn. Onze resultaten ondersteunen de verwantschap van *Ricotia lunaria* met *Maresia* en *Eremobium* en niet met *Alyssum* en *Lobularia*, zoals was voorgesteld door eerdere auteurs. *Capsella* en *Neslia*, oorspronkelijk geplaatst in Lepidieae, zijn volgens onze gegevens nauw verwant aan *Arabidopsis* en *Olimarabidopsis*. Verder onderbouwen onze resultaten een monofyletisch genus *Maresia* (*M. nana, M. pygmaea*), en suggereren dat soorten uit dit genus niet nauw verwant zijn aan *Malcolmia* (*M. africana*). Er zijn nauwe banden tussen *Anastatica, Morettia, Diceratella* en *Notoceras*; en tussen de soorten van *Matthiola, Leptaleum, Malcolmia*, en *Neotorularia torulosa*. Verder tonen onze resultaten dat *Sisymbrium* taxa nauw verwant zijn aan *Octhodium* en deze taxa vormen samen een monofyletische groep. Daarentegen is de *Nasturtium/Cardamine* clade afgescheiden van de *Rorippa* clade, en deze gegevens komen overeen met gegevens van ITS en niet-coderende chloroplastsequenties. Voorts lieten onze uitkomsten zien dat *Rorippa integrifolia* veel op *Nasturtiopsis coronopifolia* lijkt, en een hybride zou kunnen zijn tussen soorten van *Rorippa* en *Nastutiopsis*. Onze fylogenetische analyse onderbouwt in algemene zin, behoudens enige aanpassingen, de rangschikking van taxa in het systeem van Janchen.

ALGEMENE CONCLUSIES

1. Ofschoon de monofylie van de familie als geheel niet ter discussie staat, zijn de grenzen tussen tribus in Brassicaceae in sterke mate kunstmatig, en zelfs subtribus zijn zelden een weerslag van de fylogenetische verwantschappen (Koch et al., 1999), omdat het aantal kenmerken gebruikt door voorgaande auteurs zeer laag was. Slechts twee of drie kenmerken zijn gebruikt (zaadlob/kiemwortelpositie, aard van de beharing, type en plaatsing van de nectariën, vruchtlengte), terwijl deze kenmerken variëren binnen genera.
2. Ofschoon de morfologie van de traditionele tribus Euclidideae en Lunarieae zeer homogeen is, laat de fylogenetische analyse zien dat tussen de taxa van deze twee tribus diverse taxa uit andere tribus zijn geplaatst.
3. Moleculair onderzoek toonde aan dat soorten uit verschillende genera met grote verschillen in vruchtmorfologie nauw verwant blijken te zijn, bijv. *Octhodium* lijkt veel op *Sisymbrium*, *Neslia* lijkt op *Olimarabidopsis*, en *Ricotia* is gepaard met *Eremobium*; en deze resultaten stroken met eerdere moleculaire studies van Galloway et al., 1998; Koch et al., 1999; Zunk et al., 1999.
4. Zowel morfologie als moleculaire analyses suggereren dat Sisymbrieae, Arabideae, en Hesperideae inclusief de Matthioleae polyfyletische tribus zijn.

5. Zaadmorfologie en pollenexinestructuur bleken nuttige bijdragen te leveren om nauw verwante genera en soorten binnen het genus te onderscheiden.
6. De genera *Sisymbrium*, *Morettia* en *Matthiola* zijn monofyletisch.
7. Onze resultaten ondersteunen een monofyletisch genus *Maresia (M. nana, M. pygmaea*), en suggereren dat soorten uit dit genus niet nauw verwant zijn met *Malcolmia* (*M. africana*).
8. *Rorippa integrifolia* is nauw met *Nasturtiopsis coronopifolia* verwant, en kan een hybride zijn tussen soorten van *Rorippa* en *Nasturtiopsis*.
9. *Nasturtiopsis* is gescheiden van *Rorippa*, zodat onze resultaten de samenvoeging van deze twee genera onder *Nasturtium*, zoals bepleit door voorgaande auteurs (Al-Shehbaz, 1988; Jonsell, 1988; en Rollins, 1993) niet ondersteunen, en deze resultaten komen overeen met een eerdere fylogenetische analyse gebaseerd op ITS (Yang et al., 1999).

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B: Botanischer Garten und Botanisches Museum Berlin-Dahlem, Germany.
BM: Herbarium, British Museum (Natural History), London SW7 5BD, England, U.K.
BR: Herbarium, Jardin Botanique National de Belgique, Meise B1860, Belgium.
CAI: Cairo University Herbarium, Cairo, Egypt.
CAIM: Herbarium of Agricultural Research Center, Dokki, Cairo, Egypt.
E: Herbarium, Royal Botanical Garden, Edinburg EH3 5LR, Scotland, U.K.
HUJ: Herbarium of Department of Evolution, Systematics and Ecology, The Hebrew University of Jerusalem, Israel.
K: Herbarium, Royal Botanic Gardens, Kew, Richmond, Surrey TW9 3AB, England, U.K.
KSU: Herbarium of Botany Department, College of Sciences, King Saud University, Riyadh, Saudi Arabia.
L: National Herbarium of the Netherlands, Leiden branch, Leiden, the Netherlands.
LY: Herbier, Departement de Biologie Végétale, Université de Lyon, Lyon, France.
LIV: Herbarium, Botany Department, Liverpool Museum, Wiliam Brown Street, Liverpool L3 8EN, England, U.K.
OXF & FHO: Fielding-Druce Herbarium, Department of Botany, University of Oxford, Oxford OX1 3RB, England, U.K.
W: Naturhistorisches Museum, Botanische Abteilung, Burgring 7, A-1014 Vienna, Austria.
WAG: National Herbarium of the Netherlands, Wageningen University branch, Wageningen, the Netherlands.

CURRICULUM VITAE

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LIST OF PUBLICATIONS

1. El-Khatib, A.A., Abdel-Ghaney, M.M., and **Abdel Khalik, K.** 1998. Soil-vegetation relationship and distribution of *Convolvulus* in Egypt. *Feddes Repertorium* **109** (1-2): 175-185.

2. **Abdel Khalik, K.** and L.J.G. van der Maesen. 2002. Seed morphology of some tribes of Brassicaceae (Implications for taxonomy and species identification for the flora of Egypt). *Blumea* **57** (2): 363-383.

3. **Abdel Khalik, K.,** van den Berg, R. G., van der Maesen, L. J. G. and El Hadidi, M. N. 2002. Pollen morphology of some tribes of Brassicaceae from Egypt and its systematic implications. *Feddes Repertorium* (In press).

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5. **Abdel Khalik, K.,** Bakker, F.T., van der Maesen, L. J. G., and van den Berg, R. G. Phylogenetic analysis of Brassicaceae based on plastid *mat*K sequences (Implications for taxonomy of Brassicaceae in Egypt). (In preparation).

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الدراسه ان صفات خلايا البشرة ذات قيمة تصنيفية عالية و خصوصا فيما يتعلق بطرز هذه الخلايا و طبيغة الجدر الفاصله بينهما و صفات جدرها الخارجيه. و كذلك اظهرت هذه الصفات اهمية تصنيفيه للتفرقة بين الانواع النباتية قيد الدراسة على مستوى الجنس والنوع و كذلك تحت النوع. و قد تم عمل مفتاح للتفرقة بين الانواع بناء على صفات البذور.

تناول المجال الثالث دراسة الشكل المورفولوجي لحبوب اللقاح باستخدام الميكروسكوب الضوئي و الماسح الالكتروني. و اظهرت الدراسه ان حبوب اللقاح تتبع رتبة ثلاثية الفتحات و تتنوع في الشكل من المتطاول و تحت المتطاول الى البيضاوى المتطاول. وتم التعرف على ثلاث انماط من حبوب اللقاح بناءا على زركشة السطح و هي شبكي دقيق و شبكي و شبكي متسع. و قد اوضحت دراسة الشكل المورفولوجي لحبوب اللقاح اختلافات تصنيفية عالية للتفرقة بين الانواع المتشابهة في الشكل الخارجي في نفس القبيلة مثل ماتسيول و مورتيا و دسيراتيلا.

تناول المجال الرابع دراسات تحليلية باستخدام برامج احصائية و هي تحليل ابجاما (UPGMA) و كذلك التحليل التشابهي بين الانواع (PCO) بناء على اثنين و ستون صفة مورفولوجية خاصة بالجزء الخضري و حبوب اللقاح و كذلك البذور. و قد تم التعرف على اربعة مجموعات رئيسية تمثل قبائل ايوكليدى و ليناري و ماتسيولي و المجموعة المختلطة اللتى تشمل قبائل اراييدى و هسبريدى و سيسمبرى

تناول المجال الخامس دراسات تحليلية باستخدام برامج احصائية و هي تحليل برسيموني (parsimony) و كذلك تحليل اقوى الاحتمالات(likelihood) بين الانواع (٨٣ نوع) التى تمثل كل قبائل الفصيلة الصليبية في مصر بناء على تتابع القواعد النيتروجيبية في جزء من جين matK داخل البلستيدات الخضراء لنرى العلاقة والتطور بين الانواع داخل الفصيله و بين الفصائل داخل القبيلة. وقد اظهرت الدراسة ان قبائل اراييدى و هسبريدى و سيسمبرى و ليبيدى عديدة المنشا و كذلك اثبتت الدراسة ان هناك ارتباط قوى بين جنس ريكوتيا و كلا من جنسى ايروموبيوم و مارسيا. كما أوضحت الدراسة ان هناك علاقة قوية بين كلا من جنسى كابسيلا و نسليا اللذان يتبعان قبيلة ليبيدى وبين اراييدوبسس و اوليماراييدوبسس. و كذلك اثبتت الدراسه ان جنس مارسيا ليس له علاقة بجنس مالكولميا. بالاضافه الى ذلك أوضحت الدراسة ان هناك علاقة قوية بين اناستاتيكا و موريتيا و دسيراتيلا و نوتوسيرس و كلا من ماتسيولا و مالكولميا و ليبتاليوم و نيوتوريولاريا و كذلك بين سيسمبريوم و اوكسيديوم. كما اثبتت الدراسه ان جنس ناستورتوم ليس له علاقه بجنس روريبا الذى ورد انه يتبع روريبا في كثيرا من الدراسات السابقه و كذلك اوضحت الدراسة ان هناك علاقة قوية بين كلا من روريبا انتيقريفوليا و ناستورتوبسس و هذا النوع من روريبا ربما ان يكون هجين بين كلا من روريبا و ناستورتوبسس.

بسم الله الرحمن الرحيم

دراسات بيوتصنيفية على الفصيلة الصليبية في مصر

يتضمن العمل الحالي دراسات بيوتصنيفية على ستة قبائل من الفصيلة الصليبية فى مصر وهى قبائل ارابيدى و ايوكليدى و هسبريدى و ليناري و ماتسيولي و سيسمبرى. ولقد اعتمدت الدراسة على اساس المجموعات النباتية المتاحه والمحفوظه فى معشبات جامعة القاهرة و المتحف الزراعى و جامعة سوهاج و الرياض و الجامعة العبرية بالقدس و برلين و ادنبرة و المتحف الملكى البريطانى و لفربول و كيو و بروكسل و ليدن و ليون و فينا و فاخنينجن و كذلك على الدراسات الحقلية المكثفة فى كل انحاء مصر.

وقد اعتمدت الدراسة على خمس مجالات رئيسية مسبوقة بجزء عام. وتناول الجزء العام نبذة تاريخيه و دور التوزيع الجغرافى و الاهمية الاقتصادية لنباتات هذه الفصيلة وكذلك عرض الاهداف الرئيسيه من الدراسة. تناول المجال الرئيسى الاول مراجعة تصنيفية للانواع النباتية قيد الدراسة و قد تم عمل مفتاح صناعى للتعرف على الانواع النباتية بناء على الصفات المورفولوجيه وكذلك تقييم لاهم الصفات التصنيفية التى تم استخدامها. واسفرت النتائج عن وجود ٢٣ جنسا تشتمل على ٣٩ نوع و ٦ تحت نوع تمثل القبائل السابقة. كشفت الدرلسة عن وجود نوعين يسجلان لاول مرة فى الفلورا المصرية وهما: ايروموبيوم ايجبتياكم تحت نوع لونجيسليكوم و ماتسيولا لونقيبيتاله تحت نوع كرالكى. اثبتت الدراسه ان جنس ماتسيولا ليس ممثلا بستة انواع كما ورد ذكره فى تاكهولوم ١٩٧٤ بل انه ممثل ب٤ انواع فقط. وقد عولجت ماتسبولا ايليبتكا بانها نوع يتبع جنس ديسيراتيلا. و اظهرت الدراسة بان ماتسيولا لونجيبيتاله ممثل فى مصر بخمس تحت نوع وهى تحت نوع لونجيبيتاله و هرته و بايكورنيس و ليفيدا و كرالكى.

اثبتت الدراسه ان جنس ناستورتوم الذى ورد ذكره فى تاكهولوم ١٩٧٤ على انه ممثل بنوعين هما انديكم و اوفيسينالس ثبت الان انه ممثل فى مصر بنوع واحد فقط وهو ناستورتوم اوفيسينالس وتم معالجة النوع الاخر بانه يتبع جنس روريبا. اوضحت الدراسة ان جنس اريموبيوم الذى ورد ذكره تاكهولوم ١٩٧٤ على انه ممثل فى مصر بنوعين هما ايجبتياكم و دفيوزم ثبت الان ان هذا الجنس ممثل بنوع واحد وهو ايروموبيوم ايجبتياكم و ثلاثة تحت نوع: تحت نوع لينير و ايجبتياكم و لونجيسليكوم.

اظهرت الدراسه ان جنس نسليا الذى ورد ذكره فى كثيرا من المراجعات التصنيفية العالمية على انه ممثل بنوعين وهما نسليا بانيكيولاتا و نسليا ابيكيولاتا انما هو ممثل بنوع واحد فقط وهو نسليا بانيكيولاتا و يشمل صنفين هما صنف بانيكيولاتا و صنف ابيكيولاتا.

تناول المجال الثانى من الدراسة على دراسة اسطح البذور باستخدام الماسح الالكترونى و اثبتت

الله

بسم الله الرحمن الرحيم

قالوا سبحانك لا علم لنا إلا ما
علمتنا إنك أنت العليم الحكيم .

صدق الله العظيم
البقرة - ٣٢ -