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Systematic significance of the seed morphology and seed coat sculpture of the genus *Euphorbia* L. (*Euphorbiaceae*) in Egypt

Abstract

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This is the first study deals in-depth with the seed ultra-structure of the genus *Euphorbia* L in Egypt. It focuses on 29 species belonging to this genus. The seed morphology and seed coat sculpture of those species were studied using Stereoscopic and Scanning Electron Microscopy (SEM). Seed characters such as shape, caruncle, epidermal cells, anticlinal boundaries, and periclinal walls were proved to be of taxonomic importance, especially for the delimitation of the concerned species. Based on the general shape of testa surface, six seed morphotypes were recognized as follows: smooth, rugose, pitted, transversely sulcate, tuberculate and reticulate.

Key words: Micromorphology, S.E.M., Mediterranean Flora.

Introduction

Euphorbia L. comprises about 2000 species all over the world and primarily occurs in subtropics and temperate regions (Heywood 1979; Radcliff-Smith 1980). This genus grows in different life forms such as herbs, shrubs, and trees. It is characterized by the presence of milky latex (Boulos 1999), where the distribution of latex and the associated lactiferous can be informative in classification of the family as a whole (Wurdack & al. 2005). Genus *Euphorbia* is considered the largest one in the Egyptian flora. El-Hadidi (1974), reported that this genus is represented in Egypt by 39 species, about two decades later, El-Karemy (1994) recorded 42 species in Egypt including three new varieties. Recently, Boulos (1999) stated 41 species with considering *E. schimperi* is synonymy to *E. consobrina* instead of two distinct species as indicated by El-Karemy (1994).

El-Hadidi (1973) revised critically section *Anisophyllum*, while Fayed (1973) conducted a taxonomic revision of 20 species distributed among different sections namely: *Anisophyllum*, *Lyciopsis, Poinsettia, Pseudoacalypha, Tirucalli,* and *Tithymalus*. Accordingly, Fayed (1973) emphasized on the importance of some morphological characters of cyathium, capsule, and seed in distinguishing the Egyptian materials of *Euphorbia* species. On the large scale, several works (e.g., Kuzmanov 1963; Khan 1968; El-Ghazaly

1989; Gilbert 1994; Blattner & al. 2001; Wurdack & al. 2005) have dealt with genus *Euphorbia* from various aspects in different parts of the world.

Many authors (e.g., Hill 1976; Canne 1980; Hassan & al. 2005) have proved the taxonomic significance of seed coat sculpture. Therefore, the number of such studies increased over the last decades. Seed morphology of *Euphorbia* species shows important characters particularly for the oriental species within that genus (Bossier 1862, 1866). Lately, Heubl & Wanner (1996) added that SEM studies on *Euphorbia* seeds are usually indicative. The objectives of the present study are 1) to show the different patterns in seed morphology and the ultra-structure of seed coat surface of the genus *Euphorbia* in Egypt and 2) to evaluate their taxonomic significance within the genus.

Materials and Methods

Seeds of the studied taxa were procured from different sources. The data on macro and micro-morphological feature based on about five seeds taken randomly for each species. Measurements of seed length and low magnification observations were made using Wild M8 stereomicroscope. Seed samples were removed from the herbarium materials as shown in Table 1. SEM photographs were carried out by JEOL JSM-35 Model at an accelerating voltage of 15 KV at Electron microscope unit of Assiut University. The terminology used for the description follows Cutler (1979) and Barthlott (1981, 1984) with some modifications when necessary.

Results

Seed shape

Seed shape shows some variations within the studied taxa of genus *Euphorbia*. It has been observed that ovoid(-tetragonous) and oblong(-tetragonous) seed shapes or nearly so are dominant among studied taxa. On the other side, there are some species with different seed shapes such as subglobose that characterize *E. scordifolia* (Fig. 1K), *E. polyacantha* (Fig. 1M) and *E. pterococca*; ellipsoidal shape distinguishes both *E. hierosolymitana* and *E. erinacea* (Fig. 2M).

Seed size

Some differences in seed size were recorded in studied taxa. *E. prostrata* (Fig. 1I) has the smallest seeds ca. 0.8 - 1 x 0.5 - 0.6 mm. On the contrary, *E. helioscopia* (Fig. 3E) possesses the largest ones ca. 3 - 4 x 2- 3 mm., for the remaining taxa see Table 2.

Seed colour

Occasionally seed colour can be useful in recognizing some taxa. The results show that the seed colour of most studied taxa ranged from grey(ish) to brown(ish), or reddish and rarely tends to be black(ish). However, it can be observed that some taxa: *E. consobrina, E. peplus, E. retusa* and *E. terracina* differ from others by having white(ish) seeds.

Caruncle (see. Fig. 4)

According to the present work, the caruncles were found in sections *Tithymalus* and *Tirucalli***.** Colour of caruncles varied from yellow(ish) to whit(ish). The present results

Table 1. Voucher specimens used in the present study.

Taxa	Locality	Voucher
Section: *Anisophyllum*		
Euphorbia arabica Boiss.	Gebel Elba, Gebel Shendodai	*Täckholm 1959* (CAI)
E. forsskaolii J. Gay	Kafer El-Sheikh, Baltim	*El-Hadidi s.n.* (CAI)
E. granulata Forssk.	Mersa Abu Daam, sand dunes	*Täckholm & al. s.n.* (CAI)
E. hyssopifolia L.	Qaliubia, El-Kiad ed Digwa, near Tukh	*Ibrahim & al. s.n.* (CAI)
E. inaequilatera Sond.	Sinai	*El-Hadidi s.n.* (CAI)
E. indica Lam.	Assiut, Assiut University ground	*El-Karemy s.n.* (Assiut Univ. Herbarium)
E. peplis L.	Kafer El-Sheikh, Baltim, on sandy hills	*El-Hadidi s.n.* (CAI)
E. prostrata Ait.	Menofya, Ashmoun, Kafer Mansour	*Täckholm & al. s.n.* (CAI)
E. scordifolia Jacq.	Gebel Elba, Delta of wadi-Di-ib	*Täckholm & al. 1433* (CAI)
Section: *Diachantium*		
E. polyacantha Boiss.	Gebel Elba	*Täckholm s.n.* (CAI)
Section: *Lyciopsis*		
E. cuneata Vahl	Gebel Elba	*Khattab 6310* (CAI)
Section: *Poinsettia*		
E. heterophylla L.	Alexandria, Corn field at Maamoura	*El-Hadidi s.n.* (CAI)
Section: *Pseudoacalypha*		
E. acalyphoides Boiss.	Gebel Elba region	*Fahmy & Hassib s.n.* (CAI)
Section: *Tirucalli*		
E. consobrina N. E. Br.	Gebel Elba, Gebl Moga	*Täckholm & al.* s.n.(CAI
E. mauritanica L.	ad ripas Nili	*Kotschy s.n.* (CAI)
Section: *Tithymalus*		
E. arguta Banks & Sol.	El-Fayoum, Kafr Mahfouz	*El-Hadidi s.n.* (CAI)
E. hierosolymitana Boiss.	Mersa Matruh, Agiba	*Wanntrrop & Sjödin 2336* (CAI)
E. dendroides L.	Sallum, 2-5 km from the frontier	*Täckholm s.n.* (CAI)
E. dracunculoides Lam.	Gebel Hamra	*Osborn & Helmy s.n.* (CAI)
E. erinacea Boiss. & Kotschy	Bir el Qattar, on rocks	*Hassib s.n.* (CAI)
E. falcata L.	Between Al-Arish and Rafah	*Mitchel s.n.* (CAI)
E. helioscopia L.	Giza, Faculty of Agriculture Experm. Farm.	*Ghrtek & Kosinova s.n.* (CAI)
E. grosshemii (Prokh.) Prokh.	Sinai, 3 km S. of Bir Lehfen	*Täckholm s.n.* (CAI)
E. paralias L.	Mersa Matruh	*Täckholm & al. s.n.* (CAI)
E. peplus L.	New Vally, Kharga Oasis	*El-Hadidi & al. s.n.* (CAI)
E. petiolata Banks & Sol.	Beheira, Damanhur	*Muschler s.n.* (CAI)
E. pteroccoca Brot.	Alexandria, Mariut	*Duval s.n.* (CAI)
E. retusa Forssk.	Mokattam. Near Cairo, above the Citadel, gravel exposed wadi	*Davis 6299B* (CAI)
E. terracina L.	Alexandria, Burg El Arab	*El-Hadidi s.n.* (CAI)

Fig. 1. Scanning electron micrographs of seeds of *Euphorbia* species. A,B- *E. forsskaolii.* C,D -*E. granulata*. E,F- *E. hyssopifolia*. G,H- *E. inaequilatera*. I,J- *E. prostrata*. K,L- *E. scordifolia*. M,N- *E. polyacantha*.

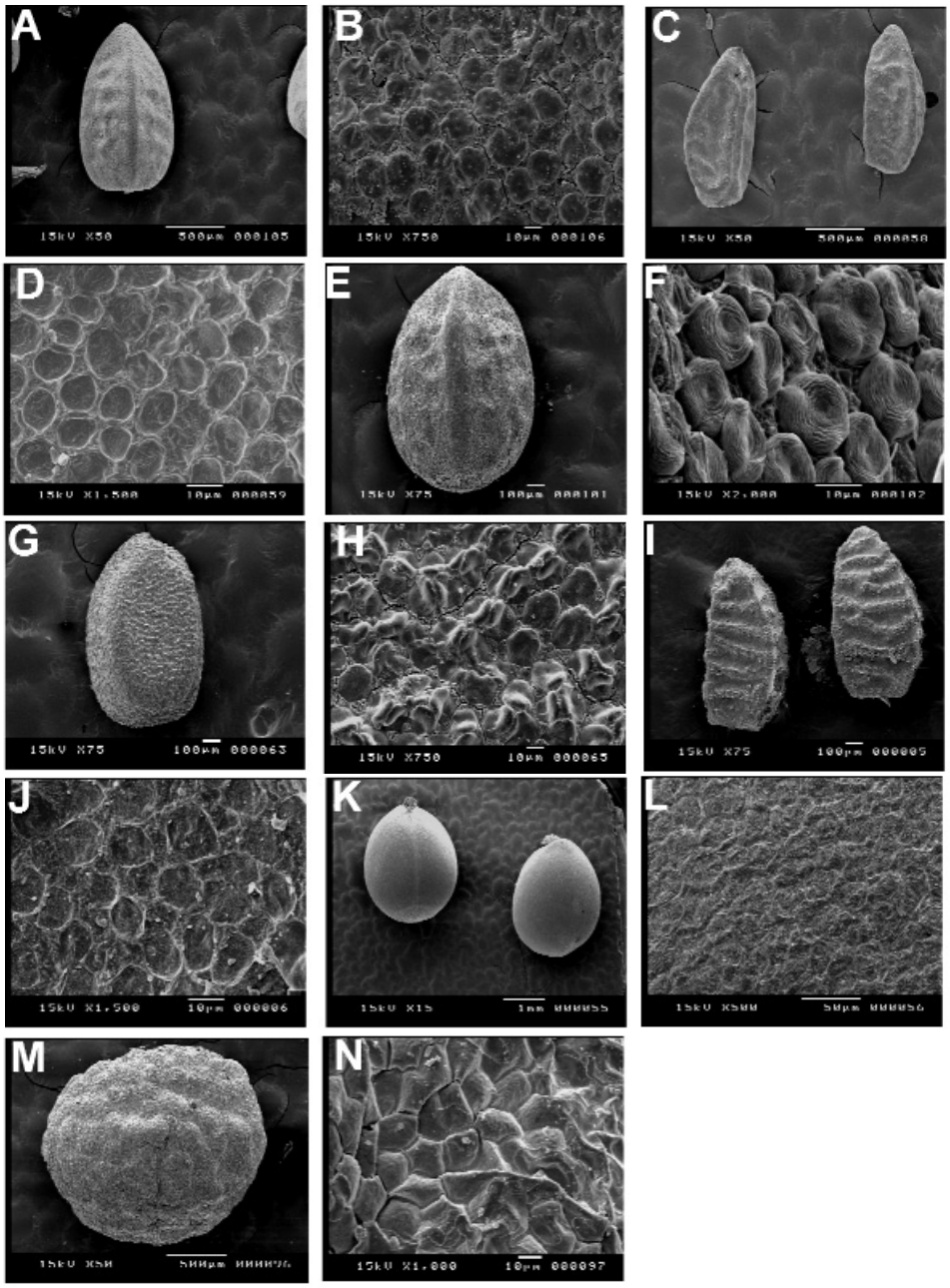


Fig. 2. Scanning electron micrographs of seeds of *Euphorbia* species. A,B- *E. cuneata*. C,D- *E. heterophylla*. E,F-*E. acalyphoides*. G,H- *E. consobrina*. I,J- *E. dendroides*. K,L- *E. dracunculoides*. M,N- *E. erinacea*.

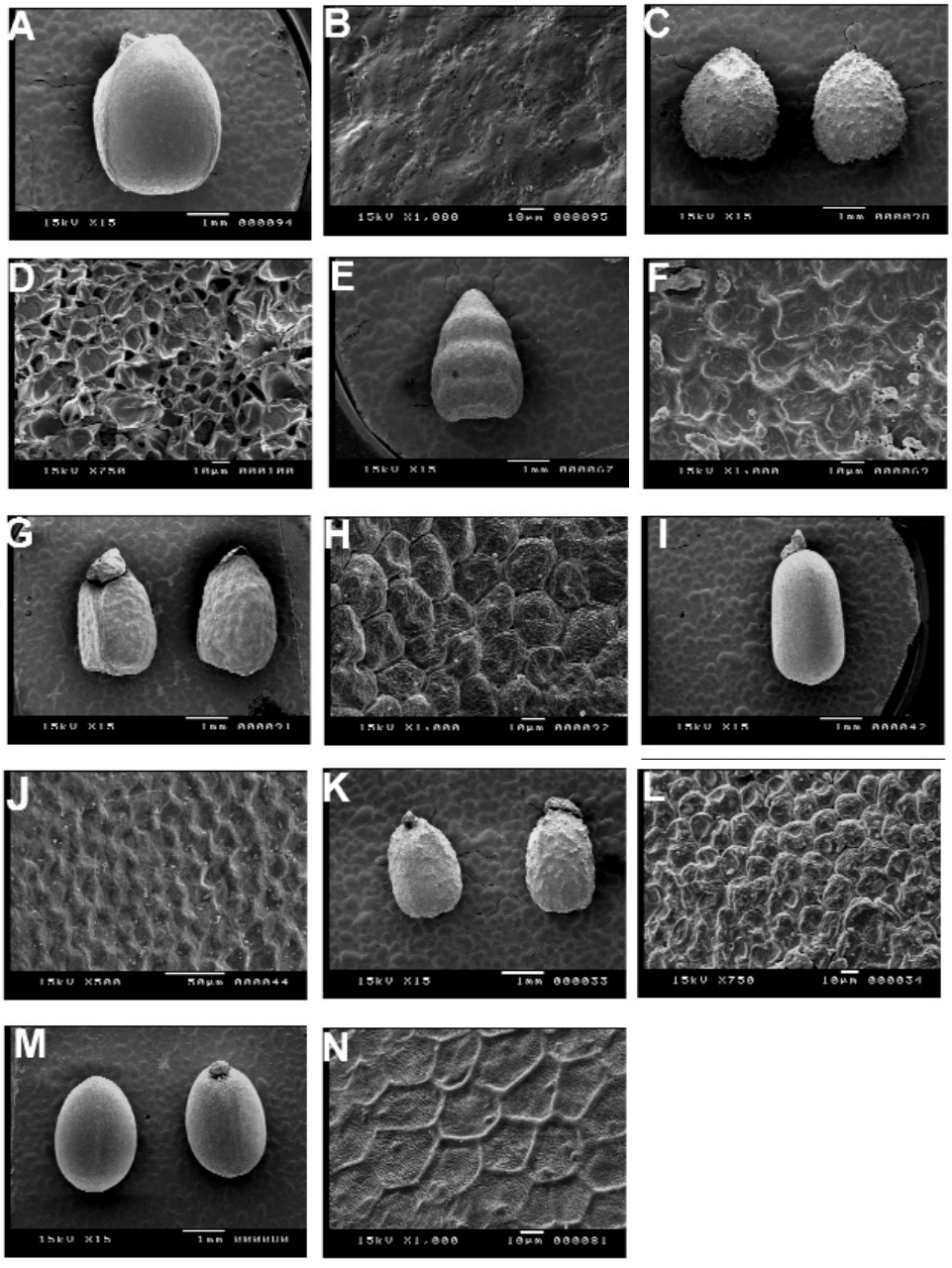


Fig. 3. Scanning electron micrographs of seeds of *Euphorbia* species. A,B- *E. falcata*. C,D- *E. grossheimii.* E,F- *E. helioscopia*, G,H- *E. paralias*. I,J- *E. peplus*. K,L- *E. petiolata*. M,N- *E. terracina.*

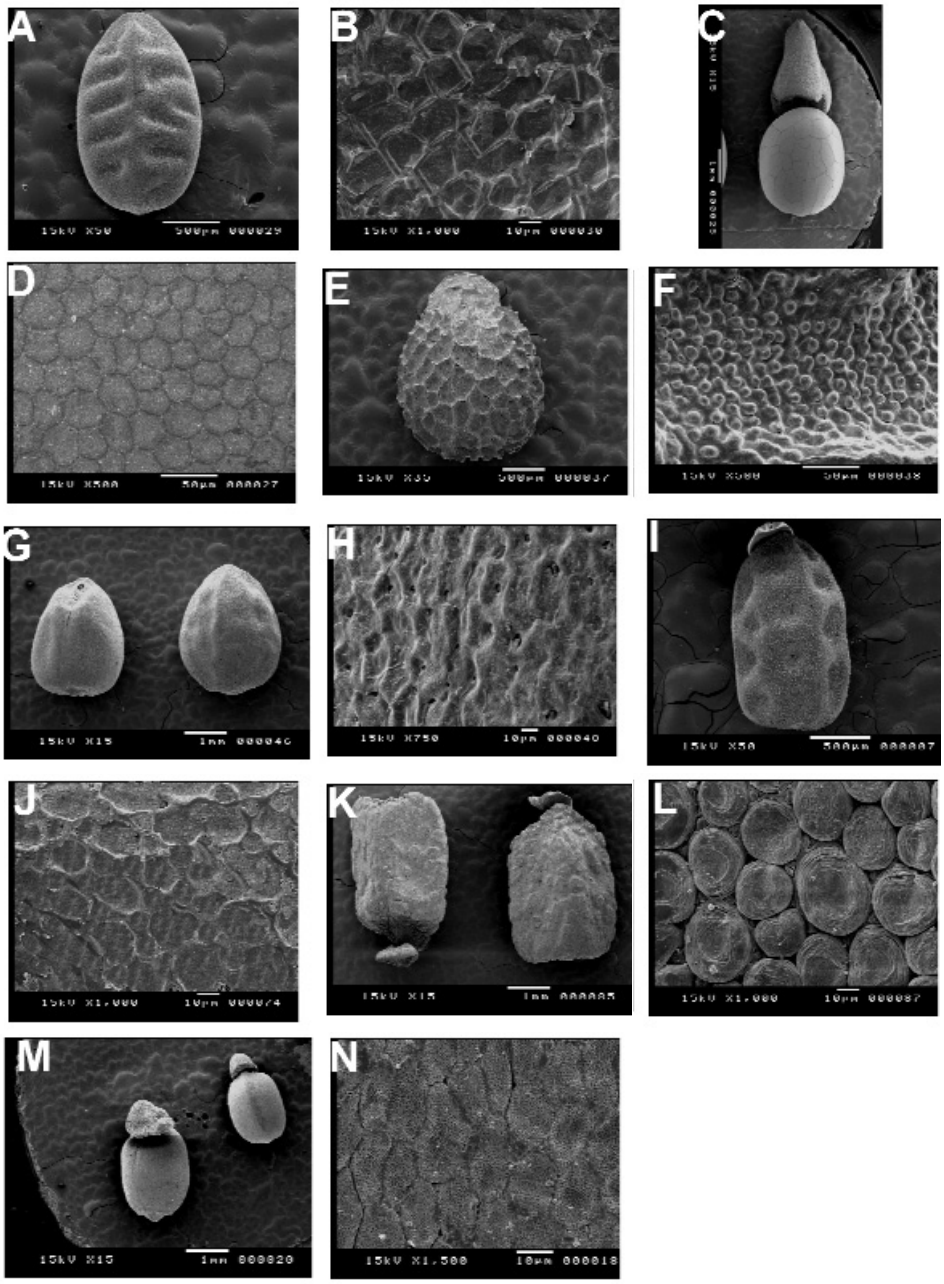
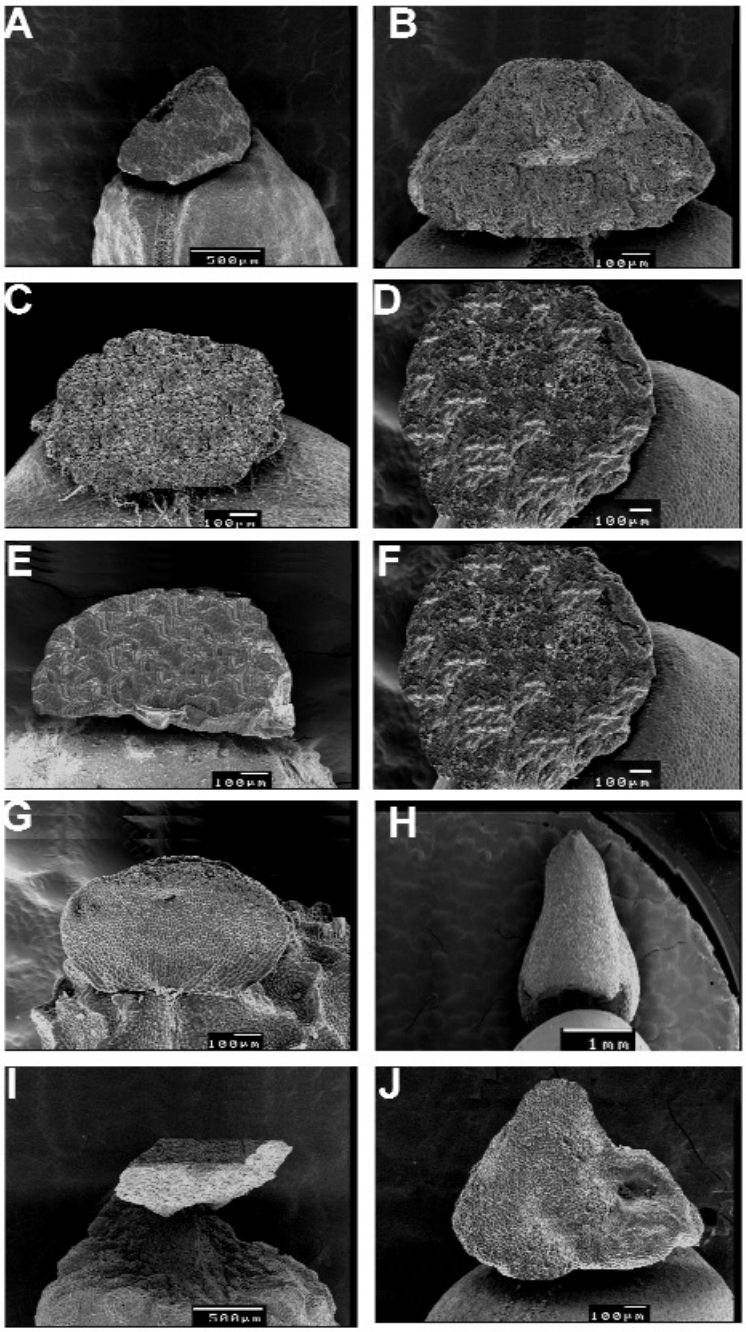


Fig. 4. Scanning electron micrographs of caruncles of some seeds belonging to *Euphorbia* species A *E. consobrina*. B- *E. mauritanica*. C- *E. hierosolymitana*. D- *E. dendroides*. E- *E. draunculoides*. F- *E. erinacea*. G- *E. helioscopia*. H- *E. grosshemii*. I- *E. petiolata*. J- *E. terracina*.



have proved that the shape of caruncle is valuable character in recognizing some studied taxa. For instance, conical-shaped distinguishes *E. falcata, E. grosshemii* (Fig. 4H), and *E. retusa*. Hemispherical caruncles were observed in *E. dendroides* (Fig. 4D) and *E. erinacea* (Fig. 4F); ± peltate in *E. arguta*, *E. draunculoides* (Fig. 4E), *E. consobrina* (Fig. 4A), *E. mauritanica*, *E. peplus* and *E. pterococca* (Fig. 4B); globose-depressed in *E. hierosolymitana* (Fig. 4C); reniform in *E. paralias* (not shown) and ± deltoid-shaped in *E. teracina* (Fig. 4J). Ovate (sometimes semi-orbicular) and ± rectangular caruncles characterize *E. helioscopia* (Fig. 4G) and *E. petiolata* (Fig. 4I) respectively. Presence or absence of stalk can be separating character in sorting them into two groups. One of them (*E. hierosolymitana, E. dendroides, E. erincea, E. helioscopia*, *E. paralias, E. peplus,* and *E. pteroccoca*) has sessile caruncles, while the other (*E. mauritanica, E. draunculoides, E. falcata, E. grosshemii*, *E. petiolata*, and *E. terracina*) with a short stalk.

Epidermal cells

According to the present work, the epidermal cells of most studied taxa can be either ±isodiametrical or penta-hexagonal. For instance, (±)isodiametrical epidermal cells can be found in *E. forsskhaolii* (Fig. 1B), *E. granulata* (Fig. 1D), *E. hyssopifolia* (Fig. 1F), *E. indica*, *E. arguta* and *E. petiolata* (Fig. 3L). Indistinct to isodiametrical cells were observed in *E. prostrata* (1J) *E. dracunculoides* (Fig. 2L). Penta-hexagonal cells were seen in *E. consobrina* (Fig. 2H), *E. dendroides* (Fig. 2J), *E. erinacea* (Fig. 2N), *E. falcata* (Fig. 3B), *E. mauritanica*, *E. grosshemii* (Fig. 3D), *E. pteroccoca* and *E. retusa* and penta-hexagonal to elongated cells characterize *E. arabica*, *E. peplus* (Fig. 3J) and *E. terracina* (Fig. 3N). Penta-hexagonal to variable shape was observed in *E. polyacantha* (Fig. 1N), *E. heterophylla* (Fig. 2D) and *E. acalyphoides* (Fig. 2F) and indistinct to penta-hexagonal in *E. scordifolia* (Fig. 1L), *E. hierosolymitana* and *E. paralias* (Fig. 3H). *E. cuneata* (Fig. 2B) is unique among other taxa with showing ill-defined pattern. The arrangement of epidermal cells of all species studied is randomly distributed.

Anticlinal boundaries

The anticlinal boundaries of the most studied species are conspicuous and vary from sunken to raised ones. The present results exhibit that the anticlinal boundaries could be indistinct, therefore the adjacent epidermal cells are fused as in *E. cuneata* (Fig. 2B). Raised boundaries were observed in *E. heterophylla* (Fig. 2D), *E. dendroides* (Fig. 2J), *E. acalyphoide*s (Fig. 2F), *E. mauritanica* and *E. erinacea* (Fig. 2N), *E. paralias* (Fig. 3H). While those are sunken in *E. hyssopifolia* (Fig. 1F), *E. inaequilatera* (Fig. 1H) and *E. petiolata* (Fig. 3L); sunken to raised boundaries were noticed in *E. arabica*, *E. granulata* (Fig. 1D) and *E. arguta*, and the rest of taxa are either slightly raised or slightly sunken. *E. grosshemii* (Fig. 3D) is being separated from the others by flat anticlinal walls.

The sculpture of anticlinal boundaries of the most studied species varied from smooth to folded. However, there are some taxa such as *E. mauritanica*, *E. hierosolymitana, E. erinacea* (Fig. 2M) and *E. grosshemii* have ± smooth boundaries, but *E. hyssopifolia* (Fig. 1F) and *E. petiolata* (Fig. 3L) are distinguishable by having irregular protrusions.

Table 2. Characters of studied seeds.

Taxa	Characters							
	Seed shape	**Seed size (mm)**	**Caruncle**	**Seed colour**	**Seed surface**	**Epidermal cell shape**	**Anticlinal boundaries**	**Outer periclinal wall**
Section: *Anisophyllum*								
Euphorbia arabica	ovoid-elliptical tetragonous	1-1.2 × 0.6-0.8	absent	redddish	rugose	penta-hxagonal to elongated	sunken to raised	flat to slightly convex
E. forskhaolii	ovoid-oblong-tetragonous	1-1.4 × 0.6-0.8	absent	greyish-red	rugose	isodiametrical	sunken	flat to slightly convex
E. granulata	obong-tetragonous	1-1.3 × 0.5-0.6	absent	greyish to reddish	rugose, slightly ridged	± isodiametrical	sunken-raised	concave
E. hyssopifolia	ovoid-tetragonous	1-1.2 × 0.5-0.7	absent	black	ruguose	isodiametrical	deeply sunken	convex
E. inaequilatera	oblong	1-1.2 × 0.6 -8	absent	light brown	rugose	penta-hexagonal	sunken	convex
E. indica	broadly ovoid-tetragonous	1.2-1.6 × 0.8-1.3	absent	reddish brown	rugose	± isodiametrical	sunken	flat
E. peplis	ovoid-pyriform	3-3.5 × 1.5 -2.5	absent	greyish-white	± smooth	isodiametrical	sunken	flat to slightly convex
E. prostrata	oblong-tetragonous	0.8-1 × 0.5-0.6	absent	reddish	rugose, transversely ridged	± isodiametrical	slightly raised	flat
E. scordifolia	subglobose	2 - 2.5 × 2-2.3	absent	greyish-white	smooth	indistinct to penta - hexagonal	indistinct to slightly sunken	flat
Section: *Diachantium*								
E. polyacantha	subglobose	1.5-2 × 1.3-1.5	absent	greyish	rugose	penta-hexagonal to variable	sunken	convex
Section: *Lyciopsis*								
E. cuneata	broadly-ovoid	2-3.5 × 2.5-3	absent	brown	smooth	indistinct	indistinct to slightly sunken	flat to slightly convex
Section: *Poinsettia*								
E. heterophyla	truncate-ovoid	2.2-2.5 × 1.8-2	absent	greyish brown	tuberculate	penta-hexagonal to variable	highly raised	concave

Table 2. (continued.)

Section: *Pseudoacalypha*								
E. acalyphoides	ovoid-deltoid	2.5-3 × 1.8-2.1	absent	blackish to brown	smooth, with constricted surface	penta-hexagonal to varaible	raised	concave
Section: ***Tirucalli***								
E. consobrina	ovoid	2.5-3 × 2-2.5	Present	whitish	minutely tuberculate	penta-hexagonal	slightly sunken	flat to slightly convex
E. mauritanica	oblong	3.7-4 × 2.3-2.5	Present	brownish to greyish	smooth, lowly tuberculated (specially on the ventral surface)	penta-hexagonal	raised	often flat
Section: *Tithymalus*								
E. arguta	ovoid-tetragonous	2-2.5 × 1.5-2	Present	dark brown	smooth	isodiametrical	slightly sunken to raised	flat
E. hierosolymitana	ellipsoid	3-3.2 × 2-2.5	Present	dark brown to black, shiny	smooth, glossy	indistinct to penta-hexagonal	indistinct to slightly raisd	flat
E. dendroides	oblong	3-3.5 × 1.8-2	Present	greyish green	smooth	penta-hxagonal	raised	concave
E. dracunculoides	ovoid	2-2.5 × 1.5-1.7	Present	blackish to brown	tuberculate	indistinct to isodiametrical	indistinct to sunken	convex
E. erinacea	ellipsoid	2.8-3 × 2-2.2	Present	dark brown	smooth	indistinct to penta - hexagonal	indistinct to raised	flat
E. falcata	compressed ovoid-tetragonous	1.2-1.5 × 1-1.2	Present	greyish	transversly-sulcate	indistinct to penta - hexagonal	indistinct to raised	flat
E. grosshemii	ovoid	3-3.5 × 1.9-2.1	Present	greyish to whitish	smooth	penta-hxagonal	flat	flat
E. helioscopia	ovoid-subglobose	3-4 × 2-3	Present	brown to black	reticulate	indistinct	indistinct	papillose
E. paralias	ovoid-tetragonous	2.5-3 × 2-2.5	Present	greyish with blackish spots	smooth	indistinct to penta-hexagonal	indistinct to raised	concave
E. peplus	oblong	1.5-2 × 0.9-1.2	Present	whitish	pitted with longitudinal furrows on the ventral surface	penta-hexagonal to elongated	slightly raised	flat to slightly concave

Table 2. (continued.)

E. petiolata	oblong-tetragonous	3.5-4 × 2.3-2.5	Present	black with grey spots	tuberculate	isodiametrical	deeply sunken	convex
E. pterococca	subglobose	0.7-1.3 × 0.8-1.1	Present	dark brown	reticulate	penta-hexagonal	slighty raised	± flat
E. retusa	oblong-ovoid	2-2.5 × 1-1.5	Present	white	smooth	penta-hexagonal	slightly sunken	flat
E. terracina	ovoid-tetragonous	1.5-2 × 1-1.5	Present	white-mealy	smooth	penta-hexagonal to elongated	slightly sunken	flat

Outer Periclinal walls

The outer periclinal walls of the majority of studied species varied from flat, flat-convex to flat-concave. However, there are some species: *E. granulata* (Fig. 1D), *E. heterophylla* (Fig. 2D)*, E. acalyphoides* (Fig. 2F), *E. dendroides* (Fig. 2J) and *E. paralias* (Fig. 3H) have just concave periclinal walls, while the other taxa such as *E. hyssopifolia* (Fig. 1F), *E. inaequilatera* (Fig. 1H), *E. polyacantha* (Fig. 1N), *E. dracunculoides* (Fig. 2L) and *E. petiolata* (Fig. 3L) possess convex surface.

The present work showed that the sculpture of periclinal walls of the most taxa ranged from smooth to uneven. Moreover, there are some species such as *E. scordifolia* (Fig. 1L), *E. mauritanica*, *E. retusa* and *E. terracina* (Fig. 3N) were characterized by ± micro-reticulate sculpture.

Six seed types were primarily recognized based on the general form of the testa surface, these types are smooth, rugose, pitted, transversly-sulcate, tuberculate and reticulate.

Type I: Smooth

This type is represented by several species: *E. hierosolymitana, E. cuneata*, *E. dendroides, E. erinecea, E. grosshemii*, *E. retusa, E. scordifolia*, *E. peplis, E. terracina*. *E. arguta*, *E. mauritanica, E. paralias* and *E. acalyphoides*.

Type II: Rugose

This type includes: *E. forsskaolii, E. hyssopifolia E. inaequilatera*, *E. indica*, *E. polyacantha*, *E. arabica*, *E. granulata* and *E. prostrata.*

Type III: Pitted

It is represented by one species: *E. peplus.*

Type IV: Transversly-sulcate

There is only one species: *E. falcata*.

Type V: Tuberculate

It can be observed that both *E. dracunculoides* and *E. heterophylla* are strongly- tuberculated than *E. consobrina* and *E. petiolata*.

Type VI: Reticulate

This type is represented by two species: *E. helioscopia* and *E. pterococca.*

Discussion

The present study on the Egyptian *Euphorbia* species emphasizes the importance of seed characters for recognizing most of the studied taxa. The combined use of Scanning Electron Microscopy (SEM) and Light Microscopy (LM) has revealed numerous taxonomically useful characteristics. El-Ghazaly & Chaudhary (1993) reported that the pollen morphology of most subsections within genus *Euphorbia* is not fully support the delimitation of those subsections within genus *Euphorbia*. Section *Anisophyllum* is characterized

by a number of synapomorphic characters such as leaves opposite, stipulate, basally asymmetrical; cyathia axillary or clustered; glands often with membranous appendages and seeds without caruncle (e.g., Radcliff-Smith, 1977). Hooker (1885) stated that *Anisophyllum* is indefinitely multiplied. El-Ghazaly & Chaudhary (1993) indicated that this section is heterogamous in relation to the shape of aperture and sexine pattern of its pollen grains.

Based on the present results, the seed features of *Anisophyllum* are rather variable. According to Fayed (1973), *E. arabica* is simply recognized by distinct macro-morphological characters besides, and according to the present work, the ovoid-elliptical tetragonous seeds and irregularly granulated anticlinal boundaries are separating characters. All studied species in this section are belonging to type II (rugose) except two species (*E. peplis* and *E. scordifolia*) are included in type I (smooth). *E. peplis* and *E. scordifolia* are distinguishable based on macro-morphological characters (Fayed 1973). The seed features support discriminating between those two former taxa, the periclinal walls are rather micro-reticulate in *E. scordifolia* (Fig. 1L), while these walls are smooth to uneven in *E. peplis*.

El-Hadidi & Fayed (1978) reported that *E. forsskaolii*, *E. granulata, E. indica* and *E. prostrata* show some ambiguity upon identification. According to the present results, those former taxa are included in type II (rugose). The seed results revealed that the periclinal walls (flat-slightly convex) are useful in recognizing *E. forsskaolii* (Fig. 1B) while just flat periclinals in *E. indica*. Both *E. granulata* and *E. prostrata* are being separated from others by having some ridges that are prominent in the last species (Fig. 1I). It has been found that the concave periclinal walls distinguish *E. granulata* (Fig. 1D), while flat periclinals characterize *E. prostrata*. El-Hadidi (1973) stated that *E. granulata* is polymorphic species regarding the indumentum cover, leaf size and shape and seed sculpture. Therefore, El-Hadidi (1973) recognized, in the Egyptian materials, three varieties of *E. granulata* {*E. granulata* var. *granulata*, *E. granulata* var. *glabrata* Boiss., and *E. granulata* var. *turcomanica* (Boiss.) Hadidi}. These varieties have some resemblance with *E. forsskaolii* and *E. prostrata*, but Fayed (1973) mentioned that those varieties deviate than the former species (*E. forsskaolii* and *E. prostrata*) with regarding to some macro-morphological characters and seed features as well.

Radcliffe-Smith (1980) reported that there is uncertainty between *E. hyssopifolia* and *E. indica*. However, El-Hadidi (1973) reported that *E. hyssopifolia* is a distinct species based on narrow leaves and black seeds. El-Hadidi's (1973) view has been confirmed by our results which show clearly that *E. hyssopifolia* can be easily distinguished by strongly convex and concentrically folded sculpture periclinal walls (Fig. 1F) but *E. indica* has flat and smooth-uneven periclinals.

Morphologically, *E. inaequilatera* (Fig. 1G,H) seems to be closer to *E. peplis* (Täckholm, 1956) than the other taxa. Nevertheless, the present results offer separating features between these two species such as seed shape, size, surface, colour and periclinal walls.

E. polyacantha (section *Diachantium*) share rugose seeds with some taxa belonging to section *Anisophyllum*. *E. polyacantha* is distinguishable from those species based on subglobose seeds (Fig. 1M), greyish colour and penta-hexagonal to variable epidermal cells (Fig. 1N). Boulos (1999) mentioned that, in Flora of Egypt, *E. polyacantha* share succu-

lent and sometimes leafless stems with *E. consobrina* and *E. mauritanica*. While, presence of angled {4-5(-7)-} stems and spine-shields (along its ribs) besides the seed characters (e.g. seed shape and size) are distinguishing of this species.

Section *Lyciopsis* is represented in our study by *E. cuneata* that shares smooth seeds (Fig. 2A) with some members from sections *Anisophyllum* and *Tithymalus*. This species would be matchless, among others, by combining of macro-morphological characters and seed features.

E. heterophylla (section *Poinsettia*) shows some similarities (tuberculate seeds) towards *E. consobrina* (*Tirucalli*), *E. dracunculoides* and *E. petiolata* (*Tithymalus*). However, *E. heterophylla* differs from the previous taxa by having rather densely and acute tuberculate seed surface (Fig. 2C). Additionally, concave periclinal walls are distinguishing of *E. heterophylla*, while convex or flat-slightly convex periclinals can be found in the other species.

E. acalyphoides (section *Pseudoacalypha*) shares ± smooth seeds with *E. mauritanica* (section *Tirucalli*), *E. arguta* and *E. paralias* (section *Tithymalus*). Nevertheless, *E. acalyphoides* shows two diagnostic characters such as ovoid-deltoid seeds and transversely constricted surface (Fig. 2E). Morphologically, *E. mauritanica* exhibits some resemblance to *E. consobrina* but the first taxon would be separated from the second by its glands with ± crenulate-margined, in addition to the cyathia and capsules are larger (Boulos 1999). Moreover, and according to the present study, *E. mauritanica* can also be isolated from *E. consobrina* based on ±oblong seeds, smooth surface, brownish to greyish colour and raised anticlinal boundaries, while *E. consobrina* has ± ovoid seeds, whitish colour, and sunken anticlinals (Fig. 2H).

Section *Tithymalus* is the larger section in our study that is characterized by some synapomorphic characters such as alternate and exstipulate leaves; diachasial cyathia; 4-5 involucral glands and carunculate seeds. Type I (smooth) includes six species: *E. hierosolymitana, E. dendroides*, *E. erinecea, E. grosshemii*, *E. retusa* and *E. terracina*. El-Hadidi (1973) mentioned that *E. grosshemii* and *E. retusa* are closely allied species, where he (El-Hadidi 1973) thought that the intermediate forms, probably, grow in the Egyptian desert. Although, Fayed (1973) could not prove the existence of those forms during revising genus *Euphorbia* in Egypt. Based on the present study, *E. grosshemii* and *E. retusa* have some seed characters in common such as seed surface and epidermal cells. However, some differences in seed size, shape and anticlinal boundaries support separating those two species. Besides, the caruncle is as long as or longer than its seeds in *E. grosshemii* (Fig. 4H) while about half as long as the seeds of *E. retusa* (Boulos 1999).

According to Boulos (1999), *E. hierosolymitana* and *E. erinacea* have similarities with respect to some macro-morphological characters and seed morphology too. However, it can be differentiated between them based on periclinal walls and caruncle shape. The present work shows that *E. hierosolymitana* is characterized by flat-slightly convex with smooth-uneven periclinal walls and a depressed-globose caruncle (Fig. 4C), but *E. erinacea* has flat periclinals with very sparsely tubercles and hemispherical caruncle (Fig. 4F).

E. terracina is considered polymorphic species in terms of habitat, habit, leaves and seeds (El-Hadidi & Fayed 1978; Jafri & El-Gadi 1982). El-Hadidi & Fayed (1978) suggested that *E. terracina* var. *prostrata* Boiss representing just an ecotype, where it grows only in the northern coast of Egypt. Moreover, *E. terracina* var. *ecarunculata* as delim-

ited (seeds small and without caruncle) earlier by Boissier (1886) match the materials from isthmic desert and Sinai Peninsula. El-Karemy (1994) reported that *E. terracina* is represented in Egypt by three varieties namely: *E. terracina* var. *terracina, E. terracina* var. *alexandrina* (Delile) El-Karemy and *E. terracina* var. *modesta* (Boiss.) Boiss. It worth mention that Fayed (1983) recorded a new taxon (*E. sanctae-catharinae* Fayed) to the Egyptian flora which is closely related to *E. terracina* complex in respect to involucres and seed features.

It has been observed that *E. dendroides* goes through many changes in its manifestation where the flattened flower heads are similar to those of *E. helioscopia* and others. According to El-Hadidi & Fayed (1978), *E. dendroides* has remarkable morphological characters and hence it can be easily recognized. Regarding the present results, this species is characterized by rough periclinals and strongly raised anticlinal boundaries.

E. paralias can be readily realized by presence of small densely compact appressed leaves (Jafri & El Gadi, 1982), and according to this work the perforated periclinal walls (Fig. 3H) are distinguishing.

The present investigation exhibits that *E. arguta* cannot be distinguished based only on the seed characteristics, therefore in such case a combination of seed and macro-morphological characters is preferable. El.-Hadidi & Fayed (1978) were able to observe two distinct forms of *E. arguta*, where the seed characters on the infra-specific level would be informative as one of them has smooth seeds and the other with a reticulate surface.

The present study shows that *E. helioscopia* and *E. pterococca* have seeds with a reticulate surface (Fig. 3E) (Type VI). The seeds of *E. peplus* (type III) have a pitted surface (Fig. 3I) by which it can be easily recognized. As far as micro-sculpturing is concerned the anticlinal boundaries and periclinal walls permit easily discriminating between those two taxa. *E. peplus* varies greatly in plant size, branching pattern, and leaf form. Therefore, it is considered as a polymorphic species (El-Hadidi & Fayed 1978). El-Karemy (1994) reported two varieties of *E. peplus* (*E. peplus* var. *peplus* and *E. peplus* var. *minima* DC), where the seed size was used as a key character. Occasionally some forms of *E. peplus* could be misidentified and mixed with specimens of *E. pterococca* (Jafri & El-Gadi 1982), but according to the present work, these two species are separable based on seed shape, colour, and testa surface. Also, *E. falcata* is a variable species regarding the habit but it tends to be stable with reference to the other morphological characters (Jafri & El-Gadi 1982). *E. falcata* (type IV) is easily segregated from the remaining taxa based primarily on the general form of the seed surface which is transversely sulcate (Fig. 3A).

E. dracunculoides and *E. petiolata* have tuberculate seeds (type V), where *E. petiolata* is lowly tuberculated (Fig. 3K) than the other. *E. dracunculoides* is noticeable by hemispherical caruncles (Fig. 4E), while *E. petiolata* has ± rectangular ones (Fig. 4I). It has been proved that seed attributes played important role in recognizing taxa such as *E. exigua* which it was considered before as a form belonging to *E. dracunculoides*. El-Hadidi (1973) used the seed characters (size, sculpture, and the cross section of seeds) in his consideration in erecting *E. exigua* as a good species. Carter (1988) stated that some confidence might be placed on the seed sculpture upon deciding and delimiting the new taxa.

Key to the studied species

1. Seeds ecarunculate (not provided with a distinct caruncle) 2
– Seeds carunculate (provided with a distinct caruncle) 14
2. Plants spiny 3
– Plants not spiny 4
3. Succulent shrubs; seeds rugose, testa epidermal cells penta-hexagonal to variable.....
.....*Euphorbia polyacantha*
– Non-succulent tree; seeds smooth, testa epidermal cells indistinct.....*E. cuneata*
4. Leaves symmetric 5
– Leaves asymmetric 6
5. Cyathia in axillary clusters; seeds with 2 horizontal constrictions .....*E. acalyphoides*
– Cyathia in terminal clusters; seeds without constrictions .....*E. heterophylla*
6. Leaves linear, blade not exceeding 2 mm broad .....*E. arabica*
– Leaves not linear, blade more than 2 mm broad 7
7. Cyathia clustered in terminal pedunculate cymes 8
– Cyathia congested in leafy cymes 9
8. Testa epidermal cells convex .....*E. hyssopifolia*
– Testa epidermal cells flat .....*E. indica*
9. Seeds rounded in transverse section 10
– Seeds often 4-angled in transverse section 11
10. Seeds ovoid pyriform, testa epidermal cells isodiametrical .....*E. peplis*
– Seeds subglobose, testa epidermal cells indistinct to penta-hexagonal ....*E. scordifolia*
11. Seeds transversely ridged .....*E. prostrata*
– Seeds not transversely ridged 12
12. Capsules glabrous; testa epidermal cells penta-hexagonal .....*E. inaequilatera*
– Capsules hairy; testa epidermal cells isodiametrical 13
13. Testa epidermal cells concave *E. granulata*
– Testa epidermal cells flat to slightly convex ..... *E. forsskaolii*
14. Succulent shrubs 15
– Non succulent shrubs 16
15. Seeds ovoid, tuberculate, anticlinal boundaries sunken .....*E. consobrina*
– Seeds oblong, smooth, anticlinal boundaries raised .....*E. mauritanica*
16. Cyathia solitary 17
– Cyathia in clusters or umbels 18
17. Branchlets spinescent; caruncle subspherical .....*E. erinacea*
– Branchlets not spinescent; caruncle depressed-globular .....*E. hierosolymitana*
18. Cyathia in clusters .....*E. petiolata*
– Cyathia in umbels 19
19. Leaves toothed 20
– Leaves entire 24
20. Caruncle half as long as the seed or longer 21
– Caruncle less than half as long as the seed 22
21. Caruncle about half as long as the seed ..... *E. retusa*
– Caruncle about as long as or longer than the seed ..... *E. grossheimii*

22. Plants villose; testa smooth ..... *E. arguta*
– Plants glabrescent; testa reticulate 23
23. Capsules winged; testa epidermal cells flat .....*E. pterococca*
– Capsules not winged; testa epidermal cells papillose .....*E. helioscopia*
24. Seeds smooth 25
– Seeds not smooth 27
25. Shrubs with woody stems .....*E. dendroides*
– Herbaceous perennials 26
26. Capsules glabrous; testa epidermal cells flat ..... *E. terracina*
– Capsules rugulose; testa epidermal cells concave ..... *E. paralias*
27. Seeds blackish-brown, tuberculate .....*E. dracunculoides*
– Seeds pale grey, not tuberculate 28
28. Seeds compressed-ovoid-quadrangular, with 5 or 6 ± regular transverse grooves per face .....*E. falcata*
– Seeds oblong, with a longitudinal groove on each of the two inner faces, and 3-4 pits on each of the 4 outer faces ..... *E. peplus*

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