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Pollen morphology of some species in family Amaranthaceae from Thailand

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Abstract. *Saensouk S, Saensouk P. 2021. Pollen morphology of some species in family Amaranthaceae from Thailand. Biodiversitas 23: 601-611.* The aim of this study was to study the pollen morphology of 14 species, eight genera from the family Amaranthaceae in Thailand by the applied acetolysis method and it was taken under light and scanning electron microcopies. All pollen grains had monad, radial symmetry and apolar. The pollens in this study can be divided into several groups based on shape, size, aperture, mesoporia, the character of aperture, and exine sculpturing. The sizes of the pollen can be divided into three groups, i.e., very small pollen group, small pollen group, and medium pollen group. The shapes of the pollen can be divided into three groups, i.e., spheroidal, pentagon, and dodecahedric. Exine sculpturing can be divided into three groups, i.e., granular, macrogranular, and microspine. The pollen in this study can be divided into five groups based on the character of the aperture, i.e., aperture with convex circular-like shape, aperture with deeply collapsed circular-like shape, aperture with collapsed circular-like shape, aperture with collapsed pentagon-like shape, and 6-angular element or hexagon-like shape. The pollen in this study can be divided into three groups based on the mesoporia, i.e., mesoporia broadly flat, mesoporia moderately and broadly vaulted, and mesoporia narrow and highly vaulted. The number of apertures was found to be between 12-54 apertures per pollen. The aperture diameters of Amaranthaceae pollen in this study ranged from 0.5-5 µm. The exine thickness of the pollen in this study was 1.12±0.04 - 2.14±0.31 µm. The pollen character of this study can be divided into eight types, i.e., *Achyranthes*-type, *Alternanthera*-type, *Amaranthus*-type, *Celosia*-type, *Cyathula*-type, *Gomphrena*-type, *Ouret*-type, and *Psilotrichum*-type. *The pollen characteristic of Alternanthera pungens* Kunth, *A. sessilis*)L.(R. BR., *Amaranthus blitum* subsp. *oleraceus* (L.) Costea, *Cyathula prostrate*)L.(Blume., *Ouret sanguinolenta* (L.) Kuntze, and *Psilotrichum ferrugineum* (Roxb.) Voigt was reported for the first time.

Keywords: Amaranthaceae, light microscope, pollen morphology, scanning electron microscope, Thailand

INTRODUCTION

Family Amaranthaceae or the amaranth family, in the order Caryophyllales is a flowering plant. Around the world, there are about 186 genera and 2,040 species (including former Chenopodiaceae) (Kew Science 2021). Amaranthaceae belongs to a cosmopolitan family that has a widespread distribution from the tropics to cool temperate regions. The Amaranthaceae (*sensu stricto*) were found predominantly in the tropics, but the former Chenopodiaceae were mostly reported in dry temperate and warm temperate areas (Christenhusz and Byng 2016). Larsen (1992) reported 22 species of the family Amaranthaceae in Thailand. This family is utilized as food, herbs, and ornamental plants, etc. The famous plant in this family is spinach (*Spinacia oleracea* L.) and amaranth (*Amaranthus viridis* L.), a highly valuable and useful local vegetable (Rahman and Gulshana 2014). There are also cocks comb trees, amaranth, which are widely used as ornamental plants due to their beautiful flowers in a variety of colors, and it is commonly planted as an ornamental plant in office gardens or parks (Christenhusz and Byng 2016).

Plant classification generally requires the study of plant morphology (Saensouk et al. 2021). Later, many techniques in biology, such as plant anatomy, pollen classification, chromosome study, and molecular techniques can be used in plant classification, for example, the karyotype of the genus *Amomum*, family Zingiberaceae in Thailand (Saensouk and Saensouk 2021a), pollen morphology of the genus *Helicteres* in Thailand (Saensouk and Saensouk 2020), pollen morphology of certain species of the family Lamiaceae in Saudi Arabia (Doaigey et al. 2018), pollen morphology of subfamily Malvoideae (Malvaceae *sensu lato*) in Thailand (Saensouk and Saensouk 2021b).

Common pollen also refers to the pollen grains, or yellow powder, found in common flowers or pollen in large numbers (Kajornjit et al. 2018(. The pollen characterizations can be used in taxonomic studies based on their exine sculpturing, pattern, aperture, pore characters, size, or shape (Saensouk and Saensouk 2020, 2021b). Different pollen grains can be used to classify plant species such as pollen of genus *Curcuma*, pollen of subfamily Malvoideae etc. (Kajornjit et al. 2018; Saensouk and Saensouk 2021b). Data on pollen morphology diversity can then be implemented as an effort for germplasm conservation strategies (Sudarmono 2019). Several botanists have studied the palynology of the Amaranthaceae worldwide. Adekanmbi and Ogundipe)2009(studied pollen of three

species (*Alternanthera* sp., *Celosia argentia*, *Gomphrena celosioides*) in family Amaranthaceae from the UK. Assadi et al. (2016) studied palynology on seven species of genus *Anabasis* L. (Amaranthaceae) namely, *A. haussknechtii*, *A. aphylla*, *A. calcarea*, *A. eugeniae*, *A. eriopoda*, *A. annua* and *A. setifera* from Iran. Alwadie (2005) reported morphology and distribution of three genera of Amaranthaceae namely, *Achyranthes aspera*, *Aerva javanica*, *A. lanata*, and *Pupalia lappaceae* in the South Western area of Saudi Arabia. Borsch)1988(, reported pollen types in 130 species from 67 genera of Amaranthaceae. Chin and Lim (2011) studied pollen morphology of three *Alternanthera* species (Amaranthaceae), i.e. *A. sessilis*, *A. bettzickiana* and *A. paronychioides*. Pollen morphology of 18 species belonging to 10 genera of the family Amaranthaceae has been investigated using a light microscope and scanning electron microscope by Perveen and Qaiser (2002). And Talebi et al. (2016) recognized palynological study of some Iranian *Amaranthus* taxa. However, the pollen morphology of many species in this family was never studied before by several botanists. Therefore, this study aimed to study the pollen morphology of the plant family Amaranthaceae in Thailand.

MATERIAL AND METHODS

The pollen of 14 species, eight genera of family Amaranthaceae from Thailand was studied between 2019 and 2020. The voucher specimens for the family Amaranthaceae from Thailand were deposited in the Mahasarakham University Herbarium, Maha Sarakham Province, Thailand (Table 1). Pollen grains of all materials were obtained from 70% ethanol. Pollen grains of all samples were analyzed using the applied acetolysis method from Erdtman (1966). The pollen grains morphology (based on Saensouk and Saensouk 2021b, i.e. exine sculpturing, spine, pattern, aperture, pore characters, size, or shape) of all species in this study was studied under light microscopy (LM) and scanning electron microscopy (SEM), respectively. For each species, 30 pollen grains were measured under a LM. The pollen grains were also dried, coated with a sputter coater, and observed with an SEM, JEOL: JSM 6460 LV. The palynological terminology follows that of Doaigey et al. (2018), Erdtman (1966), Moore et al. (1991), Punt et al. (2007), Rull (2003), and Saensouk and Saensouk (2020).

RESULTS AND DISCUSSION

From this study of the palynology from the family Amaranthaceae for 14 species, eight genera are observed by LM and SEM, respectively. It was classified following Erdtman)1966(. The results are reported in Table 2 and Figures 1-2.

General pollen morphology of family Amaranthaceae in Thailand

The pollen grains were monad, with radial symmetry, spheroidal in shape, very small or small to medium in size with a diameter 6.70±0.53-25.36±1.73 µm, apolar, 12-54 apertures, aperture diameter 0.5-5 µm, polypantoporate aperture, and the aperture areas had a membrane covering the aperture with a convex circular-like shape, deeply collapsed circular-like shape, collapsed circular-like shape, collapsed pentagon-like shape or 6-angular element, or hexagon-like shape; and, covered with granular, macrogranular or microspine; mesoporia broadly flat, moderately and broadly vaulted, or narrow and highly vaulted; length of ridge 0.5-2.5 µm or without ridge; exine sculpturing smooth with granular, macrogranular, or microspine; exine thickness 1.12±0.04 to 2.14±0.31 µm.

Table 1. Specimens from 14 species, eight genera were investigated and all specimens investigated were deposited at Mahasarakham University Herbarium, Maha Sarakham Province, Thailand

Species	Collector no.	Species locality	Coordinate altitude
Achyranthes aspera L.	P. Saensouk 07/53	Ban Paeng District, Nakhon Phanom Province	17°58′5″N 104°12′57″E
Alternanthera brasiliana (L.) Kuntze	P. Saensouk 12/52	Sangkhom District, Nong Khai Province	18°3′54″N 102°16′24″E
*Al. caracasana*Kunth	P. Saensouk 11/53	Phu Phan District, Sakhon Nakhon Province	17°0′0″N 103°57′56″E
*Al. pungens*Kunth	P. Saensouk 08/53	Ban Phue District, Udorn Thani Province	17°41′15″N 102°28′22″E
Al. sessilis (L.) R.Br. ex DC.	P. Saensouk 12/52	Phu Wiang District, Khon Kaen Province	16°39′16″N 102°22′37″E
Amaranthus blitum subsp. *oleraceus* (L.) Costea	P. Saensouk 08/56	Maerim District, Chiangmai Province	18°54′50″N 98°56′42″E
Am. spinosus L.	P. Saensouk 09/53	Chatuchak District, Bangkok Province	13°49′43″N 100°33′35″E
Am. viridis L.	P. Saensouk 13/52	Nam Nao District, Phetchabun Provinvce	16°46′6″N 101°40′18″E
Celosia argentea L.	P. Saensouk 10/53	Um Phang District, Tak Province	16°1′0″N 98°51′46″E
Cyathula prostrata (L.) Blume	P. Saensouk 14/52	Kaeng Khoi District, Saraburi Province	14°35′12″N 100°59′54″E
Gomphrena celosioides Mart.	P. Saensouk 15/52	Pak Chong District, Nakhon Ratchasima Province	14°24′42″N 101°25′18″E
G. globosa L.	P. Saensouk 14/56	Khong Chiam District, Ubon Ratchathani Province	15°19′8″N 105°29′44″E
Ouret sanguinolenta (L.) Kuntze	P. Saensouk 11/53	Nachueak District, Maha Sarakham Province	15°48′0″N 103°1′54″E
Psilotrichum ferrugineum Moq. (Roxb.) Voigt	P. Saensouk 11/53	Cha-am District, Phetchaburi Province	12°47′59″N 99°58′1″E

Table 2. Pollen morphology data of 14 species in family Amaranthaceae from Thailand

Species	Pollen size)µm(			Shape/group	Aperture character	No. of apetures	Aperture diameter)µm(	Aperture group	Length of ridge)µm(	Mesoporia /Group	Exine thickness)µm(	Exine sculpturing/group
	Size)µm(	Size	Group									
Achyranthes aspera L. Kuntze	12.48±1.25	Small	Small pollen group	Spheroidal/ Spheroidal shape group	Pantoporate	32	3.2	Aperture with convex circular-like shape group	-	Broadly flat / Mesoporia broadly flat group	1.45±0.09	Smooth with sparsely distributed granulate / Granular group
Alternanthera brasiliana (L.) Kuntze	18.56±1.16	Small	Small pollen group	Dodecahedric/ Dodecahedric shape group	Pantoporate	14	5	Aperture with collapsed pentagon-like shape group	1.5	Narrow and highly vaulted / Mesoporia narrow and highly vaulted group	1.85±0.02	Smooth with microspine arranged in one row / Microspine group
Al. caracasana Kunth	21.73±1.04	Small	Small pollen group	Dodecahedric/ Dodecahedric shape group	Pantoporate	12	3.75	Aperture with collapsed pentagon-like shape group	1.75	Narrow and highly vaulted / Mesoporia narrow and highly vaulted group	1.68±0.17	Numerous densely distributed macrogranulate / Macrogranular group
Al. pungens Kunth	18.93±0.78	Small	Small pollen group	Dodecahedric/ Dodecahedric shape group	Pantoporate	12	4	Aperture with collapsed pentagon-like shape group	1.25	Narrow and highly vaulted / Mesoporia narrow and highly vaulted group	1.71±0.24	Smooth with microspine arranged in one row / Microspine group
Al. sessilis (L.) R.BR.	14.03±0.80	Small	Small pollen group	Dodecahedric/ Dodecahedric shape group	Pantoporate	12	4	Aperture with collapsed pentagon-like shape group	1.25	Narrow and highly vaulted / Mesoporia narrow and highly vaulted group	1.59±0.11	Smooth with microspine arranged in one row / Microspine group
Amaranthus blitum subsp. *oleraceus* (L.) Costea	16.33±0.48	Small	Small pollen group	Spheroidal/ Spheroidal shape group	Pantoporate	50	2.33	Aperture with collapsed circular-like shape group	-	Moderately and broadly vaulted / Mesoporia moderately and broadly vaulted group	1.69±0.25	Smooth with numerous evenly distributed granulate / Granular group
Am. spinosus L.	25.36±1.73	Medium	Medium pollen group	Spheroidal/ Spheroidal shape group	Pantoporate	54	0.5	Aperture with collapsed circular-like shape group	-	Moderately and broadly vaulted / Mesoporia moderately and broadly vaulted group	1.94±0.17	Slightly rough with numerous evenly distributed granulate / Granular group
Am. viridis L.	14.46±0.86	small	Small pollen group	Spheroidal/ Spheroidal shape group	pantoporate	40	1.25	Aperture with collapsed circular-like shape group	-	Moderately and broadly vaulted / Mesoporia moderately and broadly vaulted group	1.87±0.23	Smooth with numerous evenly distributed granulate / Granular group
Celosia argentea L.	20.13±1.22	Small	Small pollen group	Spheroidal/ Spheroidal shape group	Pantoporate	18	2	Aperture with collapsed circular-like shape group	-	Moderately and broadly vaulted / Mesoporia moderately and broadly vaulted group	2.01±0.43	Punctuate and rough with numerous sparsely distributed granulate/ Granular group

Cyathula prostrata (L.) Blume.	6.70±0.53	Very small	Very small pollen group	Spheroidal/ Spheroidal shape group	Pantoporate	30	1.75	Aperture with collapsed circular-like shape group	-	Moderately and broadly vaulted / Mesoporia moderately and broadly vaulted group	1.76±0.23	Rough-smooth with numerous densely distributed granulate / Granular group
Gomphrena celosoides Mart	15.10±0.84	Small	Small pollen group	Dodecahedric/ Dodecahedric shape group	Pantoporate	44	2.25	6-angular element or hexagon-likeshape group	0.5	Narrow and highly vaulted / Mesoporia narrow and highly vaulted group	2.14±0.31	Metareticulate with sparsely distributed microspines, several distally arranged in one line/ Microspine group
G. globosa L.	11.73±1.01	Small	Small pollen group	Dodecahedric/ Dodecahedric shape group	Pantoporate	12	5	Aperture with collapsed pentagon-like shape group	1.5	Narrow and highly vaulted / Mesoporia narrow and highly vaulted group	1.73±0.11	Metareticulate with numerous evenly distributed microspines / Microspine group
Ouret sanguinolenta (L.) Kuntze	13.76±0.81	Small	Small pollen group	Spheroidal/ Pentagon shape group	Pantoporate	16	2.13	Aperture with deeply collapsed circular-like shape group	2.5	Moderately and broadly vaulted / Mesoporia moderately and broadly vaulted group	1.12±0.04	Smooth with sparsely distributed granulate / Granular group
Psilotrichum ferrugineum (Roxb.) Voigt	18.86±1.12	Small	Small pollen group	Spheroidal/ Spheroidal shape group	Pantoporate	20	2	Aperture with convex circular-like shape	-	Broadly flat / Mesoporia broadly flat group	1.86±0.12	Punctuate with numerous evenly distributed granulate/ Granular group

Pollen description of each species

The pollen description of 14 species, eight genera from the family Amaranthaceae based on LM and SEM.

***Achyranthes aspera* L.**)Table 2; Figures 1A, 2A1, 2A2(. Pollen grains were monad, radial symmetry, spheroidal in shape, small in size with diameter 12.48±1.25 µm, apolar, 32 apertures, aperture diameter c. 3.2 µm, polypantoporate aperture, and aperture areas have membrane covering the aperture making it look more convex and circular-like shape covered with sparse granules, mesoporia broadly flat, without ridge, exine sculpturing smooth with sparsely distributed granulates, and exine thickness 1.45±0.09 µm.

***Alternanthera brasiliana* (L.) Kuntze**)Table 2; Figures 1B, 2B1, 2B2(. Pollen grains were monad, radial symmetry, dodecahedric in shape, small in size with diameter 18.56±1.16 µm, apolar, 14 apertures, aperture diameter c. 5 µm, polypantoporate aperture, and aperture areas have membrane covering aperture with collapsed pentagon-like shape and covered with granules, mesoporia narrow and highly vaulted, length of ridge 1.5 µm, exine sculpturing smooth with microspine arranged in one row, and exine thickness 1.85±0.02 µm.

***Alternanthera caracasana* Kunth**)Table 2; Figures 1C, 2C1, 2C2(. Pollen grains were monad, radial symmetry, dodecahedric in shape, small in size with diameter 21.73±1.04 µm, apolar, 12 apertures, aperture diameter c. 3.75 µm, polypantoporate aperture and aperture areas have membrane covering aperture with collapsed pentagon-like shape and covered with dense macrogranules, mesoporia narrow and highly vaulted, length of ridge 1.75 µm, exine sculpturing numerous densely distributed macro granulates, and exine thickness 1.68±0.17 µm.

***Alternanthera pungens* Kunth**)Table 2; Figures 1D, 2D1, 2D2(. Pollen grains were monad, radial symmetry, dodecahedric in shape, small in size with diameter 18.93±0.78 µm in size, apolar, 12 apertures, aperture diameter c. 4 µm, polypantoporate aperture and aperture areas have membrane covering aperture with collapsed pentagon-like shape and covered with microspine, mesoporia narrow and highly vaulted, length of ridge 1.25 µm, exine sculpturing smooth with microspine arranged in one row, and exine thickness 1.71±0.24 µm.

***Alternanthera sessilis*)L.(R. BR.**)Table 2; Figures 1E, 2E1, 2E2(. Pollen grains were monad, radial symmetry, dodecahedric in shape, small in size with diameter 14.03±0.80 µm, apolar, 12 apertures, aperture diameter c. 4 µm, polypantoporate aperture and aperture areas have membrane covering aperture with collapsed pentagon like-shape and covered with microspine, mesoporia narrow and highly vaulted, length of ridge 1.25 µm, exine sculpturing smooth with microspine arranged in one row, and exine thickness 1.59±0.11 µm.

***Amaranthus blitum* subsp. *oleraceus* (L.) Costea**)Table 2; Figures 1F, 2F1, 2F2(. Pollen grains were monad, radial symmetry, spheroidal in shape, small in size with diameter 16.33±0.48 µm, apolar, 50 apertures, aperture diameter c. 2.33 µm, polypantoporate aperture and aperture areas have membrane covering aperture with collapsed circular-like shape and covered with sparse granules, mesoporia moderately and broadly vaulted, without ridge, exine sculpturing smooth with numerous evenly distributed granulates, and exine thickness 1.69±0.25 µm.

***Amaranthus spinosus* L.**)Table 2; Figures 1G, 2G1, 2G2(. Pollen grains were monad, radial symmetry, spheroidal in shape, medium in size with diameter 25.36±1.73 µm, apolar, 54 apertures, aperture diameter c. 0.5 µm, polypantoporate aperture and aperture areas have membrane covering aperture with collapsed circular-like shape and covered with granules, mesoporia moderately and broadly vaulted, without ridge, exine sculpturing slightly rough with numerous evenly distributed granulates, and exine thickness 1.94±0.17 µm.

***Amaranthus viridis* L.**)Table 2; Figures 1H, 2H1, 2H2(. Pollen grains were monad, radial symmetry, spheroidal in shape, small in size with diameter 14.46±0.86 µm, apolar, 40 apertures, aperture diameter c. 1.25 µm, polypantoporate aperture and aperture areas have membrane covering aperture with collapsed circular-like shape and covered with sparse granules, mesoporia moderately and broadly vaulted, without ridge, exine sculpturing smooth with numerous evenly distributed granulates, and exine thickness 1.87±0.23 µm.

***Celosia argentea* L.**)Table 2; Figures 1I, 1J, 2I1, 2I2, 2J1, 2J2(. Pollen grains were monad, radial symmetric, spheroidal in shape, small in size with diameter 20.13±1.22 µm, apolar, 18 apertures, aperture diameter c. 2 µm, polypantoporate aperture and aperture areas have membrane covering aperture with collapsed circular-like shape and covered with sparse granules, mesoporia moderately and broadly vaulted, without ridge, exine sculpturing punctuate and rough with numerous sparsely distributed granulates, and exine thickness 2.01±0.43 µm.

***Cyathula prostrate*)L.(Blume**)Table 2; Figures 1K, 2K1, 2K2(. Pollen grains were monad, radial symmetry, spheroidal in shape, very small in size with diameter 6.7±0.53 µm, apolar, 30 apertures, aperture diameter c. 1.75 µm, polypantoporate aperture and aperture areas have membrane covering aperture with collapsed circular-like shape and covered with granules, mesoporia moderately and broadly vaulted, without ridge, exine sculpturing rough-smooth with numerous densely distributed granulates, and exine thickness 1.76±0.23 µm.

***Gomphrena celosoides* Mart**)Table 2; Figures 1L, 2L1, 2L2(. Pollen grains were monad, radial symmetry, dodecahedric in shape, small in size with diameter 15.10±0.84 µm, apolar, 44 apertures, aperture diameter c. 2.25 µm, polypantoporate aperture and aperture areas have membrane covering aperture with collapsed 6-angular element or hexagon-like shape, and covered with microspine, mesoporia narrow and highly vaulted, length of ridge 0.5 µm, exine sculpturing metareticulate with sparsely distributed microspines, several distally arranged in one line, and exine thickness 2.14±0.31 µm.

***Gomphrena globosa* L.**)Table 2; Figures 1M, 2M1, 2M2(. Pollen grains were monad, radial symmetric, dodecahedric in shape, small in size with diameter 11.73±1.01 µm, apolar, 12 apertures, aperture diameter c. 5 µm, polypantoporate aperture and aperture areas have membrane covering aperture with collapsed pentagon-like

shape and covered with granules, mesoporia narrow and highly vaulted, length of ridge 1.5 µm, exine sculpturing metareticulate with numerous evenly distributed microspines, several distally arranged in one line, and exine thickness 1.73±0.11 µm.

***Ouret sanguinolenta* (L.) Kuntze**)Table 2; Figures 1N, 2N1, 2N2(. Pollen grains were monad, radial symmetry, pentagon in shape, small in size with diameter 13.76±0.81 µm, apolar, 16 apertures, apertures diameter c. 2.13 µm, polypantoporate aperture, and aperture areas have membrane covering the aperture with deeply collapsed circular-like shape, covered with sparse granules, mesoporia moderately and broadly vaulted, length of ridge 2.5 µm, exine sculpturing smooth with sparsely distributed granulates, and exine thickness 1.12±0.04 µm.

***Psilotrichum ferrugineum* (Roxb.) Voigt**)Table 2; Figures 1O, 2O1, 2O2(. Pollen grains were monad, radial symmetric, spheroidal in shape, small in size with diameter 18.86±1.12 µm, apolar, 20 apertures, aperture diameter c. 2 µm, polypantoporate aperture and aperture areas have membrane covering aperture making aperture look more convex circular-like shape and covered with microspine, mesoporia broadly flat, without ridge, exine sculpturing punctuates with numerous evenly distributed granulates, and exine thickness 1.86±0.12 µm.

The results of this pollen study are consistent with the study by Erdtman (1966), which examined pollen grains from the genus. For Amaranthaceae, nine genera, 12 species, were found to have pollen shapes of spheroidal and mixed with both round and oval apertures. This is also consistent with Borsch (1988), who studied the pollen morphology and found them to be dodecahedral or spheroidal, pantoporate apertures for 36 species of Amaranthaceae.

Therefore, the pollen characters of this study can be divided into eight types based on aperture area (Table 2 and Figures 1-2).

***Achyranthes*-Type**: The character of this type is aperture areas with a membrane covering the aperture, making it look more convex and circular-like shape covered with sparse granules, mesoporia broadly flat, without ridge. Only pollen of *Achyranthes aspera* is found in this pollen type (Figures 1A, 2A1, 2A2). This pollen type is reported for the first time.

***Alternanthera*-Type**: The character of this type is aperture areas with a membrane covering aperture with collapsed pentagon-like shape and covered with granules, mesoporia narrow and highly vaulted, length of ridge 1.25-1.75 µm. Pollen of four species, i.e., *Alternanthera brasiliana* (L.) Kuntze, *Al. caracasana* Kunth, *Al. pungens* Kunth, and *Al. sessilis* (L.) R. BR., have been found in this pollen type (Figures 1B, 1C, 1D, 1E, 2B1, 2B2, 2C1, 2C2, 2D1, 2D2, 2E1, 2E2). This pollen type is reported for the first time.

***Amaranthus*-Type**: The character of this type is aperture areas with a membrane covering aperture with collapsed circular-like shape and covered with sparse granules, mesoporia moderately and broadly vaulted, without ridge. Pollen of *Amaranthus blitum* subsp. *oleraceus* (L.) Costea, *Am. viridis* L., and *Am. spinosus* are found in this pollen type (Figures 1F, 1G, 1H, 2F1, 2F2, 2G1, 2G2, 2H1, 2H2). This pollen type is consistent with that previously reported by Borsch (1988) who listed pollen types of some Amaranthaceae.

***Celosia*-Type**: The character of this type is aperture areas with a membrane covering aperture with collapsed circular-like shape and covered with sparse granules, mesoporia moderately and broadly vaulted, without ridge. Pollen of *Celosia argentea* belongs to this pollen type (Figures 1I, 1J, 2I1, 2I2, 2J1, 2J2). This pollen type is reported for the first time.

***Cyathula*-Type**: The character of this type is aperture areas with a membrane covering aperture with collapsed circular-like shape and covered with granules, mesoporia moderately and broadly vaulted, without ridge. Only the pollen of *Cyathula prostrata* was reported in this pollen type (Figures 1K, 2K1, 2K2). This pollen type is reported for the first time.

***Gomphrena*-Type**: The character of this type is aperture areas with a membrane covering aperture with collapsed 6-angular element or hexagon-like shape, and covered with microspine, mesoporia narrow and highly vaulted, length of ridge 0.5-1.5 µm. Pollen of *Gomphrena celosoides* and *G. globosa* are reported in this pollen type (Figures 1L, 1M, 2L1, 2L2, 2M1, 2M2). This pollen type is consistent with that previously reported by Borsch (1988) who listed pollen types of some Amaranthaceae.

***Ouret*-Type**: The character of this type is aperture areas with membrane covering the aperture with deeply collapsed circular-like shape, covered with sparse granules, mesoporia moderately and broadly vaulted, length of ridge 2.5 µm. Only pollen of *Ouret sanguinolenta* is reported in this type (Figures 1N, 2N1, 2N2). This pollen type is reported for the first time.

***Psilotrichum*-Type:** The character of this type is aperture areas with membrane covering aperture making aperture look more convex circular-like shape and covered with microspine, mesoporia broadly flat, without ridge. Only pollen of *Psilotrichum ferrugineum* was found in this pollen type (Figures 1O, 2O1, 2O2). This pollen type is consistent with that previously reported by Borsch (1988) who listed pollen types of some Amaranthaceae.

Moreover, the pollen of the family Amaranthaceae can be classified into several groups based on size, shape, character of aperture, mesoporia, and exine sculpturing as follows (Table 2).

The number of apertures was found to be between 12-54 per pollen type (Table 2). The number of apertures from the pollen of three species, i.e., *Alternanthera caracasana* Kunth, *Al. pungens* Kunth, and *Al. sessilis* (L.) R. BR. was found to be 12. At the same time, the number of apertures from the pollen of *Amaranthus spinosus* L. was found to be 54.

The aperture diameter of Amaranthaceae pollen in this study ranged from 0.5 µm (found in *Amaranthus spinosus* L.) -5 µm (found in *Alternanthera brasiliana* (L.) Kuntze and *Gomphrena globosa* L.) (Table 2).

The exine thickness of the pollen in this study was found to be 1.12±0.04 µm (found in *Ouret sanguinolenta* (L.) Kuntze) to 2.14±0.31 µm (found in *Gomphrena celosoides* Mart) (Table 2).

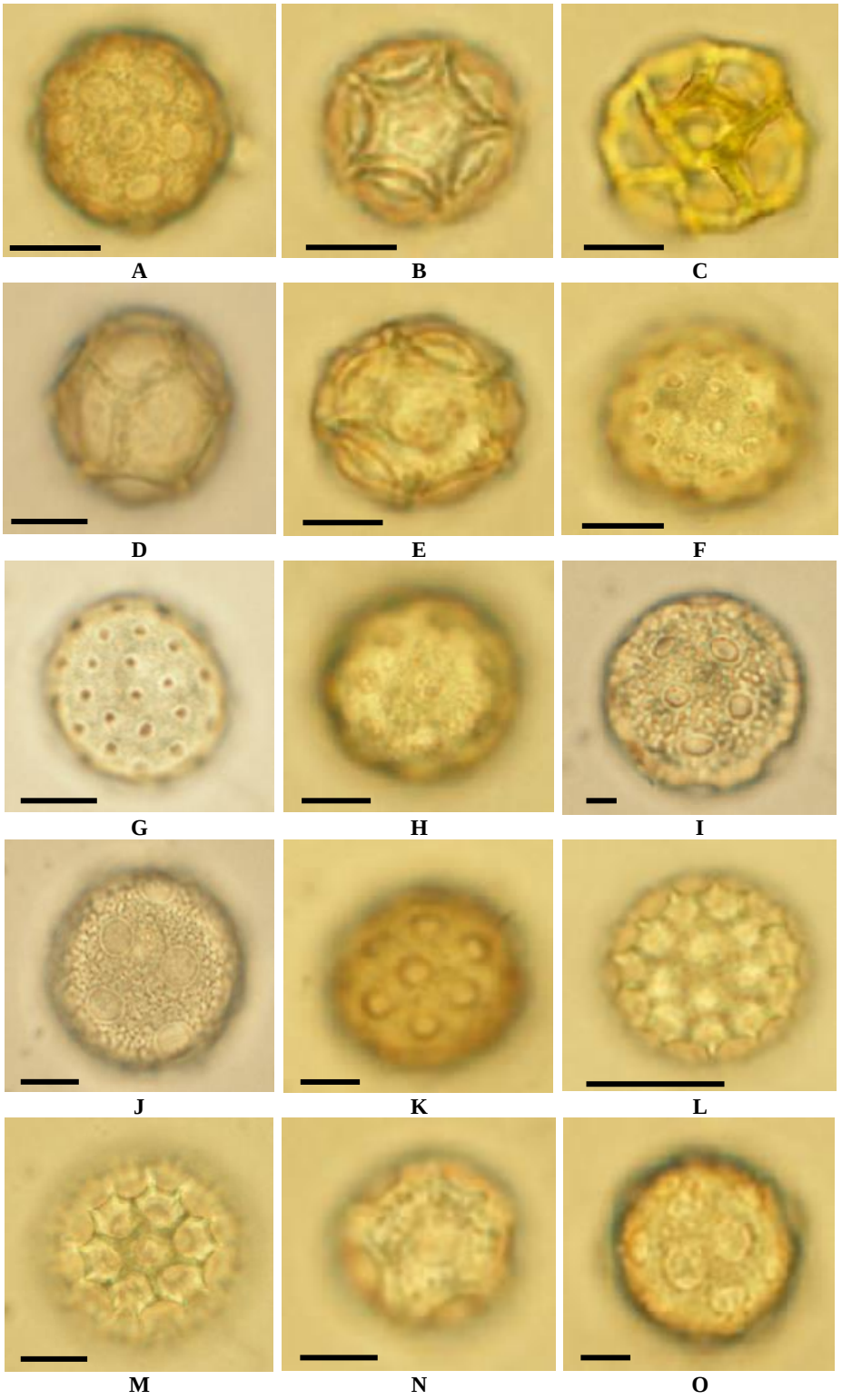
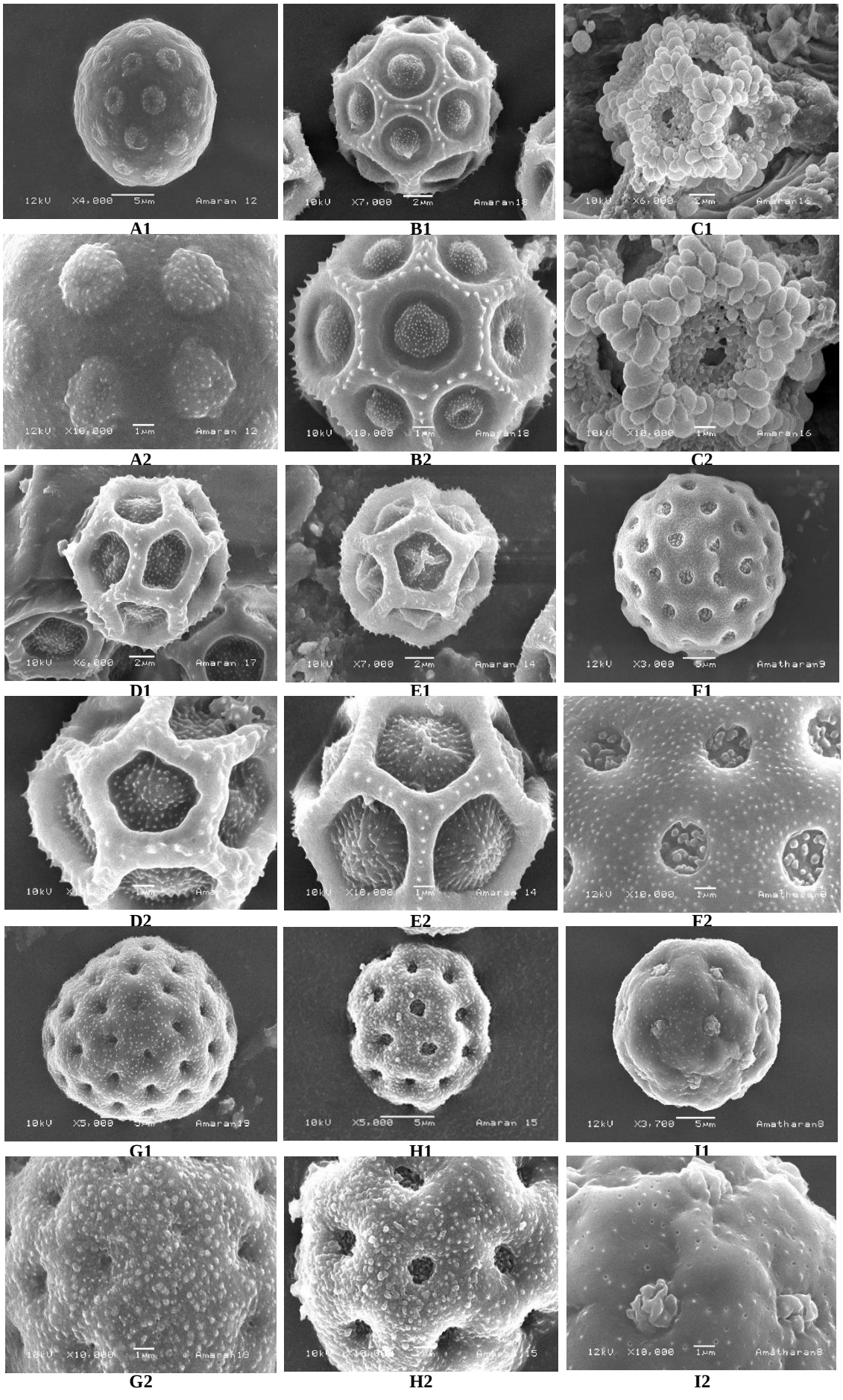


Figure 1. Light micrographs of pollen grains of *Achyranthes aspera* (A); *Alternanthera brasiliana* (B); *Al. caracasana* (C); *Al. pungens* (D); *Al. sessilis* (E); *Amaranthus blitum* subsp. *oleraceus* (F); *Am. spinosus* (G); *Am. viridis* (H); *Celosia argentea* (I); *Ce. argentea* (J); *Cyathula prostrate* (K); *Gomphrena celosoides* (L); *G. globosa* (M); *Ouret sanguinolenta* (N); and *Psilotrichum ferrugineum* (O). (Scale bars =5 µm)


12kV X4,000 5µm Amaran 12
A1
10kV X7,000 2µm Amaran18
B1
10kV X6,000 2µm Amaran16
C1
12kV X10,000 1µm Amaran 12
A2
10kV X10,000 1µm Amaran18
B2
10kV X10,000 1µm Amaran16
C2
10kV X6,000 2µm Amaran 17
D1
10kV X7,000 2µm Amaran 14
E1
12kV X3,000 5µm Amatharam9
F1
10kV X10,000 1µm Amaran 14
E2
12kV X10,000 1µm Amatharam9
F2
10kV X5,000 5µm Amaran19
G1
10kV X5,000 5µm Amaran 15
H1
12kV X3,700 5µm Amatharam8
I1
10kV X10,000 1µm Amaran18
G2
12kV X10,000 1µm Amatharam8
I2

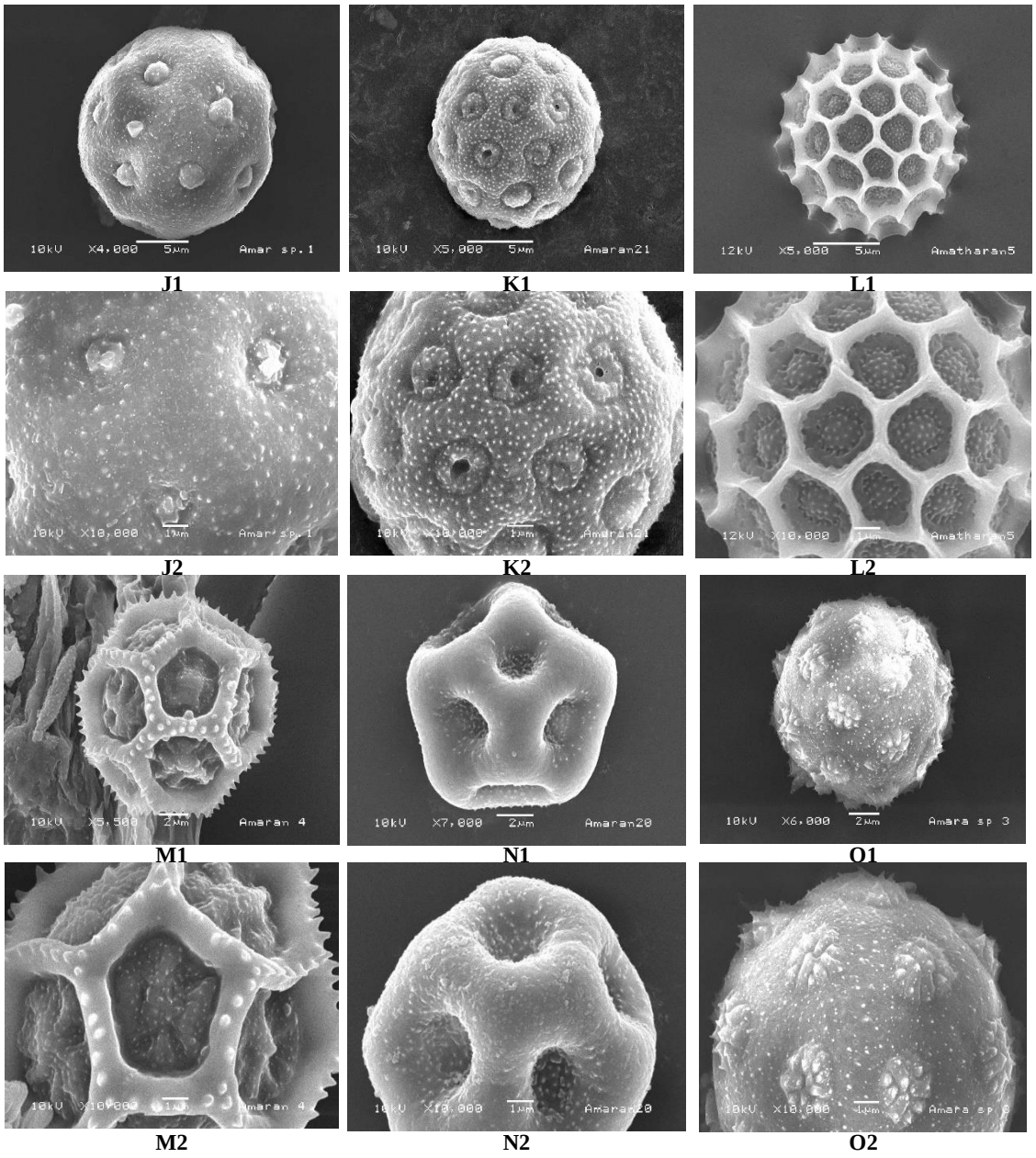


Figure 2. SEM micrographs of pollen grains of *Achyranthes aspera* (A1-A2); *Alternanthera brasiliana* (B1-B2); *Al. caracasana* (C1-C2); *Al. pungens* (D1-D2); and *Al. sessilis* (E1-E2); *Amaranthus blitum* subsp. *oleraceus* (F1-F2); *Amaranthus spinosus* (G1-G2); *Am. viridis* L. (H1-H2); *Celosia argentea* (I1-I2); *Ce. argentea* (J1-J2); *Cyathula prostrate* (K1-K2); and *Gomphrenacelosoides* (L1-L2); *Gomphrena globosa* (M1-M2); *Ouret sanguinolenta* (N1-N2); and *Psilotrichum ferrugineum* (O1-O2)

Moreover, the pollen characters of this study can be divided into several group based on size, shape, exine sculpturing, the character of the aperture, and mesoporia follow as below:

1. The size of the pollen can be divided into three groups (Table 2):
   - 1.1 Very small pollen group: less than 10 micrometers in size, including *Cyathula prostrata* (L.) Blume.
   - 1.2 Small pollen group: 10-25 µm in size, including *Achyranthes aspera* L., *Ouret sanguinolenta* (L.) Kuntze, *Alternanthera brasiliana* (L.) Kuntze, *Al. caracasana* L., *Al. pungens* Kunth, *Al. sessilis* (L.) R. BR., *Am. viridis* L., *Celosia argentea* L., *Gomphrena celosoides* Mart, *G. globosa* L., and *Psilotrichum ferrugineum* (Roxb.) Voigt.
   - 1.3 Medium pollen group: 25-50 µm in size, including *Amaranthus spinosus* L.
2. The shape of the pollen can be divided into three groups (Table 2):
   - 2.1 Spheroidal shape group: this shape is found in eight species and one variety; i.e., *Achyranthes aspera* L., *Alternanthera pungens* Kunth, *Amaranthus blitum* subsp. *oleraceus* (L.) Costea, *Am. viridis* L., *Am. spinosus* L, *Celosia argentea* L., *Cyathula prostrata* (L.) Blume, and *Psilotrichum ferrugineum* (Roxb.) Voigt.
   - 2.2 Pentagon shape group: this shape is found only in *Ouret sanguinolenta* (L.) Kuntze.
   - 2.3 Dodecahedric shape group: this group is recognized in six species, i.e., *Alternanthera brasiliana* (L.) Kuntze, *Al. caracasana* Kunth, *Al. pungens* Kunth, *Al. sessilis* (L.) R. BR., *Gomphrena celosioides* Mart, and *G. globosa* L..

3. Exine sculpturing can be divided into three groups (Table 2):
   3.1 Granular group: this group is discovered in eight species and one variety, i.e., *Achyranthes aspera* L., *Ouret sanguinolenta* (L.) Kuntze, *Amaranthus blitum* subsp. *oleraceus* (L.) Costea, *Am. viridis* L., *Am. spinosus* L., *Celosia argentea* L., *Cyathula prostrata* (L.) Blume, and *Psilotrichum ferrugineum* (Roxb.) Voigt.
   3.2 Macrogranular group: only the pollen of *Alternanthera caracasana* Kunth has been found in this group.
   3.3 Microspine group: it was found in *Alternanthera brasiliana* (L.) Kuntze, *Al. pungens* Kunth, *Al. sessilis* (L.) R. BR., *Gomphrena celosioides* Mart, and *G. globosa* L..
4. The pollen in this study can be divided into five groups based on the character of the aperture (Table 2):
   4.1 Aperture with convex circular-like shape group: two species, i.e., *Achyranthes aspera* L. and *Psilotrichum ferrugineum* (Roxb.) Voigt was reported in this pollen group.
   4.2 Aperture with deeply collapsed circular-like shape group: only pollen of *Ouret sanguinolenta* (L.) Kuntze was found in this pollen group.
   4.3 Aperture with collapsed circular-like shape group: five species and one variety, i.e., *Am. viridis* L.., *Am. lividus* L., *Am. spinosus* L., *Celosia argentea* L., and *Cyathula prostrate*)L.(Blume was reported in this pollen group.
   4.4 Aperture with collapsed pentagon-like shape group: five species, i.e., *Alternanthera brasiliana* (L.) Kuntze, *Al. caracasana* Kunth, *Al. pungens* Kunth, *Al. sessilis*)L.(R. BR, and *Gomphrena globosa* L. were reported in this pollen group.
   4.5 Six-angular element or hexagon-like shape group: only pollen of *Gomphrena celosoides* Mart was found in this pollen group.
5. The pollen in this study can be divided into three groups based on the mesoporia (Table 2):
   5.1 Mesoporia broadly flat group: *Achyranthes aspera* L. and *Psilotrichum ferrugineum* (Roxb.) Voigt has been found in this pollen group.
   5.2 Mesoporia moderately and broadly vaulted group: six species and one variety, i.e., *Ouret sanguinolenta* (L.) Kuntze, *Amaranthus blitum* subsp. *oleraceus* (L.) Costea, *Am. viridis* L. , *Am. spinosus* L., *Celosia argentea* L., and Cyathula prostrate)L.(Blume was found in this pollen group.
   5.3 Mesoporia narrow and highly vaulted group: six species, i.e., *Alternanthera brasiliana* (L.) Kuntze, *Al. caracasana* Kunth, *Al. pungens* Kunth, *Al. sessilis*)L.(R. BR, *Gomphrena celosoides* Mart, and *G. celosoides* Mart were found in this pollen group.

In conclusion, from the results of this study, it was found that the distinctive features of the pollen morphology of the family Amaranthaceae were a single grain, radial symmetry, apolar, dodecahedric, pentagon or hexagon or spheroidal shaped, polypantoporate aperture, exine sculpturing granulate, macrogranulate, and microspine. The pollen morphology of the family Amaranthaceae can be divided into several groups based on shape, size, aperture, mesoporia, character of aperture, and exine sclupturring. Six species of family *Amaranthaceae* from this study, i.e., *Alternanthera pungens* Kunth, *A. sessilis*)L.(R. BR., *Amaranthus blitum* subsp. *oleraceus* (L.) Costea, *Cyathula prostrate*)L.(Blume., *Ouret sanguinolenta* (L.) Kuntze, and *Psilotrichum ferrugineum* (Roxb.) Voigt was reported for the first time.

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