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Original article

Taxonomic characters of fruit, mericarp, and seed for some Malvaceae species

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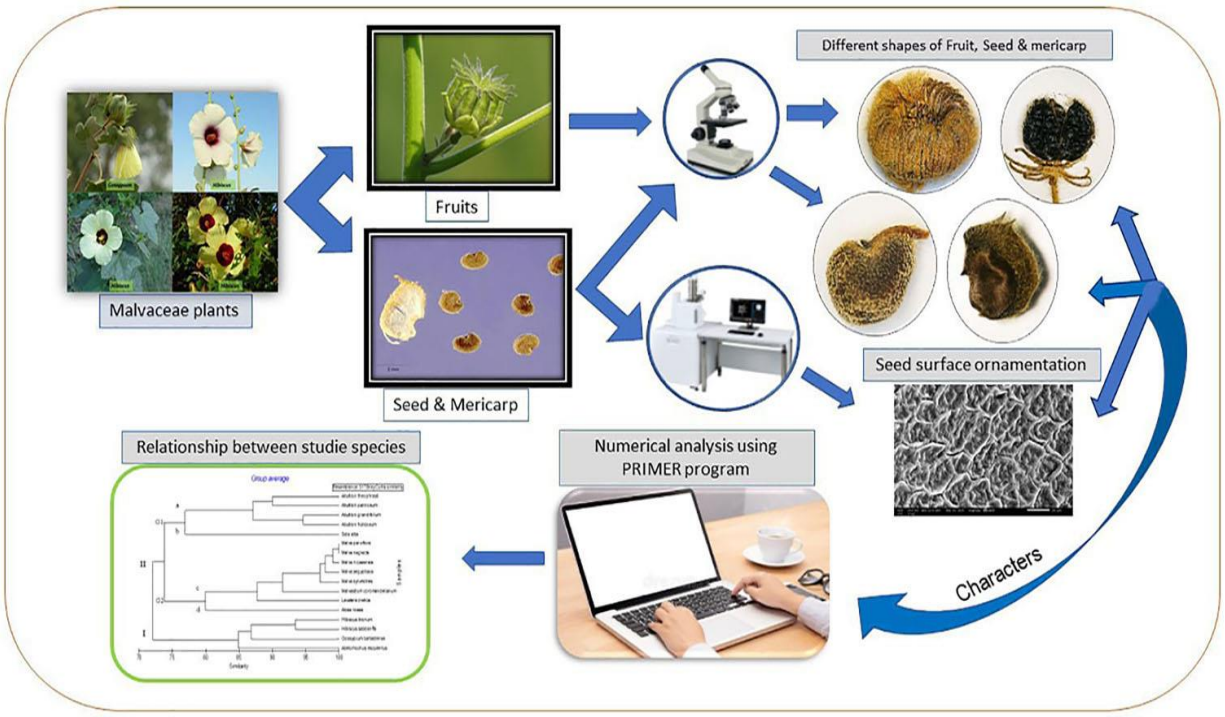
ABSTRACT

An investigation of the fruit, mericarp, and seed macro- and micromorphology of seventeen species belonging to nine genera of Malvaceae was performed through light microscopy and scanning electron microscopy to evaluate their taxonomic significance. The studied species demonstrated heterogeneous characteristics of the fruits, mericarp, and seed as shown in general shape, size, color, surface texture, hilum position, and funiculus observed under stereomicroscope. According to the seed coat patterns seen through SEM, the seeds of the studied species showed four different patterns: reticulate, reticulate foveate, reticulate rugose, and scalariform; four different shapes of epidermal cells: irregular polygonal cell, regular polygonal cell, elongated rectangle, and irregular undulate. PRIMER (software, version 6) is a statistical program used to get morphometric analysis. The numerical analysis revealed two main clusters and four groups. Generally, the variation in fruit, mericarp, and seed characters is useful for identification and to separate closely related Malvaceae species.

Graphical abstract



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1. Introduction

The Malvaceae (Mallow family) is a major group of flowering plants. It is widely distributed except the very cold regions [1,2]. According to the 2022plant list the family is composed of about 245 genera and 4465 species. The number of species and genera of Malvaceae in Egypt has varied over time [3]**;** it has 31 species belonging to eight genera have been recognized by Täckholm [4], while El-Hadidi and Araffa [1] recorded 26 species within 10 genera. Finally, the number of species has been updated to 32 in 10 genera [5]. The members of this family have great economic importance; they can be used for food, ornaments, fiber, and medicinal importance [6,7].

The fruit and seeds of plants provide a base of morphological features that have the taxonomic potential to delimit species. The use of SEM to analyze fruit and seed characters has increased significantly in taxonomic studies [8-11]**.** Many authors have proved the taxonomic significance of fruit and seed coat sculpture [11-14]. Several previous studies have examined the seed morphology of various members of some species of Malvaceae using both light and scanning electron microscopy [11**,** 15-17]. Mericarps and seeds of four species belonging to the genus *Althaea L*. (Malvaceae) were studied to identify their characteristics and importance as taxonomic evidence [18]. Macro- and micro-morphological characters of fruits in some species of the tribe Malveae were examined and established by [19]. Rao and Dave [20] and Bharati [21] studied the schizocarp fruit and mericarp of S*ida* species and considered the mericarp morphology a key character to determine the identity of the species.

Numerical taxonomic studies are important for discovering and documenting new morphological character and character states, and many attempts have been made in this regard for understanding phenetic relationships in different groups of plants [22-27]. In the current study, the macro- and micro-morphological features of fruit, mericarp, and seed were studied to evaluate the taxonomic relationships among the studied Malvaceae species.

2. Materials and Methods

The recent investigation was based on fresh materials, which were collected from their natural habitats at different localities in Egypt during flowering and fruiting periods between 2020 and 2021, and some plant specimens were acquired from the Alexandria University Herbarium, Faculty of Science, and Desert Research Center Herbarium, Egypt, Cairo. Locality and date information of the specimens investigated were given in Table 1. The specimens studied were identified by means of comparison with specimens kept in the herbarium of the Agricultural Museum (CAIM), along with the plant keys [4, 28, 29]. The specimens of the studied species were prepared and kept in the herbarium of the Botany and Microbiology Department, Faculty of Science, Al-Azhar University (girls).

Table 1. List of studied species, localities, and data of collection. The classification of tribes according to Takhtajan, (2009):

NO.	Species	Locality and date	Tribe Takhtajan, (2009)
1.	*Abutilon fruticosum* Guill. & Perr.	Wadi Akaw (Desert research center). 26/1/2001.	**Malveae**
2.	*Abutilon grandifolium* (Willd.) Sweet	El-Zohria botanical Garden, El-Zamalek. 15/3/2021	
3.	*Abutilon pannosum* (G.Forst.) Schltdl.	Gebel Alba, Wadi Eikwan upstream, southeast of Halayeb (Alexandria University Herbarium, Faculty of Science). 3/3/1998	
4.	*Abutilon theophrasti* Medik.	Kafr El-dawar, El-Beheira. 7/7/2020	
5.	*Alcea rosea* L.	Nasr city, Cairo. 26/1/2021	
6.	*Lavatera cretica* L.	Alexandria, Matrouh road. 13/2/2021	
7.	*Malva aegyptiaca* L.	Burg El-Arab (Alexandria University Herbarium, Faculty of Science). 23/3/1992	
8.	*Malva neglecta* Wallr.	Sinai, Saint Catherine. 28/6/2021	
9.	*Malva nicaeensis* All.	Kafr El-dawar, El-Beheira. 3/3/2020	
10.	*Malva parviflora* L.	North Coast-Matrouh Road. 13/2/2021	
11.	*Malva sylvestris* L.	North Coast-Matrouh Road. 13/2/2021	
12.	*Malvastrum coromandelianum* (L.) Garcke	El-Saff, Giza. 15/8/2021	
13.	*Sida alba L.*	Kafr El-dawar, El-Beheira. 7/7/2020	
14.	*Gossypium barbadense* L.	Kafr El-dawar, El-Beheira. 7/10/2021	**Gossypieae**
15.	*Abelmoschus esculentus* (L.) Moench.	El-Sheikh Dergham, Damietta Road. 20/10/2020	**Hibisceae**
16.	*Hibiscus sabdariffa* L.	El-Sheikh Dergham, Damietta Road. 20/10/2020	
17.	*Hibiscus trionum* L.	Kafr El-dawar, El-Beheira. 7/7/2020	

Mature fruits and seeds were used in the analysis of macro- and micro-morphological characteristics. For fruit and seed morphology, 3-5 fruits and seeds per species were measured for their lengths and widths. The size, shape, color, hair density, mericarp number, apex, surface, awn position and number, and hilum features were recorded and photographed using a stereoscope (Olympus SZ40-PT) coupled with a digital camera to determine the variation among species.

Micromorphological features of seeds were analyzed through SEM. First, seeds were cleaned with ethanol. Later, the dried seeds were transferred onto specimen stubs using double adhesive tapes, coated with a thin gold film using (JEOL JFC 1100E ion-sputtering device), and examined with an electron microscope (JEOL ISM-IT200), at the Electron Microscope Unit, Faculty of Science, Alexandria University. The terminology used for describing the morphology of fruit, mericarp, and seed is in accordance with Khalik et al. [17], Özbek and Uzunhisarcikli, [18 and 38], and Masullo et al. [19].
For numerical analysis, PRIMER software (version 6.0) was used to generate a cluster analysis of the similarity matrix between the species under study to construct a dendrogram.

3. Results

1- Fruit morphology

Fruit is very variable in type, shape, texture, color, size, and dehiscence (Table 2; Figure 1). There are only two types of fruit that have been found in this study: schizocarpic in most studied species and capsule in *Gossypium barbadense*, *Abelmoschus esculentus*, *Hibiscus sabdariffa*, and *Hibiscus trionum*. The fruit of the studied species could be dehiscent in *Abutilon fruticosum*, *Abutilon grandifolium*, *Abutilon pannosum*, *Abutilon theophrasti*, *Gossypium barbadense*, *Abelmoschus esculentus*, *Hibiscus sabdariffa*, and *Hibiscus trionum*, and partially dehiscent in the remaining species.

The fruit color is often light brown, brown in *Sida alba*, *Abelmoschus esculentus*, and *Hibiscus sabdariffa*, dark brown in *Abutilon grandifolium*, *Abutilon theophrasti*, and *Gossypium barbadense*, and black in *Hibiscus trionum* only. Fruit shape ranged between discoid in most studied species, subglobose in *Abutilon fruticosum*, *Abutilon grandifolium*, *Abutilon pannosum*, *Abutilon theophrasti*, and *Alcea rosea*, ovoid in *Sida alba*, *Gossypium barbadense*, *Hibiscus sabdariffa*, and *Hibiscus trionum*, and conical in *Abelmoschus esculentus*. The fruit apex is depressed in *Abutilon fruticosum*, *Abutilon grandifolium*, *Abutilon pannosum*, and *Abutilon theophrasti*; acute in *Gossypium barbadense*, *Abelmoschus esculentus*, *Hibiscus sabdariffa*, and *Hibiscus trionum*; acute to beaked in *Sida alba* and *Malvastrum coromandelianum;* and notched in the remainders. The fruit surface in the studied species is glabrous in *Lavatera cretica*, *Malva aegyptiaca*, *Malva neglecta*, *Malva nicaeensis*, *Malva parviflora*, *Malva sylvestris*, and *Gossypium barbadense*, whereas the surface is hairy in the rest.

Fruit length is less than 0.9 cm in most studied species, 0.9- 2 cm in *Abutilon fruticosum*, *Abutilon grandifolium*, *Abutilon pannosum*, *Abutilon theophrasti*, *Alcea rosea*, *Hibiscus sabdariffa*, and *Hibiscus trionum*, and more than 2 cm in *Gossypium barbadense* and *Abelmoschus esculentus*, while width is 0.8-2 cm in *Abutilon fruticosum*, *Abutilon grandifolium*, *Abutilon pannosum*, *Abutilon theophrasti*, *Alcea rosea*, *Hibiscus sabdariffa*, and *Hibiscus trionum*, more than 2 cm in *Gossypium barbadense* and *Abelmoschus esculentus*, and less than 0.8 cm in the rest. Also, the largest fruit has a size of 10 cm × 2.6 cm is present in *Abelmoschus esculentus*, while the smallest fruit is in *Sida alba* with a size of 0.4 cm × 0.3 cm.

2- Mericarp morphology

Mericarp is very variable in color, shape, texture, and number (Table 2; Figure 2). The mericarp is present in 13 species of this study and absent in *Gossypium barbadense*, *Abelmoschus esculentus*, *Hibiscus sabdariffa*, and *Hibiscus trionum*. The shape of the mericarp in the studied species has been recorded as rounded reniform in *Alcea rosea*, *Lavatera cretica*, *Malva aegyptiaca*, *Malva neglecta*, *Malva nicaeensis*, *Malva parviflora*, *Malva sylvestris*, and *Malvastrum coromandelianum*, deltoid in *Sida alba* only, and reniform in *Abutilon fruticosum*, *Abutilon grandifolium*, *Abutilon pannosum*, and *Abutilon theophrasti*.

The number of mericarps in the fruit is more than 10 in most studied species, ranging from 8 to 10 in *Lavatera cretica*, *Malva neglecta*, *Malva nicaeensis*, *Malva parviflora*, and *Malva sylvestris*, and five mericarps in *Sida alba*. The surface of mericarp is smooth in *Abutilon fruticosum*, *Abutilon grandifolium*, *Abutilon pannosum*, *Abutilon theophrasti*, and *Sida alba*, while wrinkled in the rest. The number of seeds per mericarp is one in most studied species, three to five seeds in *Abutilon fruticosum*, *Abutilon grandifolium*, *Abutilon pannosum*, and *Abutilon theophrasti*, while the number in each locule in capsule fruit ranged from six to ten seeds in *Gossypium barbadense*, *Hibiscus sabdariffa*, and *Hibiscus trionum*, and many seeds in *Abelmoschus esculentus.*

Apex of mericarp is rounded in Abutilon pannosum, Alcea rosea, Lavatera cretica, Malva aegyptiaca, Malva neglecta, Malva nicaeensis, Malva parviflora, and Malva sylvestris, while it has awaned apex in Abutilon fruticosum, Abutilon grandifolium, Abutilon theophrasti, Malvastrum coromandelianum, and Sida alba. In *Abutilon fruticosum*, *Abutilon grandifolium*, *Abutilon theophrasti*, and *Sida alba* the mericarp with two apical awns, while the mericarp with three awns; one apical and two dorsal in *Malvastrum coromandelianum*.

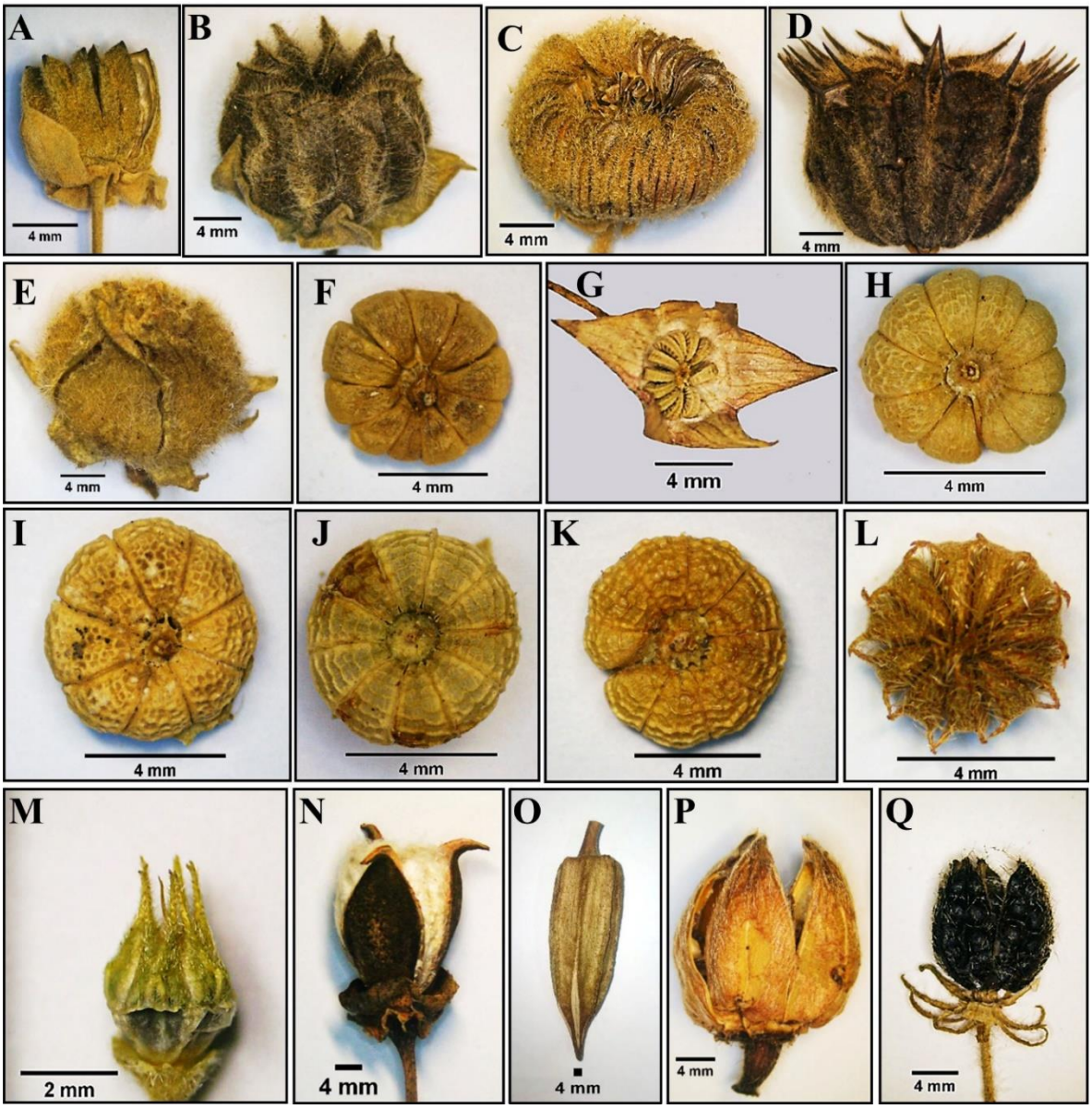

Figure 1: Morphological characters of fruit for 17 studied species of Malvaceae as revealed by light microscope: (A) *Abutilon fruticosum,* (B) *Abutilon grandifolium,*(C) *Abutilon pannosum,* (D) *Abutilon theophrasti,*(E) *Alcea rosea,* (F) *Lavatera cretica,* (G) *Malva aegyptiaca,* (H) *Malva neglecta,* (I) *Malva nicaeensis,* (J) *Malva parviflora,* (K) *Malva sylvestries,* (L) *Malvastrum coromandelianum,* (M) *Sida alba,* (N) *Gossypium barbadense,* (O) *Abelomochus esculentus,* (P) *Hibiscus sabdariffa,* (Q) *Hibiscus trionum.*

3- Seed morphology

The morphology of mature seed showed some variations in shape, color, texture, measurements, hilum position, and ornamentation (Table 3 and Figure 3). The dominant seed shape was rounded-reniform, followed by cordate-reniform, ovate in *Gossypium barbadense* only, D-shaped in *Alcea rosea*, elliptic as in *Sida alba*, and sub-globose in *Abelmoschus esculentus.* The seed color in the studied species diverse from dark brown in *Abutilon fruticosum, Abutilon grandifolium*, *Abutilon pannosum, Abutilon theophrasti*, *Gossypium barbadense*, and *Hibiscus sabdariffa,* light brown in *Alcea rosea* and *Lavatera cretica,* brown to black in *Sida alba* and *Hibiscus trionum,* black in *Abelmoschus esculentus,* brown in the rest species.

The texture of the seed is, hairy in *Abutilon grandifolium*, *Abutilon pannosum*, *Abutilon theophrasti*, *Alcea rosea*, *Lavatera cretica*, *Hibiscus sabdariffa*, and *Gossypium barbadense*, while the papillae are in *Hibiscus trionum,* whereas it glabrous in 9 species. The hair density of seed surface was found to be pubescent in seven species, glabrous in eight species, and tomentose in *Lavatera cretica* and *Gossypium barbadense*. Seed length and width varied among the studied species; seed length was less than 2 mm in most studied species, 2-5 mm in *Abutilon grandifolium, Abutilon theophrasti, Alcea rosea, Lavatera cretica*, *Malva nicaeensis*, *Abelmoschus esculentus*, and *Hibiscus trionum,* and more than 5 mm

in *Gossypium barbadense*, while width was 2-3.5 mm in *Abutilon grandifolium, Abutilon pannosum, Abutilon theophrasti, Alcea rosea, Lavatera cretica, Malva nicaeensis,* and *Hibiscus sabdariffa,* ranging between 4-5.1 mm in *Gossypium barbadense, Abelmoschus esculentus* and *Hibiscus trionum*, and less than 2 mm in the rest. Also, the largest seed has a size of 9.5 mm × 5 mm is present in *Gossypium barbadense*, while the smallest seed is *Malva aegyptiaca* with a size of 1.3 mm × 1.3 mm

The position of the hilum is central in ten species, followed by sub-central in six species, and terminal in *Gossypium barbadense* only. Hilum shape is reniform in most studied species, acute in *Gossypium barbadense*, and truncate in *Alcea rosea* and *Abelmoschus esculentus.*

The Hilum level being depressed in *Lavatera cretica, Malva aegyptiaca, Malva neglecta, Malva nicaeensis, Malva parviflora, Malva sylvestris,* and *Malvastrum coromandelianum,* superficial in *Gossypium barbadense,* and semi-depressed in the remaining species. Hilum surfaces are often glabrous in most of the studied species and hairy in *Abutilon pannosum, Abutilon theophrasti, Alcea rosea, Lavatera cretica, Gossypium barbadense*, and *Hibiscus sabdariffa.* Seed funicles are present in *Abutilon fruticosum, Abutilon grandifolium, Abutilon pannosum, Abutilon theophrasti, Alcea rosea, Sida alba, Abelmoschus esculentus, Hibiscus sabdariffa,* and *Hibiscus trionum* and absent in the remainders.

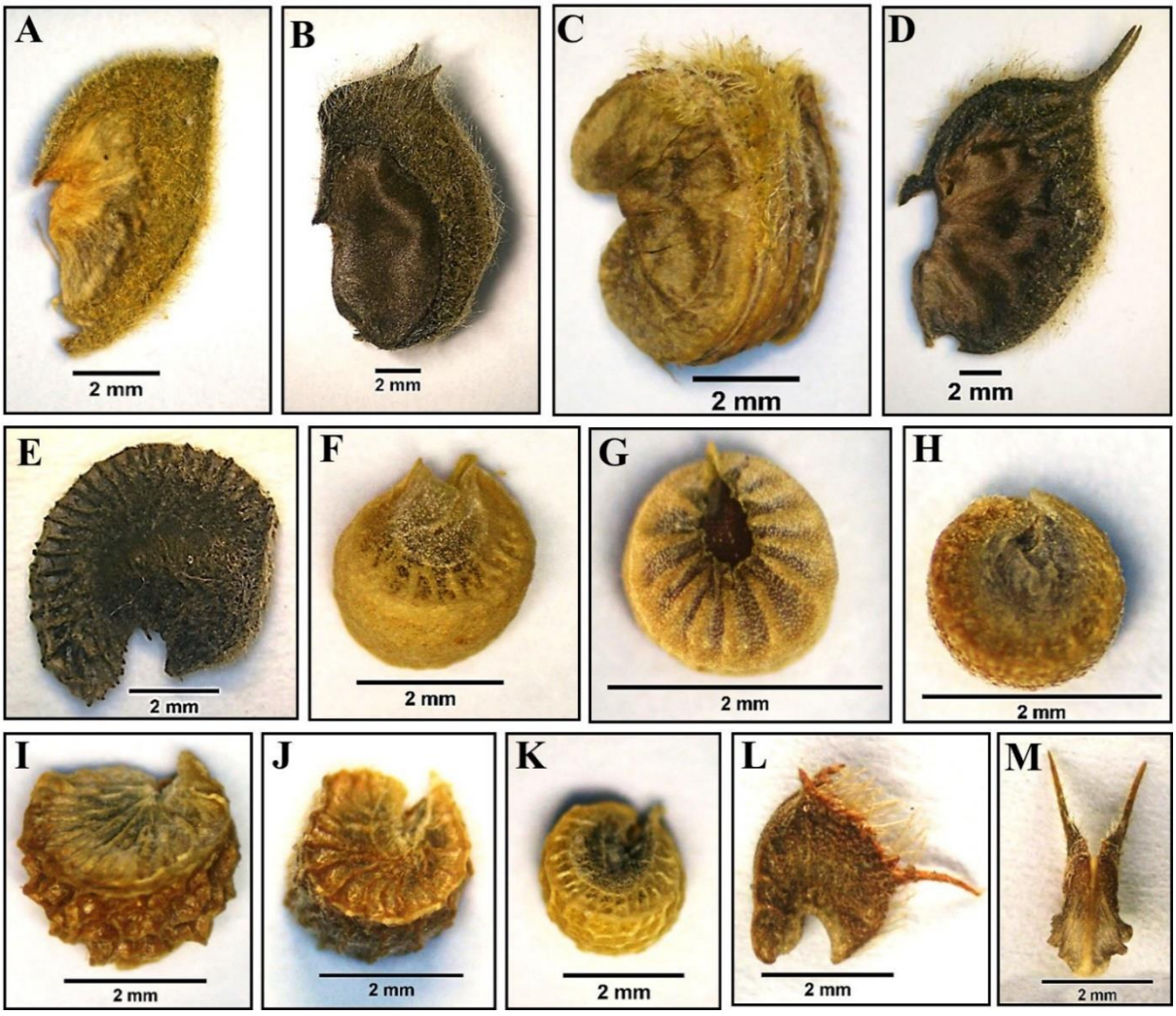

Figure 2. Morphological characters of mericarp for 17 studied species of Malvaceae as revealed by light microscope: (A) *Abutilon fruticosum,* (B) *Abutilon grandifolium,* (C) *Abutilon pannosum,* (D) *Abutilon theophrasti,* (E) *Alcea rosea,* (F) *Lavatera cretica,* (G) *Malva aegyptiaca,* (H) *Malva neglecta,* (I) *Malva nicaeensis,* (J) *Malva parviflora,* (K) *Malva sylvestries,* (L) *Malvastrum coromandelianum,* (M) *Sida alba.*

4-Seed Coat Pattern Sculpture

There were four major patterns of seed coat ornamentation recorded (Table 4 and Figure 4): reticulate in*Abutilon fruticosum, Abutilon grandifolium, Alcea rosea, Hibiscus sabdariffa,* and *Hibiscus trionum*; reticulate-foveate in *Abutilon pannosum, Abutilon theophrasti, Sida alba, Abelmoschus esculentus,* and *Gossypium barbadense*; scalariform in *Malva aegyptiaca, Malva neglecta, Malva nicaeensis, Malva parviflora*, and *Malvastrum coromandelianum*; and reticulate-rugose in *Lavatera cretica* and *Malva sylvestris*.

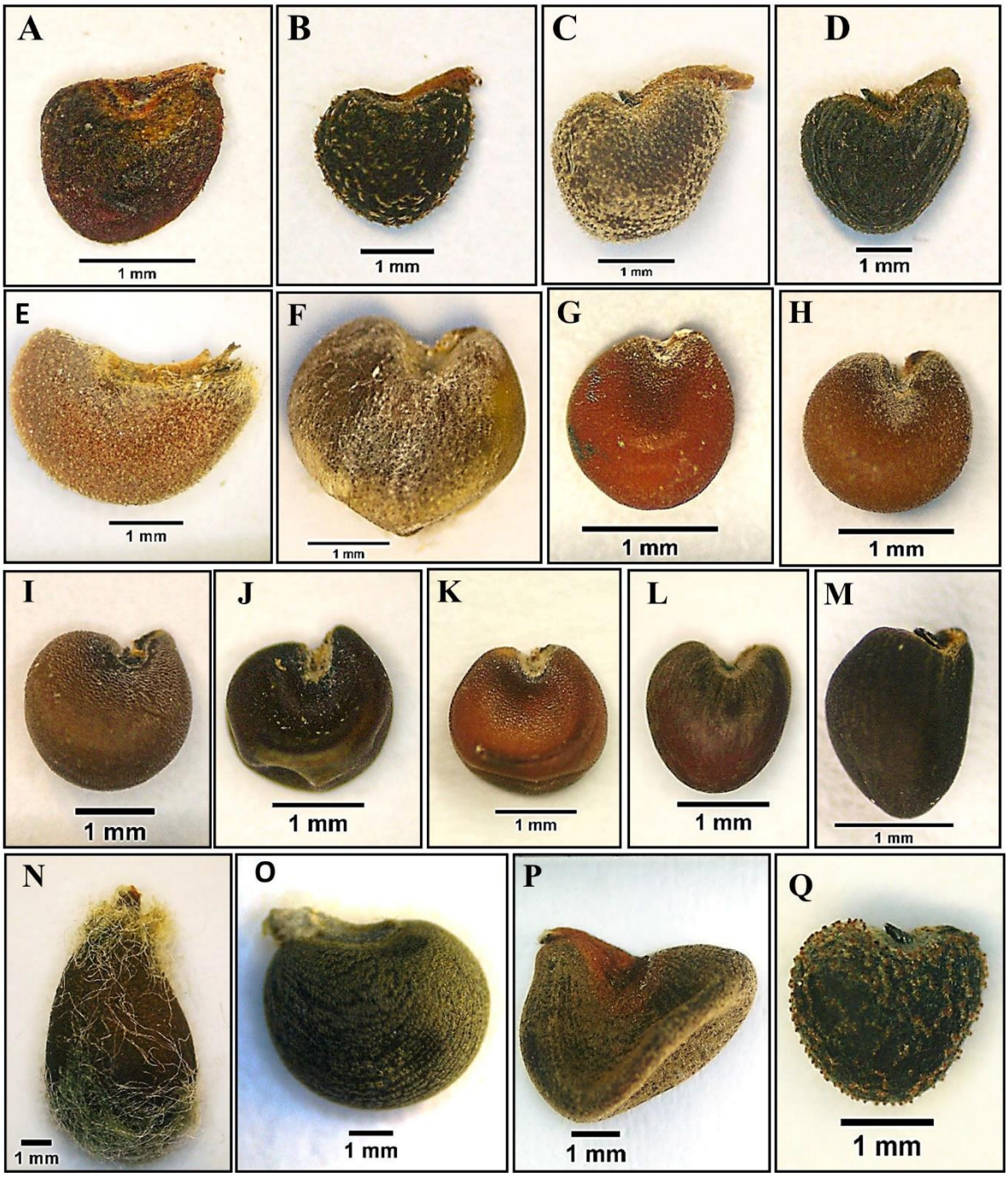

Figure 3: Morphological characters of seeds for 17 studied species of Malvaceae by as revealed by light microscope: (A) *Abutilon fruticosum,* (B) *Abutilon grandifolium,* (C) *Abutilon pannosum,* (D) *Abutilon theophrasti,* (E) *Alcea rosea,* (F) *Lavatera cretica,* (G) *Malva aegyptiaca,* (H) *Malva neglecta,* (I) *Malva nicaeensis,* (J) *Malva parviflora,* (K) *Malva sylvestries,* (L) *Malvastrum coromandelianum,* (M) *Sida alba,* (N) *Gossypium barbadense,* (O) *Abelomochus esculentus,* (P) *Hibiscus sabdariffa,* (Q) *Hibiscus trionum*.

The epidermal cell shape is an irregular polygonal cell in *Abutilon fruticosum*, *Abutilon grandifolium*, *Alcea rosea*, *Lavatera cretica*, *Hibiscus sabdariffa*, and *Hibiscus trionum*, but a regular polygonal cell in *Abutilon pannosum*, *Abutilon theophrasti*, *Sida alba*, and *Abelmoschus esculentus*, irregular undulate in *Gossypium barbadense*, and an elongated rectangle in the remainders. The anticlinal wall shapes range from straight to sinuous in most studied species, but straight in *Abutilon pannosum*, *Abutilon theophrasti*, *Sida alba*, and *Abelmoschus esculentus*, sinuous in *Lavatera cretica*, and undulate in *Gossypium barbadense*.

Anticlinal wall texture is warty in *Abutilon fruticosum, Abutilon grandifolium*, *Abutilon pannosum*, *Alcea rosea*, *Lavatera cretica*, *Malva nicaeensis*, *Malvastrum coromandelianum,* and *Abelmoschus esculentus*, while smooth in the rest. The anticlinal wall is thick (5–10 µm) in most studied species and thin (3-4.5 µm) in *Alcea rosea, Malva aegyptiaca, Malva sylvestris*, *Malvastrum coromandelianum*, *Sida alba*, *Hibiscus sabdariffa,* and *Hibiscus trionum*.

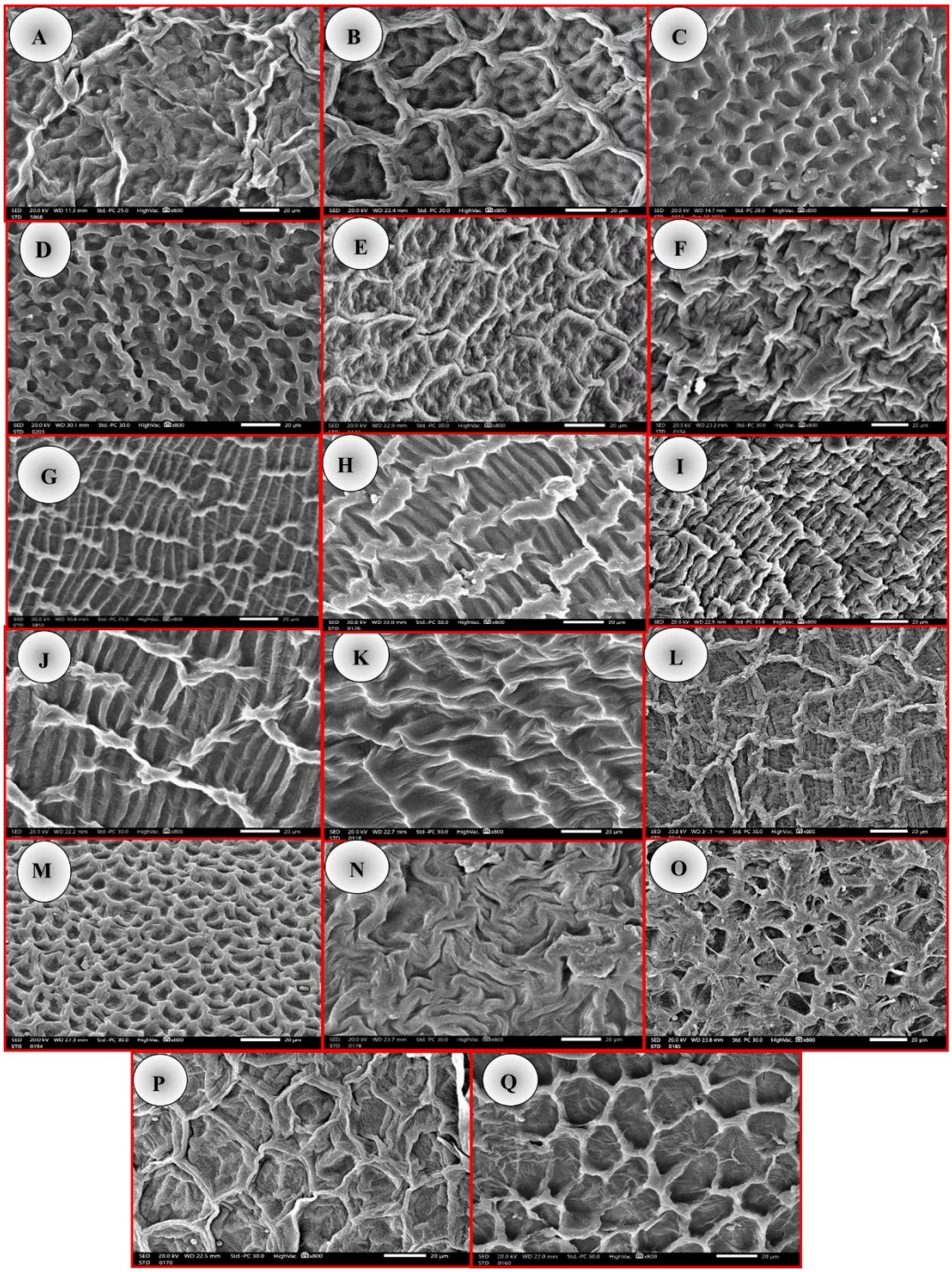

Figure 4: Micro-morphological characters of seeds for 17 studied species of Malvaceae by scanning electron microscope (SEM): (A) *Abutilon fruticosum,* (B) *Abutilon grandifolium,* (C) *Abutilon pannosum,* (D*) Abutilon theophrasti,* (E) *Alcea rosea,* (F) *Lavatera cretica,* (G) *Malva aegyptiaca,* (H) *Malva neglecta,* (I) *Malva nicaeensis,* (J) *Malva parviflora,* (K) *Malva sylvestries,* (L) *Malvastrum coromandelianum,* (M) *Sida alba,* (N) *Gossypium barbadense,* (O) *Abelomochus esculentus,* (P) *Hibiscus sabdariffa,* (Q) *Hibiscus trionum.*

The shape of the periclinal wall recorded four types: foveate in *Abutilon fruticosum, Abutilon grandifolium*, and *Alcea rosea*; striate in *Abutilon pannosum*, *Malva aegyptiaca, Malva neglecta, Malva nicaeensis, Malva*

parviflora, *Malva sylvestris*, and *Malvastrum coromandelianum*, rugose in *Lavatera cretica* only; and smooth in the rest. The level of the periclinal cell wall is concave in most studied species and concave to flat in *Lavatera cretica*, *Malva aegyptiaca*, *Malva neglecta*, *Malva nicaeensis*, *Malva parviflora*, and *Malvastrum coromandelianum*.

5- Numerical analysis

The numerical analysis was performed using the PRIMER (software version 6.0) statical program for seventeen species of Malvaceae. The obtained data of fruit, mericarp, and seed morphological features of thirty- two characters with a one-hundred-character state in figure 5 showed that the studied species belonged to two main clusters in the dendrogram. Cluster 1 consisted of four species: *Abelmoschus esculentus*, *Gossypium barbadense*, *Hibiscus sabdariffa*, and *Hibiscus trionum*. Cluster 2 contains 13 species, which are divided into two groups. Group (1) was divided into two subgroups. Subgroup (a) included *Abutilon grandifolium*, *Abutilon pannosum*, *Abutilon theophrasti*, and *Abutilon fruticosum* and was separated into a distinct subgroup. Subgroup (b) consisted of one species, *Sida alba*, whereas the second group (2) contained eight species, which were further split into two subgroups; subgroup (c) included seven species, *Malva parviflora*, *Malva neglecta*, *Malva nicaeensis*, *Malva aegyptiaca*, *Malva sylvestris*, *Malvastrum coromandelianum*, and *Lavatera cretica*, while subgroup (d) had one species, *Alcea rosea*.

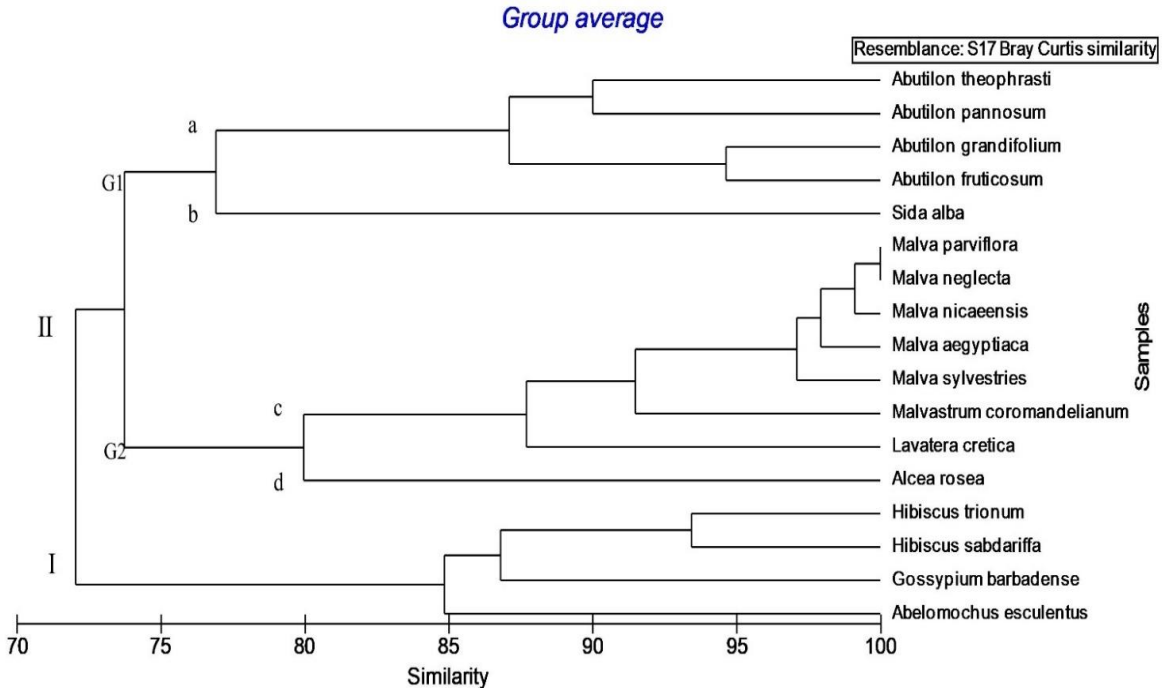

Figure 5. Dendrogram showing the relationships between 17 species of Malvaceae based on 32 characters of fruit, mericarp, and seed morphological characters by using the PRIMER program.

4. Discussion

The fruit and seed morphological characters provide great, valuable taxonomic evidence that can be used to define generic limits and for species identification [19]. In this research, LM and SEM were used to observe the seed macro- and micromorphological properties of 17 members of the family Malvaceae. The fruit in Malvaceae represents a wide morphological variation and may be considered a great source of useful characters for the classification and identification of species or even genera. The study distinguished two types of fruits: schizocarp fruit, which is present in most studied species (13 species), and capsule fruit, which consists of five chambers with many seeds as in the genus *Hibiscus* or three chambers as in *Gossypium barbadense*, while the fruit in *Abelmochus esculentus* consists of many chambers and many seeds, agreeing with Dave et al. [32].

The shape of the fruit varied from discoid as in all *Malva* species, *Lavatera cretica*, and *Malvastrum coromandelianum*, conical in *Abelmoschus esculentus*, and ovoid in the remaining species, agreeing with Said et al. [33], whereas it is sub globose in the genus *Abutilon* with a mericarp of reniform shape and rounded or awned apex, the awns are apical as in *Abutilon theophrasti*, or absent as in *Abutilon pannosum*; this finding agrees with Alzahrani et al. [25].

The number of awns has been found to be two apical as in *Abutilon fruticosum*, *Abutilon grandifolium*, *Abutilon theophrasti*, and *Sida alba*, three apical and one dorsal in *Malvastrum coromandelianum*, or absent in the remaining species. The mericarp with one seed present in the genus *Malva*, *Lavatera cretica*, and *Malvastrum coromandelianum*, all these characters

agree with different studies for some species of Malvaceae [19, 21, 34, 35].

Table 2: Morphological characters of fruit and mericarp for the studied species of Malvaceae.

Characters \ Species			*Abutilon fruticosum*	*Abutilon grandifolium*	*Abutilon pannosum*	*Abutilon theophrasti*	*Alcea rosea*	*Lavatera cretica*	*Malva aegyptiaca*	*Malva neglecta*	*Malva nicaeensis*	*Malva parviflora*	*Malva sylvestris*	*Malvastrum coromandelianum*	*Sida alba*	*Gossypium barbadense*	*Abelmoschus esculentus*	*Hibiscus sabdariffa*	*Hibiscus trionum*
Fruit	Type:1-Schizocarpic 2-Capsule		1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
	Dehiscence: 1-Dehiscent/ 2-Partially dehiscent.		1	1	1	1	2	2	2	2	2	2	2	2	2	1	1	1	1
	Calyx in fruit: 1-Accrescent/ 2-Not accrescent.		2	2	2	2	1	2	2	2	2	2	2	2	1	2	2	1	1
	Color: 1-Ligth brown/ 2-Brown/ 3-Dark brown/ 4-Black.		1	3	1	3	1	1	1	1	1	1	1	1	2	3	2	2	4
	Apex of fruit: 1-Depressed/2-Notched/ 3-Acute/4-Acute to beaked.		1	1	1	1	2	2	2	2	2	2	2	4	4	3	3	3	3
	Surface:1-Glabrous/2- Hairy.		2	2	2	2	2	1	1	1	1	1	1	2	2	1	2	2	2
	Shape:1-Descoid/2-Sub globose/3- Ovoid/4-Conical.		2	2	2	2	2	1	1	1	1	1	1	1	3	3	4	3	3
	Length(cm)	Mean	0.9	1.5	1.1	1.7	1.3	0.7	0.4	0.4	0.6	0.6	0.5	0.4	0.4	4.6	10	2	1.3
		SD. (±)	± 0.1	± 0.1	± 0.1	± .06	± 0.1	± 0.1	± .04	± .06	± 0.1	± .08	± .06	± .03	± .08	± 0.1	± 1.8	± 0.3	± 0.3
	width (cm)	Mean	0.8	1.7	1.4	1.6	1.5	0.7	0.4	0.4	0.6	0.6	0.5	0.5	0.3	4.4	2.6	1.7	1.2
		SD. (±)	± 0.8	± 0.2	± 0.2	± 0.2	± .08	± 0.1	± .04	± .06	± 0.1	± .08	± .06	± .09	± .02	± 0.1	± 0.6	± 0.1	± 0.1
Mericarp	Mericarp: 1-Present /2-Absent.		1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
	Shape:1-Rounded reniform / 2-Reniform/3-Deltoid / 4-Absent.		2	2	2	2	1	1	1	1	1	1	1	1	3	4	4	4	4
	Apex: 1-Awned/2-Round/ 3-Absent.		1	1	2	1	2	2	2	2	2	2	2	1	1	3	3	3	3
	Number: 1- (8-10) /2-(More than10)/3-Five/4-Absent.		2	2	2	2	2	1	2	1	1	1	1	2	3	4	4	4	4
	Texture: 1-Smooth / 2-Wrinkled/ 3-Absent.		1	1	1	1	2	2	2	2	2	2	2	2	1	3	3	3	3
	No of seeds per mericarp, locule of capsule: 1- One /2- (3 to 5) /3-(6 to 10) /4- More than10.		2	2	2	2	1	1	1	1	1	1	1	1	1	3	4	3	3
Awns	Awn: 1- Present /2-Absent.		1	1	2	1	2	2	2	2	2	2	2	1	1	2	2	2	2
	Awn No.: 1-Two /2-Three/ 3- Absent.		1	1	3	1	3	3	3	3	3	3	3	2	1	3	3	3	3
	Position: 1- Apical /2- Dorsal & Apical /3-Absent.		1	1	3	1	3	3	3	3	3	3	3	2	1	3	3	3	3

Table 2: Macro-morphological characters of seeds for studied species of Malvaceae

Characters \ Species		*Abutilon fruticosum*	*Abutilon grandifolium*	*Abutilon pannosum*	*Abutilon theophrasti*	*Alcea rosea*	*Lavatera cretica*	*Malva aegyptiaca*	*Malva neglecta*	*Malva nicaeensis*	*Malva parviflora*	*Malva sylvestris*	*Malvastrum coromandelianum*	*Sida alba*	*Gossypium barbadense*	*Abelmoschus esculentus*	*Hibiscus sabdariffa*	*Hibiscus trionum*
Color:1-Dark brown /2- Light brown /3-Brown/ 4-Brown-black/ 5- Black.		1	1	1	1	2	2	3	3	3	3	3	3	4	1	5	1	4
Shape: 1-Rounded-reniform/2-Cordate-reniform /3- Ovate/ 4-D-shape /5-Ellipsoid/ 6-Subglobose.		2	2	2	2	4	1	1	1	1	1	1	1	5	3	6	2	2
Texture: 1-Hairy/ 2-Glabrous / 3-papillate.		2	1	1	1	1	1	2	2	2	2	2	2	2	1	2	1	3
Hair density: 1- Pubescent / 2-Tomentose / 3- Glabrous.		1	1	1	1	1	2	3	3	3	3	3	3	3	2	3	1	1
Seed length (mm)	Mean	1.8	2	1.9	2.7	2	2.3	1.3	1.9	2.1	1.6	1.7	1.4	1.7	9.5	4.9	1.7	3.7
	SD. (±)	± 0.1	± .05	± .09	± 0.1	± 0.2	± 0.3	± .07	± 0.6	± 0.2	± 0.1	± 0.1	± 0.1	± 0.1	± 0.8	± 0.3	± 0.1	± 0.2
Seed width (mm)	Mean	1.7	2.3	2.2	3.2	3.4	2.6	1.3	1.5	2.1	1.5	1.9	1.5	1.2	5	5.1	2.3	4.8
	SD. (±)	± 0.1	± .08	± 0.1	± 0.1	± 0.1	± 0.2	± 0.1	± 0.1	± 0.1	± 0.1	± 0.1	± 0.03	± 0.03	± 0.3	± 0.4	± 0.1	± 0.3
Ratio L/W		1	0.8	0.7	0.6	0.6	0.9	1	1.3	1	1.03	0.8	0.9	1.4	1.9	0.9	0.8	0.8
Hilum	position: 1-Central/ 2-Subcentral 3-Terminal/	2	2	2	2	1	1	1	1	1	1	1	1	2	3	2	1	1
	level: 1-Depressed /2-Semi depressed /3-Superficial.	2	2	2	2	2	1	1	1	1	1	1	1	2	3	2	2	2
	shape: 1-Reniform / 2-Acute/ 3-Truncate.	1	1	1	1	3	1	1	1	1	1	1	1	1	2	3	1	1
	surface: 1-Glabrous / 2-Hairy.	1	1	2	2	2	2	1	1	1	1	1	1	1	2	1	2	1
Funiculus: 1-Present/ 2-Absent.		1	1	1	1	1	2	2	2	2	2	2	2	1	2	1	1	1

Table 3: Seed coat micromorphology for the studied species of Malvaceae

Characters \ Species		*Abutilon fruticosum*	*Abutilon grandifolium*	*Abutilon pannosum*	*Abutilon theophrasti*	*Alcea rosea*	*Lavatera cretica*	*Malva aegyptiaca*	*Malva neglecta*	*Malva nicaeensis*	*Malva parviflora*	*Malva sylvestris*	*Malvastrum coromandelianum*	*Sida alba*	*Gossypium barbadense*	*Abelmoschus esculentus*	*Hibiscus sabdariffa*	*Hibiscus trionum*
Seed coat pattern sculpture: 1- Reticulate 2- Reticulate-foveate. 3-Scalariform. 4- Reticulate-rugose.		1	1	2	2	1	4	3	3	3	3	4	3	2	2	2	1	1
Epidermal cell shape: 1-Irregular polygonal cell. 2- Regular polygonal cell. 3- Elongated rectangle. 4- Irregular undulate.		1	1	2	2	1	1	3	3	3	3	3	3	2	4	2	1	1
Anticlinal wall	Shape: 1-Straight. 2-Straight-undulate. 3- Sinuous. 4- Undulate.	2	2	1	1	2	3	2	2	2	2	2	2	1	4	1	2	2
	Texture: 1-Smooth. 2-Warty.	2	2	2	1	2	2	1	1	2	1	1	2	1	1	2	1	1
	Thick: 1-Thick (5-10 μm). 2-Thin (3- 4.5 μm).	1	1	1	1	2	1	2	1	1	1	2	2	2	1	1	2	2
Periclinal wall	Shape: 1- Foveate. 2-Striate. 3-Smooth. 4- Rugose.	1	1	2	3	1	4	2	2	2	2	2	2	3	3	3	3	3
	Level: 1- Concave 2- Concave- flat.	2	2	1	1	1	2	2	2	2	2	1	2	1	1	1	1	1

On the other hand, seed morphological characters can be used as a parameter for species identification, as supported by Özbek and Uzunhisarcikli [16] and Khalik et al. [17]. In the present study, several seed macro-morphological characters, such as shape, color, texture, size, and hilum characters, as well as the details of the seed coat surface were recorded. Seeds provided five shapes: rounded-reniform, cordate- reniform, ovate, D-shape, and sub-globose. The dimensions of seeds are variable among the examined species. Seed lengths range from 1.3 mm to 9.5 mm, whereas the widths range from 1.3 mm to 5.1 mm. The seed color varied from light to dark brown. The seed surface is glabrous in ten studied species and hairy in seven species, while the seeds of *Gossypium barbadense* are easily recognized by their densely white indumentum.

Three types of hilum positions were observed: central, sub-central, and terminal. The central type is the dominant one among the studied species. The shape of the hilum is reniform in most studied species, these characters support the results of Khalik et al. [17].

SEM investigation showed that the surface pattern sculpturing was reticulate-foveate in five species, scalariform in *Malvastrum coromandelianum*, *Malva aegyptiaca*, *Malva neglecta*, *Malva nicaeensis*, *Malva parviflora*, reticulate in five species, and reticulate-rugose in *Lavatera cretica* and *Malva sylvestris*. The epidermal cell revealed diverse shapes by SEM. Six species are characterized by irregular polygonal epidermal cells; regular polygonal cells are characteristic of four studied species, whereas irregular undulate exist in *Gossypium barbadense* and elongated

rectangle cell shapes in the rest. Barthlott [36] spotted that the anticlinal and periclinal walls of the epidermis cell had great taxonomic importance at interspecific levels in different families. The anticlinal wall was raised in all taxa under investigation, being thick in ten species and thin in the rest (7 species). The wall could be straight, straight-sinuous, sinuous, or undulate with a smooth or warty surface. These results are congruent with the findings of different studies for some species of Malvaceae [15-17, 31, 37]**.** The seed of *Alcea rosea* species is characterized by some morphological features: a light-brown color, a hairy surface, a seed size ranging from 2 mm in length to 3.4 mm in width, a reticulate seed coat pattern sculpture, an irregular polygonal cell shape, a strait, and smooth anticlinal wall, and a foveate concave periclinal wall. This obtained result agrees with Özbek and Uzunhisarcikli [38].

In the present study, the dendrogram clearly revealed the division of the studied species into two clusters. Three genera, Abelmoschus, Gossypium, and Hibiscus, are contained in Cluster 1, while Cluster 2 consists of six genera. These six genera are then subclassified into two groups. Group (1) included *Abutilon* and *Sida*, whereas the second group (2) contained four genera: *Malva*, *Malvastrum*, *Lavatera cretica*, and *Alcea*. This result supports and agrees with previous studies [39-43]**.** Based on numerical analysis, this study provided appropriate information on the taxonomic significance of fruit, seed, and mericarp macro- and micro-morphological characters, confirming its efficiency in separating and distinguishing the studied species.

5. Conclusion

This study was conducted on macro- and micro-morphological features of the fruit, mericarp, and seed of seventeen species of the Malvaceae family, using optical and scanning electron microscopy to evaluate their taxonomic importance. The present study demonstrates the importance of LM and SEM for the accurate and complete identification and separation between studied species, based on fruit, and seed features. Predominantly, the variation in fruit, mericarp, and seed characters is very useful for plant systematics. According to the cluster analysis based on the obtained data from the morphological characteristics of the fruit, its type, shape, colour, size, mericarp numbers, mericarp shape, surface texture of mericarp, present or absence of awn, number of seeds, seed length and width, surface hair density, hilum characters, seed coat ornamentations, and periclinal and anticlinal surface patterns of epidermal cells prove to be significant morpho-logical characteristics to clarify taxonomic relationships within the family Malvaceae.

The current work will contribute to sharing knowledge about the family Malvaceae, and a DNA genetic analysis can be used for more identification by the taxonomists for further studies on this family.

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