

TAXONOMIC ASSESSMENT OF THE FAMILY AMARANTHACEAE WITH SPECIAL EMPHASIS ON SEED MORPHOLOGY

DURDANA KANWAL AND RUBINA ABID

Department of Botany, University of Karachi, Karachi-72570, Pakistan
Corresponding author's email: say2kanwal@yahoo.com

Abstract

Seed macro and micro morphological characters of 68 taxa within the family Amaranthaceae were examined by using light and scanning electron microscopy. Generic and keys for species along with detailed seed description have been provided. Great variation was observed in seed shape and surface at generic and specific levels. The present study will provide an additional tool to strengthen the recognition of taxa within the family Amaranthaceae from Pakistan. This data is further analysed numerically by clustering to trace out the phylogenetic relationship of Amaranths taxa at various levels.

Keywords: Taxonomic assessment, Seed morphology, Amaranthaceae, Pakistan

Introduction

The families Amaranthaceae and Chenopodiaceae previously remained a matter of debate for many years such as, Rendle (1925) treated both the families separately under the former order Centrospermae, which was followed by many workers (Takhtajan, 1966; Townsend, 1974; Cronquist, 1981; Heywood, 1993; Freitag *et al.*, 2001). Recently, the members of the family Chenopodiaceae are merged within the family Amaranthaceae on the basis of *rchl* data, chloroplast structures and DNA restriction sites (APG III, 2009; Frank-De-Carvalho, *et al.*, 2010). According to APG III (2009) the family Amaranthaceae (*s.l.*) has been divided into 10 subfamilies. In Pakistan the family is represented by 7 subfamilies viz., Amaranthoideae, Betoideae, Chenopodoideae, Gomphrenoideae, Salsoloideae, Selicornioideae and Suaedoideae.

The genus *Amaranthus* was examined for its seed morphology by various workers (Jain and Hauptli, 1980; Irving *et al.*, 1984; Saunders & Becker, 1984; Khalid & Shad, 1990). Similarly, Soliman (2006) correlated the seed coat morphology with cytological data for the genus *Aerva* and concluded that granulation on seed surface of *Aerva* was proportional to the level of ploidy in this genus.

Moreover, Khalid & Shad, (1990) studied the genera *Achyranthus*, *Aerva* and *Celosia* and emphasized the importance of seed morphology in dispersal adaptability of seeds in these genera. Sage *et al.* (2007) examined the evolutionary lineage in species of the family Amaranthaceae by using Carbon isotopes. Malekloo *et al.* (2010) studied the seed coat structure, pollen grains and stem anatomy of 2 subspecies of *Chenopodium album* using scanning electron microscope and elevated the subspecies *Chenopodium album* ssp. *iranicum* as a separate species *Chenopodium iranicum*. While, Khalid & Shad (1990) examined the seed morphology of the genus *Chenopodium* in order to check its seed dispersal and adaptability as a weed. Yao *et al.* (2010) examined the germination capacity of heteromorphic seeds in *Chenopodium album* and its effects on salinity stress, where he concluded that brown seeds are more resistant to salt stress than black seeds.

The purpose of the present research is twofold. Firstly, is to provide detailed information on seed

morphology of Amaranths taxa. Secondly to use the seed characters as an additional tool for taxonomic delimitation and for tracing phylogenetic relationships among the Amaranths taxa at various levels from Pakistan.

Material and Methods

Mature seeds of 68 taxa of the family Amaranthaceae were collected from herbarium specimens and fresh material was also collected from field. Mostly 10 plants/species and 15-20 seeds/plant were studied (depending on availability of material; Appendix I). The seeds were examined for their morphological characters under stereomicroscope (SMZ800) and scanning electron microscope (JSM-6380A). For scanning electron microscopy dry seeds were directly mounted on metallic stub using double adhesive tape and coated with gold for a period of 6 minutes in sputtering chamber and observed under SEM. The terminology used is in accordance to Bergreen (1981) and Stearn (1983) with slight modifications. Presently different seed characters viz., seed aril, position, number, weight, size, shape, colour, surface and position of hilum have been observed.

Numerical analysis: Hierarchical clustering was performed by using Euclidean distance index and group strategy with the computer package (SPSS 18, 2012). Each of the species was treated as operational taxonomic unit (OTU). Characters were recorded in binary state and coded as presence or absence (1 or 0 respectively). The average values of the quantitative characters viz., seed number, weight, length and breadth were directly used.

Observations and Results

General characters of the family Amaranthaceae: Single seed per fruit, horizontal or vertical in position, 0.5-3.5x0.3-2.5 mm, arillate or non-arillate, compressed or not compressed, reniform, sub reniform, orbicular, sub orbicular, cuneate, transversely cuneate, oblong, oblanceolate, ovoid, obovate or elliptic pyriform, radially striate or non-striate, cream, light brown, dull brown, golden brown, reddish brown, dark brown, chest nut brown, greenish brown, black brown, or black, shiny or unshiny, surface smooth or

centrally smooth, reticulate, rugose, colliculate, punctulate, favulariate, lineate, striate areolate, falsifoveate, undulate, foveate, granulate, sclariiform, punctate, appressedly tuberculate, covered with plates, sculptured with ruminant lines, verrucate or lepidote. Hilum conspicuous or inconspicuous, basal, sub-basal, sub-central, lateral or marginal. (Tables 1-3; Figs. 1-9; Plts. 1-9)

It is represented by 7 subfamilies viz., Amaranthoideae, Gomphrenoideae, Betoideae, Chenopodioideae, Salicornioideae, Salsoloideae and Suaedioideae.

General seed characters of the subfamily Amaranthoideae: Seeds 0.5-3x0.5-2.5mm, vertical in

position, non-arillate, compressed or not compressed, reniform, sub-reniform, orbicular, obovate or oblong, dark brown, greenish brown, chest nut brown, dark brown-black or black, shiny, foveate and lineate, lepidote, colliculate, colliculate and punctulate, favulariate, reticulate, reticulate and punctulate, colliculate and favulariate, colliculate and reticulate, verrucate or centrally smooth and reticulate, punctulate or undulate at edges. Hilum conspicuous or inconspicuous, sub-central, basal, sub-basal or marginal.

Presently represented by 6 genera viz., *Aerva* Forssk, *Amaranthus* L., *Celosia* L., *Digera* Forssk, *Nothosaerva* Wight and *Pupalia* Juss.

Key to the genera

- 1+Seeds greenish brown, surface lepidote, hilum basal.....*Digera*
 -Seeds not as above.....2
 2+Seeds chest nut brown.....*Nothosaerva*
 -Seeds dark brown or black.....3
 3+Seeds cuneate.....*Pupalia*
 -Seeds reniform, sub-reniform, orbicular-sub orbicular or obovate.....4
 4+Seeds reniform or sub-reniform.....*Aerva*
 -Seeds orbicular, sub orbicular or obovate.....*Celosia, Amaranthus*

Aerva Forssk.

Seeds 0.0002-0.0003 gm, 0.5-1.5 x 0.5-1mm, reniform or sub-reniform, compressed or not compressed, dark brown or black and shiny, surface colliculate, colliculate and

punctulate or favulariate. Hilum conspicuous, sub central, sub-basal or marginal. (Plt. 1 A-F)

Presently represented by 3 taxa viz., *A. javanica* (Burm.f.) Juss ex. Schultes var *javanica*, *A. javanica* (Burm.f.) Juss. ex. schultes var. *bovei* Webb and *A. sanguinolenta* (L.) Blume

Key to the species

- 1+Seeds compressed, surface colliculate or punctulate.....*A. javanica*
 -Seeds not compressed, surface favulariate*A. sanguinolenta*

Amaranthus L.

Seeds 0.5-1.5x0.5-1mm, orbicular or obovate, compressed or not compressed, dark brown or black and shiny, colliculate and favulariate, colliculate and punctulate, reticulate and punctulate, colliculate and reticulate, verrucate, lepidote or centrally smooth and reticulate, punctulate or undulate at edges. Hilum

conspicuous, marginal, sub-central or sub-basal. (Plts. 1M-O, 2 A-O, 3 A-B).

Presently represented by 10 taxa viz., *Amaranthus caudatus* L., *A. graecizans* L., ssp. *graecizans*, *A. graecizans* L., ssp. *Silvestris* (Vill) Brenan, *A. graecizans* L., ssp. *thellungianus* (Nevski) Gusev, *A. hybridus* ssp. *cruentus* (L.) Thell., *A. hybridus* L., ssp. *hybridus*, *A. retroflexus* L., *A. spinosus* L., *A. tricolor* L. and *A. viridus* L.

Key to the species

- 1+Seeds with marginal hilum.....2
 -Seeds with sub-central or sub-basal hilum (except in *A. hybridus* ssp. *cruentus*).....4
 2+Seed surface verrucate or undulate.....3
 -Seed surface colliculate, reticulate or punctulate.....*A. graecizans*
 3+Seeds dark brown, surface verrucate.....*A. viridus*
 -Seeds black, surface undulate.....*A. tricolor*
 4+Seeds with sub-central hilum.....*A. retroflexus*
 -Seeds with sub-basal hilum (except in *A. hybridus* ssp. *cruentus*)...5
 5+Seed surface reticulate at edges.....*A. spinosus*
 -Seed surface colliculate and favulariate, colliculate and reticulate or reticulate and punctulate.....6
 6+Seed surface colliculate and favulariate*A. caudatus*
 -Seed surface colliculate and reticulate or reticulate and punctulate.....*A. hybridus*

Celosia L.

Seeds 1-1.5 x 1-1.5 mm, orbicular-sub orbicular, compressed, black and shiny, surface foveate and reticulate. Hilum conspicuous and marginal. (Plt. 4 J-K)

It is represented by a single species viz., *Celosia argentea* L.

Digera Forssk.

Seeds 2.5-3x2-2.5 mm, orbicular and beaked at both sides, not compressed, greenish brown and shiny, surface lepidote and covered with ribbon like appendages. Hilum inconspicuous and basal. (Plt. 6 L-M)

It is represented by a single species viz., *Digera muricata* (L.) Mart.

Nothosaerva Wight

Seeds 0.5-1x0.3-0.5 mm, orbicular-sub orbicular, not compressed, chest nut brown and shiny, surface faintly reticulate. Hilum inconspicuous and marginal. (Plt. 8 F-G)

It is represented by a single species i.e., *Nothosaerva brachiata* (L.) Wight

Pupalia Juss.

Seeds 1.5-2x1-1.5mm cuneate, not compressed, black and shiny, surface centrally depressed and faintly reticulate. Hilum inconspicuous and sub-basal. (Plt. 8 H-I)

It is represented by a single species viz., *P. lappacea* (L.) Juss.

General seed characters of the subfamily Gomphrenoideae

Seeds 1-1.5x0.5-1.5mm, vertical in position, non-arillate, compressed or not compressed, orbicular, sub-orbicular, obovate, transversely cuneate or oblong, dull brown or chest nut brown, surface reticulate and punctulate, undulate and rugose, colliculate, favulariate and rugose or colliculate. Hilum conspicuous or inconspicuous, lateral, sub-basal or sub-central.

Represented by 2 genera viz., *Alternanthera* Forssk. and *Gomphrena* L.

Key to the genera

- 1+Seeds compressed, orbicular, sub-orbicular or obovate.....*Alternanthera*
 -Seeds not compressed, transversely cuneate or oblong.....*Gomphrena*

Alternanthera Forssk.

Seeds 1-1.5 x 0.5-1mm, orbicular, sub-orbicular or obovate with retuse apex, compressed, brown and shiny, surface reticulate and punctulate, undulate and rugose,

colliculate, favulariate and rugose. Hilum conspicuous or inconspicuous and lateral. (Plt. 1G-L)

Presently represented by 3 species viz., *Alternanthera paronychioides* St. Hil., *A. pungens* Kunth and *A. sessilis* (L.) DC.

Key to the species

- 1+Seeds orbicular or sub-orbicular.....2
 -Seeds obovate.....*A. pungens*
 2+Seeds surface reticulate and punctulate.....*A. paronychioides*
 -Seed surface colliculate, favulariate and granulate.....*A. sessilis*

Gomphrena L.

Seeds 1-1.5x1-1.5mm, transversely cuneate or oblong not compressed, chest nut brown and shiny, surface

colliculate or reticulate and punctulate. Hilum inconspicuous or sub-central. (Plt. 7 A-D).

Presently represented by 2 species viz., *Gomphrena celosioides* Mart and *G. globosa* L.

Key to the species

- 1+Seeds oblong, surface reticulate and punctulate.....*G. globosa*
 -Seeds transversely cuneate, surface colliculate*G. celosioides*

General seed characters of the subfamily Betoideae

Seeds 1-3x1-2mm, horizontal in position, non-arillate, not compressed, reniform or obovate, black and

shiny, surface reticulate or rugose. Hilum conspicuous, sub-central or inconspicuous.

Represented by 2 genera viz., *Acroglochin* Schrad. Ex Schult. f. and *Beta* L.

Key to the genera

- 1+Seeds reniform, surface reticulate.....*Acroglochin*
 - Seeds obovate, surface rugose.....*Beta*

Acroglochin Schrad. ex Schult.f.

Seeds 1-1.5 x 1-1.5mm, reniform, black and shiny, surface faintly reticulate. Hilum conspicuous and sub-central. (Plt. 3 C-D)

Presently represented by a single species viz., *Acroglochin persicarioides* (Poir.) Moq.

Beta L.

Seeds 2.5-3x1.5-2mm, obovate, black and shiny, surface rugose. Hilum inconspicuous. (Plt. 4 F-G)

Presently represented by a single species viz., *Beta vulgaris* L. ssp. *maritima* (L.) Archangeli

General seed characters of the subfamily Chenopodioideae

Seeds 0.5-3.5x0.5-2.5mm, horizontal or vertical, arillate or non-arillate, compressed or not compressed,

radially striate or non-striate, obovate, elliptic pyriform, elliptic pyriform-obovate, orbicular, orbicular-obovate, orbicular-obovate to elliptic pyriform, oblanceolate, light brown, dark brown, dull brown, reddish brown, dark brown-black, black-brown or black, shiny, dull shiny or unshiny, surface, smooth or striate, rugose, punctate with ruminant lines, favulariate, favulariate and rugose, falsifoveate, lineate, areolate, rugose and tuberculate or ruminant. Hilum conspicuous or inconspicuous, marginal, basal, sub-basal or sub-central.

Represented by 6 genera viz., *Atriplex* L., *Axyris* L., *Ceratocarpus* L., *Chenopodium* L., *Kochia* Roth and *Spinacia* L.

Key to the genera

- 1+Seeds oblanceolate.....2
 -Seeds orbicular, obovate, elliptic pyriform, ovoid or oblong.....3
 2+Seed surface striate.....*Axyris*
 -Seed surface rugose..... *Ceratocarpus*
 3+Seeds with conspicuous hilum.....*Atriplex*, *Chenopodium*, *Spinacia*
 -Seeds with inconspicuous hilum.....*Kochia*

Atriplex L.

Seeds 1-2x0.5-2mm, vertical or horizontal in position, arillate or non-arillate, compressed or not compressed, radially non-striate, elliptic pyriform, orbicular, obovate, or elliptic pyriform-cuneate, light brown, dark brown, dull brown or black, shiny, surface lineate, rugose or striate-

rugose. Hilum conspicuous or inconspicuous, marginal basal or sub-basal. (Plts. 3 I-O, 4 A-C).

Presently represented by 5 species viz., *Atriplex dimorphostegia* Kar. And Kir., *A. lasiantha* Boiss., *A. leucoclada* Boiss., *A. schugnanica* Iljin and *A. stocksii* Boiss.

Key to the species

- 1+Hilum basal.....*A. schugnanica*
 -Hilum sub-basal or marginal.....2
 2+Seeds obovate and compressed.....*A. dimorphostegia*
 -Seeds elliptic pyriform or elliptic pyriform-cuneate.....3
 3+Seed surface lineate.....*A. lasiantha*
 -Seed surface rugose.....4
 4+Seeds vertical, hilum marginal.....*A. stocksii*
 -Seeds horizontal, hilum sub-basal..... *A. leucoclada*

Axyris L.

Seeds 1.5-2x 1-1.5 mm, vertical in position, arillate, not compressed, radially non-striate, oblanceolate, centrally black and brown towards the corners, shiny, surface striate. Hilum inconspicuous. (Plts. 4 D-E)

Presently represented by a single species viz., *Axyris hybrida* L.

Ceratocarpus L.

Seeds 3-3.5x1-1.5mm, vertical in position, non-arillate, not compressed, radially non-striate, oblanceolate, black and unshiny, surface rugose. Hilum inconspicuous. (Plt. 4 L-M).

It is represented by a single species viz., *Ceratocarpus arenarius* L.

Chenopodium L.

Seeds 0.5-2x0.5-2mm, horizontal or vertical in position, arillate, compressed or not compressed, radially striate or non-striate, orbicular, obovate, orbicular-obovate, oblong or orbicular-obovate-elliptic pyriform, reddish brown, dark brown, black-brown or black, shiny or unshiny, surface smooth or rugose, favulariate, favulariate and rugose, lineate, punctate, falsifoveate, areolate, rugose and tuberculate or sculptured with faintly ruminant lines. Hilum conspicuous or inconspicuous, marginal or rarely marginal-sub-central. (Plts. 4 N-O, 5 A-O, 6 A-K)

Presently represented by 17 species viz., *Chenopodium album* L., *C. ambrosioides*, *C. atripliciforme* Murr, *C. badachschanicum* Tzvelev, *C. ficifolium* Sm. ssp. *blomianum* (Aellen) Aellen, *C. foliosum* Asch., *C. glaucum* L., *C. karoii* (Murr) Aellen, *C. korshinskyi* (Litv.) Minkw., *C. litwinowii* (Paulsen) Uotila, *C. murale* L., *C. nepalense* Colla, *C. novopokrovskyanum* (Aellen) Uotila, *C. pamiricum* Iljin, *C. schraderianum* Schult., *C. strictum* Roth and *C. vulvaria* L.

Key to the species

1+Seeds horizontal in position,	2
-Seeds vertical in position.....	12
2+Seed surface smooth or faintly favulariate.....	3
-Seed surface not as above.....	7
3+Seeds radially striate.....	5
-Seeds radially non-striate.....	4
4+Seed surface smooth.....	<i>C. nepalense</i>
-Seed surface faintly favulariate	<i>C. pamiricum</i>
5+Seeds orbicular or orbicular-obovate.....	6
-Seeds obovate.....	<i>C. album</i>
6+Seeds black.....	<i>C. novopokrovskyanum</i>
-Seeds blackish brown.....	<i>C. vulvaria</i>
7+Seeds compressed	8
-Seeds not compressed.....	<i>C. strictum</i>
8+Seeds surface punctuate with appressedly ruminant lines.....	<i>C. ambrosioides</i>
-Seeds surface not as above.....	9
9+Seeds radially striate.....	10
-Seeds radially non-striate.....	<i>C. schraderianum</i>
10+Seed surface faintly lineate.....	<i>C. karoii</i>
-Seed surface other than lineate.....	11
11+Surface favulariate.....	<i>C. badachschanicum</i> , <i>C. murale</i>
-Surface falsi foveate.....	<i>C. ficifolium</i> ssp. <i>blomianum</i>
12+Seed radially striate.....	<i>C. glaucum</i>
-Seed radially non-striae.....	13
13+Seeds orbicular or obovate, hilum conspicuous.....	14
-Seeds oblong, hilum inconspicuous	<i>C. korshinskyi</i>
14+Seeds orbicular, reddish brown.....	<i>C. foliosum</i>
-Seeds obovate, dark brown-black	15
15+Surface areolate.....	<i>C. litwinowii</i>
-Surface sparsely punctuate.....	<i>C. atripliciforme</i>

Kochia Roth

Seeds 0.5-2.5x0.5-2mm, vertical in position, arillate or non-arillate, not compressed, radially non-striate, obovate, ovoid or elliptic pyriform, cream-light brown, dark brown or black and shiny, surface rugose,

appressedly tuberculate or covered with plates. Hilum inconspicuous. (Plts. 7 M-O, 8 A-E)

Presently represented by 4 species viz., *Kochia indica* Wight, *K. iranica* Litv. ex Bornm., *K. prostrata* (L.) Schrad, *K. scoparia* (L.) Schrad.

Key to the species

- 1+Seeds ovoid.....*K. iranica*
 -Seeds obovate or elliptic pyriform.....2
 2+Seed surface covered with elongated plate.....*K. indica*
 -Seed surface not covered with elongated plates.....3
 3+Seeds brown.....*K. scoparia*
 -Seeds black.....*K. prostrata*

***Spinacia* L.**

Seeds 2-2.5 x 2-2.5mm, vertical in position, arillate, not compressed, radially non-striate, elliptic pyriform-obovate, dark brown and shiny, surface rugose. Hilum conspicuous and marginal. (Plt. 9 A-B)

Presently represented by a single species viz., *Spinacia oleracea* L.

General seed characters of the subfamily Salicornioideae

Seeds 0.5-1x0.3-1mm, vertical in position, arillate or non-arillate, not compressed, radially non-striate, obovate, light brown or dull brown, unshiny, surface covered with plates and rugose or striate. Hilum inconspicuous.

Represented by 2 genera viz., *Arthrocnemum* Moq. and *Halostachys* C.A. Mey.

Key to the genera

- 1+Seed surface covered with plates.....*Arthrocnemum*
 -Seed surface striate.....*Halostachys*

***Arthrocnemum* Moq.**

Seeds 0.5-1x0.5-1mm, obovate, light brown and unshiny, surface covered with plates and rugose. Hilum inconspicuous. (Plt. 3 G-H)

Presently represented by a single species viz., *Arthrocnemum macrostachyum* (Moric.) C. Koch

***Halostachys* C.A. Mey.**

Seeds 0.5-1x0.3-0.6mm, obovate, dull brown and shiny, surface striate. Hilum inconspicuous. (Plt. 7 G-H)

It comprises single species viz., *Halostachys belangerana* (Moq.) Botsch.

General seed characters of the subfamily Salsoloideae

Seeds 0.5-3x0.5-2.5mm, horizontal or vertical in position, arillate, not compressed, radially non-striate, oblong, elliptic pyriform, orbicular, obovate, orbicular-obovate or ovoid, dull brown, golden brown-brown or black, shiny or unshiny, surface colliculate, lineate, reticulate and favulariate, rugose, favulariate and rugose, striate and rugose or rugose and lineate. Hilum inconspicuous or basal.

Represented by 5 genera viz., *Anabasis* L., *Girgensohnia* Bunge, *Halogeton* C.A. Mey., *Haloxylon* Bunge and *Salsola* L.

Key to the genera

- 1+Seeds oblong or elliptic pyriform.....2
 -Seeds orbicular-obovate or orbicular-ovoid.....3
 2+Seeds oblong, surface lineate.....*Girgensohnia*
 -Seeds elliptic pyriform, surface favulariate and rugose.....*Halogeton*
 3+Seed surface colliculate.....*Anabasis*
 -Seed surface reticulate and favulariate, striate-rugose, rugose and lineate, rugose or lineate.....4
 4+Seeds orbicular or ovoid, surface rugose or lineate.....*Haloxylon*
 -Seeds orbicular or obovate, surface reticulate and favulariate, striate-rugose or rugose and lineate.....*Salsola*

***Anabasis* L.**

Seeds 2-3x2-2.5mm, vertical in position, arillate, orbicular-obovate apically beaked, black and shiny, surface appressedly colliculate. Hilum inconspicuous. (Plt. 3 E-F)

Presently represented by a single species viz., *Anabasis haussknechtii* Bunge ex Boiss.

***Girgensohnia* Bunge**

Seeds 1.5-2x0.5-1mm, position not prominent, arillate, oblong, dull brown and shiny, surface faintly lineate. Hilum conspicuous and basal. (Plt. 6 N-O)

It comprises of single species viz., *Girgensohnia oppositiflora* (Pall.) Fenzl.

Halogeton C.A. Mey.

Seeds 1-1.51x0.5-1mm, vertical in position, arillate, elliptic pyriform, brown and unshiny, surface favulariate and rugose. Hilum inconspicuous. (Plt. 7 E-F).

Presently represented by a single species viz., *Halogeton glomeratus* (M.Bieb.) C.A.Mey.

Haloxylon Bunge

Seeds 1-2x1-1.5mm, horizontal or vertical in position, arillate, orbicular or ovoid, golden brown-brown or black and shiny, surface faintly lineate or rugose. Hilum inconspicuous. (Plt. 7 I-L).

Presently represented by 2 species viz., *Haloxylon griffithii* (Moq.) Boiss., *H. salicornicum* (Moq.) Bunge ex Boiss.

Key to the species

- 1+Seed surface rugose.....*H. griffithii*
 -Seed surface faintly lineate.....*H. salicornicum*

Salsola L.

Seeds 0.5-2x1-2 mm, horizontal in position, arillate, orbicular or obovate brown or black and shiny, surface

reticulate-favulariate, appressedly lineate and rugose or striate-rugose. Hilum inconspicuous. (Plt. 8 J-O).

Presently represented by 3 species viz., *Salsola drummondii* Ulbr., *S. nitraria* Pall. and *S. tragus* L.

Key to the species

- 1+Seeds orbicular.....2
 -Seeds obovate.....*S. tragus*
 2+Seed surface striate-rugose.....*S. nitraria*
 -Seed surface reticulate-favulariate.....*S. drummondii*

General seed characters of the subfamily Suaedioideae

Seeds 0.5-2x0.4-2mm, horizontal or vertical in position, arillate or non-arillate, not compressed, radially non-striate, reniform or sub reniform, black and shiny, surface colliculate, reticulate, sclariform or centrally

smooth and lineate or reticulate at margins. Hilum conspicuous, marginal or sub-central.

Represented by 2 genera viz., *Bienertia* Bunge ex Boiss. and *Suaeda* Forssk.

Key to the genera

- 1+Seed surface colliculate.....*Bienertia*
 -Seed surface, reticulate, sclariform or lineate.....*Suaeda*

Bienertia Bunge ex Boiss.

Seeds 1.5-2x1.5-2mm, horizontal in position, arillate, reniform, black and shiny, surface colliculate. Hilum conspicuous, sub-central. (Plt. 4 H-I).

It is represented by a single species viz., *Bienertia cycloptera* Bunge ex Boiss.

sub reniform, black and shiny, surface reticulate, sclariform or centrally smooth and lineate or reticulate at margins. Hilum conspicuous, marginal or sub-central. (Plt. 9 C-H).

Presently represented by 4 species viz., *Suaeda aegyptiaca* (Hasselq.) Zohary, *S. arcuata* Bunge, *S. fruticosa* Forssk. Ex J.F. Gmelin and *S. monoica* Forssk. ex J.F. Gmelin

Suaeda Forssk.

Seeds 0.5-1.5 x 0.4-2 mm, vertical or rarely horizontal in position, arillate or non-arillate, reniform or

Key to the species

- 1+Hilum sub-central2
 -Hilum marginal*S. arcuata*
 2+Seed surface reticulate*S. monoica*,*S. aegyptiaca*
 -Seed surface smooth centrally and lineate towards the base*S. fruticosa*

Table 1. Seed morphological characters of the family Amaranthaceae.

Name of taxa	Quantitative characters				Qualitative characters				Hilum position and visibility	
	Seed No.	Size (mm)		Arl	Seed position	Colour	Shape	Radial striae		Surface
		Length	Breadth							
<i>Aerva javanica</i> var. <i>bovei</i>	1	(0.5)(0.9)(1) (±0.04)	(0.5)(0.9)(1) (±0.04)	Absent	Vertical	Dark brown, shiny	Reniform, compressed	Absent	Appressedly colliculate and punctulate	Sub-central conspicuous
<i>A.javanica</i> var. <i>javanica</i>	1	(0.5)(0.9)(1) (±0.04)	(0.5)(0.7)(1) (±0.04)	Absent	Vertical	Dark brown, shiny	Sub-reniform, compressed	Absent	Colliculate	Marginal conspicuous
<i>A.sanguinolenta</i>	1	(1)(1.2)(1.5) (±0.10)	(0.5)(0.9)(1) (±0.04)	Absent	Vertical	Black, shiny	Reniform, not compressed	Absent	Favulariate	Sub-basal conspicuous
<i>Acroglochin persicarioides</i>	1	(1)(1.2)(1.5) (±0.10)	(1)(1.2)(1.5) (±0.10)	Absent	Horizontal	Black and shiny	Reniform and not compressed	Absent	Faintly reticulate	Sub-central conspicuous
<i>Alternanthera paronychioides</i>	1	(1)(1.2)(1.5) (±0.10)	(0.5)(0.9)(1) (±0.04)	Absent	Vertical	Dull Brown, shiny	Orbicular-sub orbicular, compressed	Absent	Reticulate and punctulate	Lateral conspicuous
<i>A.pungens</i>	1	(1)(1.2)(1.5) (±0.10)	(0.5)(0.7)(1) (±0.10)	Absent	Vertical	Dull Brown, shiny	Obovate with retuse apex, not compressed	Absent	Undulate and rugose	Lateral conspicuous
<i>A.sessilis</i>	1	(1)(1.2)(1.5) (±0.10)	(0.5)(0.9)(1) (±0.04)	Absent	Vertical	Dull Brown, shiny	Orbicular, beaked at base, compressed	Absent	Appressedly colliculate, favulariate and granulate	Lateral conspicuous
<i>Amaranthus caudatus</i>	1	(1)(1.2)(1.5) (±0.10)	(0.5)(0.9)(1) (±0.024)	Absent	Vertical	Black, shiny	Obovate, compressed	Absent	Colliculate and faintly favulariate	Sub-basal conspicuous
<i>A. graecizans</i> ssp. <i>gracizans</i>	1	(1)(1.2)(1.5) (±0.10)	(0.5)(0.9)(1) (±0.024)	Absent	Vertical	Black, shiny	Orbicular, compressed	Absent	Colliculate and punctulate	Marginal conspicuous
<i>A. graecizans</i> ssp. <i>sibvestris</i>	1	(1)(1.2)(1.5) (±0.10)	(0.5)(0.8)(1) (±0.06)	Absent	Vertical	Black, shiny	Orbicular, compressed	Absent	Punctulate at edges	Marginal conspicuous
<i>A. graecizans</i> ssp. <i>thellungianus</i>	1	(1)(1.2)(1.5) (±0.10)	(0.5)(0.9)(1) (±0.024)	Absent	Vertical	Black, shiny	Obovate, compressed	Absent	Reticulate and punctulate	Marginal conspicuous
<i>A. hybridus</i> ssp. <i>cruentus</i>	1	(1)(1.3)(1.5) (±0.10)	(0.5)(0.8)(1) (±0.024)	Absent	Vertical	Black, shiny	Orbicular, compressed	Absent	Faintly Reticulate and punctulate	Marginal conspicuous
<i>A. hybridus</i> ssp. <i>hybridus</i>	1	(1)(1.3)(1.5) (±0.06)	(0.5)(0.8)(1) (±0.02)	Absent	Vertical	Black, shiny	Obovate, compressed	Absent	Colliculate and reticulate	Sub-basal conspicuous
<i>A. retroflexus</i>	1	(1)(1.2)(1.5) (±0.10)	(0.5)(0.9)(1) (±0.024)	Absent	Vertical	Black, shiny	Obovate, compressed	Absent	Faintly reticulate at edges	Sub-central conspicuous
<i>A. spinosus</i>	1	(0.5)(0.9)(1) (±0.04)	(0.5)(0.7)(1) (±0.04)	Absent	Vertical	Black, shiny	Obovate, compressed	Absent	Faintly reticulate at edges	Sub-basal conspicuous
<i>A. tricolor</i>	1	(1)(1.2)(1.5) (±0.10)	(0.5)(0.9)(1) (±0.024)	Absent	Vertical	Black, shiny	Orbicular, compressed	Absent	Undulate at edges	Marginal conspicuous
<i>A. viridis</i>	1	(0.5)(0.9)(1) (±0.024)	(0.5)(0.9)(1) (±0.024)	Absent	Vertical	Dark brown, shiny	Orbicular, compressed	Absent	verrucate	Marginal conspicuous
<i>Anabasis haussknechtii</i>	1	(2)(2.5)(3) (±0.18)	(2)(2.2)(2.5) (±0.08)	Present	Vertical	Black and shiny	Broadly orbicular- obovate and beaked terminally	Absent	Appressedly colliculate	Inconspicuous
<i>Arthrocnemum macrostachyum</i>	1	(0.5)(0.9)(1) (±0.034)	(0.5)(0.8)(1) (±0.05)	Absent	Vertical	Light brown and unshiny	Obovate and not Compressed	Absent	Covered with plates and rugose	Inconspicuous
<i>Atriplex dimorphostegia</i>	1	(1)(1.5)(2) (±0.05)	(0.5)(1.8)(2) (±0.25)	Present	Vertical	Light brown and shiny	Obovate and Compressed	Absent	Striate rugose	Marginal conspicuous
<i>A. lasiantha</i>	1	(1)(1.4)(1.5) (±0.06)	(1)(1.2)(1.5) (±0.08)	Absent	Vertical	Black and shiny	Elliptic pyriform not Compressed	Absent	Lineate	Marginal conspicuous
<i>A. leucoclada</i>	1	(1.5)(1.9)(2) (±0.34)	(1)(1.4)(1.5) (±0.08)	Absent	Horizontal	Dark brown and shiny	Elliptic pyriform- Cuneate not Compressed	Absent	Faintly rugose	Sub-basal conspicuous
<i>A.schugnanica</i>	1	(1)(1.4)(1.5) (±0.06)	(1)(1.3)(1.5) (±0.12)	Present	Vertical	Dull Brown and shiny	Orbicular not Compressed	Absent	Rugose	Basal conspicuous

Table 1. . (Cont'd.)..

Name of taxa	Quantitative characters			Qualitative characters						
	Seed No	Size (mm)		Seed position	Colour	Shape	Radial striae	Surface	Hilum position and visibility	
		Length	Breadth							
<i>A. stockii</i>	1	(1.5)(1.9)(2)	(1.5)(1.8)(2)	Absent	Dull Brown and shiny	Elliptic pyriform and compressed	Absent	Rugose	Marginal conspicuous	
<i>Axyris hybrida</i>	1	(1.5)(1.6)(2)	(1)(1.1)(1.5)	Present	Centrally black and brown at corners	Oblanceolate not compressed	Absent	Striate	Inconspicuous	
<i>Beta vulgaris</i> ssp. <i>maritima</i>	1	(2.5)(2.7)(3)	(1.5)(1.9)(2)	Absent	Black and shiny	Obovate and not compressed	Absent	Faintly rugose	Inconspicuous	
<i>Bieneria cycloptera</i>	1	(1.5)(1.9)(2)	(1.5)(1.9)(2)	Present	Black and shiny	Broadly reniform not compressed	Absent	Colliculate	Sub-central conspicuous	
<i>Celosia argentea</i>	1	(1)(1.2)(1.5)	(1)(1.4)(1.5)	Absent	Black, shiny	Orbicular-sub orbicular, compressed	Absent	Faintly foveate and faintly reticulate	Marginal conspicuous	
<i>Ceratocarpus arenarius</i>	1	(3)(3.2)(3.5)	(1)(1.2)(1.5)	Absent	Black and unshiny	Oblanceolate and not compressed	Absent	Rugose	Inconspicuous	
<i>Chenopodium album</i>	1	(1)(1.2)(1.5)	(1)(1.1)(1.5)	Present	Black and shiny	Obovate and compressed	Present	Smooth	Marginal Conspicuous	
<i>C. ambrosioides</i>	1	(0.5)(0.9)(1)	(0.5)(0.9)(1)	Present	Reddish brown and shiny	Orbicular, obovate and compressed	Present	Punctate and sculptured with ruminate lines	Marginal conspicuous	
<i>C. atripliciforme</i>	1	(1)(1.1)(1.5)	(1)(1.1)(1.5)	Present	Black and shiny	Obovate and compressed	Absent	Almost smooth but sparsely punctate	Marginal conspicuous	
<i>C. badachshanicum</i>	1	(1.5)(1.9)(2)	(1.5)(1.9)(2)	Present	Black and unshiny	Orbicular and compressed	Present	Favulariate and rugose	Marginal conspicuous	
<i>C. ficifolium</i> ssp. <i>blomianum</i>	1	(0.5)(0.9)(1)	(0.5)(0.9)(1)	Present	Black and shiny	Orbicular and compressed	Present	Falsifoveate	Marginal conspicuous	
<i>C. foliosum</i>	1	(1)(1.1)(1.5)	(1)(1.2)(1.5)	Present	Reddish brown and unshiny	Orbicular and compressed	Absent	Rugose	Marginal conspicuous	
<i>C. glaucum</i>	1	(0.5)(0.9)(1)	(0.5)(0.9)(1)	Present	Reddish brown and shiny	Orbicular and compressed	Present	Falsifoveate	Marginal conspicuous	
<i>C. karoi</i>	1	(0.5)(0.9)(1)	(1)(1.1)(1.5)	Present	Black and shiny	Orbicular-obovate and compressed	Present	Faintly lineate	Marginal conspicuous	
<i>C. korshinskyi</i>	1	(0.5)(0.9)(1)	(0.5)(0.7)(1)	Present	Dark brown and shiny	Oblong and compressed	Absent	Falsifoveate	Inconspicuous	
<i>C. litwinowii</i>	1	(1)(1.4)(1.5)	(0.5)(0.9)(1)	Present	Dark brown and shiny	Obovate and compressed	Absent	Areolate	Marginal conspicuous	
<i>C. murale</i>	1	(0.5)(0.9)(1)	(1)(1.4)(1.5)	Present	Black and dull shiny	Orbicular and compressed	Present	Favulariate	Marginal conspicuous	
<i>C. nepalense</i>	1	(0.5)(0.8)(1)	(0.5)(0.9)(1)	Present	Reddish brown and shiny	Orbicular and compressed	Absent	Smooth	Marginal conspicuous	
<i>C. novopokrovskyanum</i>	1	(0.5)(0.9)(1)	(1)(1.1)(1.5)	Present	Black and shiny	Orbicular and compressed	Present	Smooth	Marginal conspicuous	
<i>C. pamiricum</i>	1	(0.5)(0.9)(1)	(1)(1.1)(1.5)	Present	Black and shiny	Orbicular-obovate-elliptic pyriform, compressed or not	Absent	Faintly favulariate	Marginal-sub-central conspicuous	
<i>C. schraderianum</i>	1	(0.5)(0.9)(1)	(0.5)(0.9)(1)	Present	Dark brown-black and unshiny	Orbicular and compressed	Absent	Rugose and appressedly tuberculate	Marginal conspicuous	
<i>C. strictum</i>	1	(1)(1.1)(1.5)	(0.5)(0.9)(1)	Present	Black and shiny	Orbicular and not compressed	Present	Sculptured with ruminate lines	Marginal conspicuous	
<i>C. vulvaria</i>	1	(0.5)(0.9)(1)	(1)(1.1)(1.5)	Present	Dark brown and shiny	Orbicular and compressed	Present	Smooth	Marginal conspicuous	

Table 1. . (Cont'd.)..

Name of taxa	Quantitative characters			Qualitative characters						
	Seed No	Size (mm)		Seed position	Colour	Shape	Radial striae	Surface	Hilum position and visibility	
		Length	Breadth							
<i>Digera muricata</i>	1	(2.5)(2.7)(3)	(2)(2.4)(2.5)	Absent	Vertical	Greenish brown, shiny	Orbicular, beaked at both sides, not compressed	Absent	lepidote	Basal conspicuous
<i>Girgensohnia oppositiflora</i>	1	(1.5)(1.9)(2)	(0.5)(0.9)(1)	Present	Not Prominent	Dull Brown and shiny	Oblong not Compressed	Absent	Faintly lineate	Sub-central conspicuous
<i>Gomphrena celosoides</i>	1	(1)(1.2)(1.5)	(1)(1.2)(1.5)	Absent	Vertical	Chest nut brown, shiny	Transversely cuneate, not compressed	Absent	Colliculate	Sub-central conspicuous
<i>G. globosa</i>	1	1-1.5	1-1.5 (±0.10)	Absent	Vertical	Chest nut brown, shiny	Oblong, beaked at base, not compressed	Absent	Appressedly reticulate and punctulate	Sub-basal conspicuous
<i>Halogeton glomeratus</i>	1	(1)(1.4)(1.5)	(0.5)(0.9)(1)	Present	Vertical	Dull Brown and unshiny	Elliptic pyriform not Compressed	Absent	Favulariate and rugose	Inconspicuous
<i>Holostachys belangerana</i>	1	(0.5)(0.9)(1)	(0.3)(0.5)(0.6)	Absent	Vertical	Dull Brown and shiny	Obovate and not compressed	Absent	Striate	Inconspicuous
<i>Haloxylon giffithii</i>	1	(1.5)(1.9)(2)	(1)(1.3)(1.5)	Present	Vertical	Black and shiny	orbicular-ovoid not Compressed	Absent	Rugose	Inconspicuous
<i>H. salicornicum</i>	1	(1)(1.3)(1.5)	(1)(1.3)(1.5)	Present	Horizontal	Golden brown-dull brown and shiny	Orbicular not Compressed	Absent	Faintly lineate	Inconspicuous
<i>Kochia indica</i>	1	(0.5)(0.9)(1)	(0.5)(0.6)(0.7)	Absent	Vertical	Black and shiny	Elliptic pyriform obovate and not compressed	Present	Covered with plates	Inconspicuous
<i>K. iranica</i>	1	(2)(2.2)(2.5)	(0.5)(0.9)(1)	Absent	Vertical	Cream-light brown	Ovoid and not compressed	Absent	Appressedly tuberculate	Inconspicuous
<i>K. prostrata</i>	1	(1.5)(1.7)(2)	(1.5)(1.8)(2)	Absent	Vertical	Black and shiny	Obovate and not Compressed	Absent	Faintly rugose	Inconspicuous
<i>K. scoparia</i>	1	(1)(1.3)(1.5)	(0.5)(0.9)(1)	Present	Vertical	Dark brown and shiny	Obovate and compressed	Absent	Rugose	Marginal conspicuous
<i>Nothosaerva brachiata</i>	1	(0.5)(0.8)(1)	(0.3)(0.4)(0.5)	Absent	Vertical	Chest nut brown, shiny	Orbicular-sub-orbicular, not compressed	Absent	Faintly reticulate	Marginal conspicuous
<i>Pupalia lappacea</i>	1	(1.5)(1.9)(2)	(1)(1.4)(1.5)	Absent	Vertical	Black, shiny	Cuneate, not compressed	Absent	Faintly reticulate	Sub-basal conspicuous
<i>Salsola drummondii</i>	1	(1.5)(1.8)(2)	(1.5)(1.7)(2)	Present	Horizontal	Dull Brown-black and shiny	Orbicular not Compressed	Absent	Reticulate favulariate	Inconspicuous
<i>S. nitriaria</i>	1	(0.5)(0.9)(1)	(1)(1.1)(1.5)	Present	Horizontal	Dull Brown and shiny	Orbicular not Compressed	Absent	Striate-rugose	Inconspicuous
<i>S. tragus</i>	1	(1)(1.5)(2)	(1)(1.4)(2)	Present	Horizontal	Dull Brown and shiny	Obovate not Compressed	Absent	Appressedly lineate	Inconspicuous
<i>Spinacia oleracea</i>	1	(2)(2.2)(2.5)	(2)(2.1)(2.5)	Present	Vertical	Dark brown and shiny	Elliptic pyriform -obovate not Compressed	Absent	Rugose	Marginal Conspicuous
<i>Suaeda aegyptiaca</i>	1	(1)(1.2)(1.5)	(1.5)(1.7)(2)	Present	Vertical	Black and shiny	Reniform not Compressed	Absent	Reticulate	Sub-central Conspicuous
<i>S. arcuata</i>	1	(0.5)(0.9)(1)	(0.4)(0.45)(0.5)	Absent	Vertical	Black and shiny	Sub-reniform not Compressed	Absent	Scleriform	Marginal Conspicuous
<i>S. fruticosa</i>	1	(0.5)(0.9)(1)	(0.4)(0.45)(0.5)	Absent	Vertical or horizontal	Black and shiny	Reniform not Compressed	Absent	Smooth but lineate at margins	Sub-central Conspicuous
<i>S. monoica</i>	1	(1)(1.4)(1.5)	(0.5)(0.9)(1)	Present	Vertical	Black and shiny	Reniform not Compressed	Absent	Smooth- faintly reticulate	Sub-central

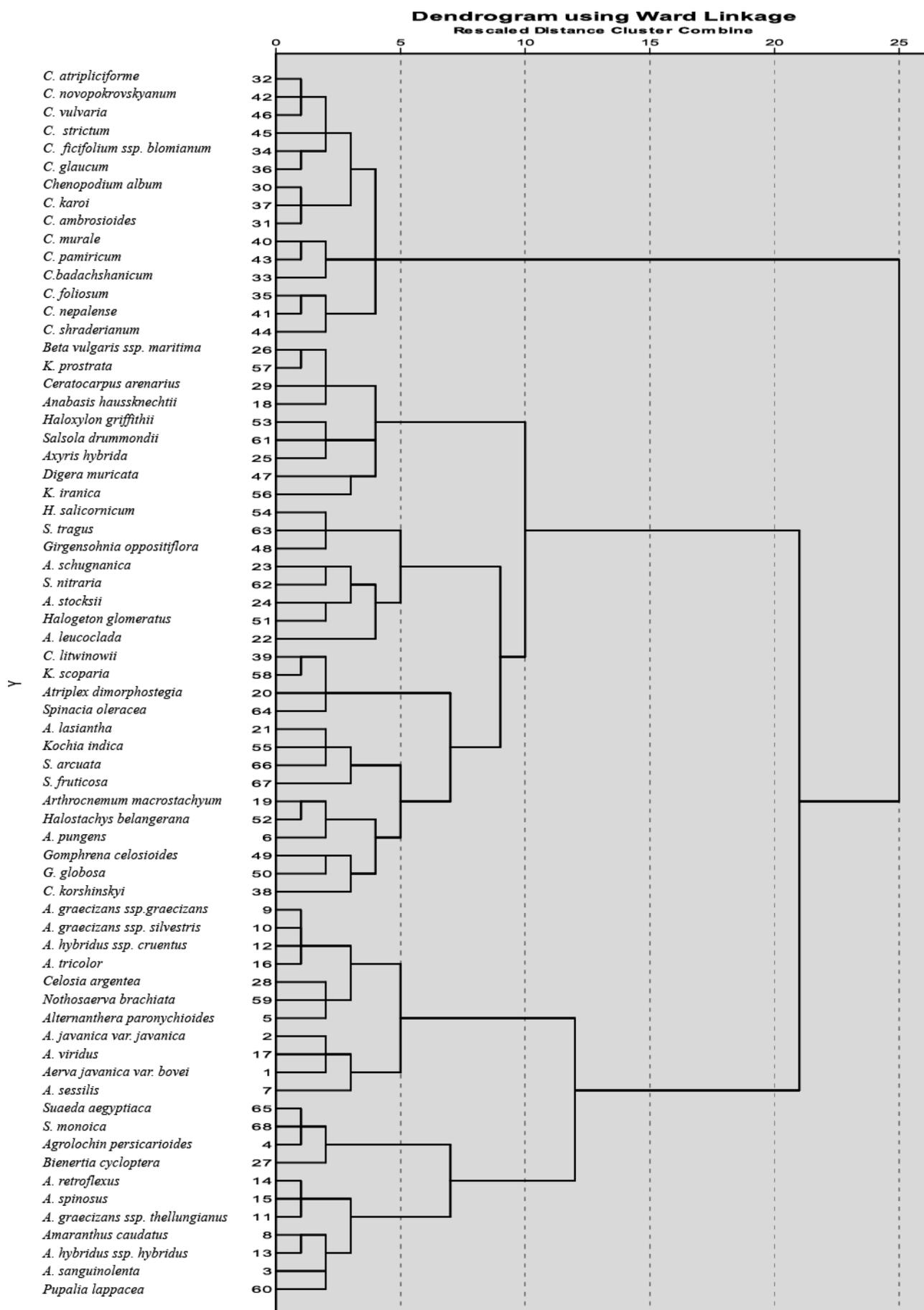


Fig.1. Dendrogram showing the relationships within the taxa of the family Amaranthaceae.

Table 2. List of characters, scored for cluster analysis

No.	Character description
1	Seed number
2	Length (mm)
3	Breadth (mm)
4	Presence or absence of aril: Absent (0), Present (1)
5	Compressed or non-compressed: Non-compressed (0), Compressed (1)
6	Seed position: Not prominent (0), Horizontal (1), Vertical (2), Horizontal-vertical (3)
Shape	
7	Reniform: Absent (0), Present (1)
8	Sub-reniform: Absent (0), Present (1)
9	Orbicular: Absent (0), Present (1)
10	Sub-orbicular: Absent (0), Present (1)
11	Obovate: Absent (0), Present (1)
12	Cuneate: Absent (0), Present (1)
13	Transversely cuneate: Absent (0), Present (1)
14	Oblong: Absent (0), Present (1)
15	Elliptic pyriform: Absent (0), Present (1)
16	Oblanceolate: Absent (0), Present (1)
17	Ovoid: Absent (0), Present (1)
Colour	
18	Cream: Absent (0), Present (1)
19	Light brown: Absent (0), Present (1)
20	Dull Brown: Absent (0), Present (1)
21	Dark brown: Absent (0), Present (1)
22	Greenish brown: Absent (0), Present (1)
23	Chestnut brown: Absent (0), Present (1)
24	Reddish brown: Absent (0), Present (1)
25	Golden brown: Absent (0), Present (1)
26	Black: Absent (0), Present (1)
Surface	
27	Smooth: Absent (0), Present (1)
28	Lineate: Absent (0), Present (1)
29	Striate: Absent (0), Present (1)
30	Areolate: Absent (0), Present (1)
31	Rugose: Absent (0), Present (1)
32	Favulariate: Absent (0), Present (1)
33	Falsifoveate: Absent (0), Present (1)
34	Reticulate: Absent (0), Present (1)
35	Scalariform: Absent (0), Present (1)
36	Punctate: Absent (0), Present (1)
37	Tuberculate: Absent (0), Present (1)
38	Colliculate: Absent (0), Present (1)
39	Verrucate: Absent (0), Present (1)
40	Puncticulate: Absent (0), Present (1)
41	Undulate: Absent (0), Present (1)
42	Granulate: Absent (0), Present (1)
43	Foveate: Absent (0), Present (1)
44	Lepidote: Absent (0), Present (1)
45	Hilum visibility: Inconspicuous (0), Conspicuous (1)
46	Marginal hilum: Absent (0), Present (1)
47	Lateral hilum: Absent (0), Present (1)
48	Sub-central hilum: Absent (0), Present (1)
49	Sub-basal hilum: Absent (0), Present (1)
50	Basal hilum: Absent (0), Present (1)
51	Presence of radial striae: Absent (0), Present (1)

Discussion

Dendrogram (Fig. 1) of the family Amaranthaceae clearly shows the establishment of 3 broad groups. The first group includes mostly Amaranths genera (former Amaranthaceae) and represented by 4 subfamilies viz., Amaranthoideae, Betoideae, Gomphrenoideae and Suaedoideae. This group includes 22 taxa with orbicular, sub orbicular, reniform, sub reniform, rarely obovate or cuneate seeds. This group consist of those genera which are usually characterized by non-halophytic members with scaly bracts (Townsend, 1974). The above group is further separated into 2 subgroups. The first subgroup is represented by 11 taxa viz., *Acroglochin persicarioides*, *Aerva sanguinolenta*, *Amaranthus caudatus*, *A. graecizans* ssp. *thellungianus*, *A. hybridus* ssp. *hybridus*, *A. retroflexus*, *A. spinosus*, *Bienertia cycloptera*, *Pupalia lappacea*, *Suaeda aegyptiaca* and *S. monoica*. This group may be distinguished due to the presence of seeds having sub-basal, sub-central and rarely marginal hilum. Within this group 4 taxa viz., *Aerva sanguinolenta*, *Amaranthus caudatus*, *A. hybridus* ssp. *hybridus* and *Pupalia lappacea* grouped in a common cluster. Among them *Pupalia lappacea* and *Aerva sanguinolenta* show close affinity with each other by having brown seeds with sub-basal hilum. Similarly *Amaranthus caudatus* and *A. hybridus* ssp. *hybridus* remain close by sharing colliculate seeds. While *Amaranthus graecizans* ssp. *thellungianus*, *A. retroflexus* and *A. spinosus* fall within a same cluster as all having obovate and black seeds. Among them *A. retroflexus* and *A. spinosus* are more closely related by having reticulate seeds. The last cluster of the first subgroup includes 4 taxa viz., *Acroglochin persicarioides*, *Bienertia cycloptera*, *Suaeda aegyptiaca* and *S. monoica* and this group is characterized by the presence of reniform seeds. Among them *Bienertia cycloptera* shows colliculate seeds surface, while rest of the taxa have reticulate seed surface. Similarly, the second subgroup includes 11 taxa viz., *Aerva javanica* var. *javanica*, *A. javanica* var. *bovei*, *Alternanthera paronychioides*, *A. sessilis*, *Amaranthus graecizans* ssp. *graecizans*, *A. graecizans* ssp. *silvestris*, *A. hybridus* ssp. *cruentus*, *A. tricolor*, *A. viridus*, *Celosia argentea* and *Nothosaerva brachiata* and this group is considered as purely Amaranths group as all the taxa were treated under former Amaranthaceae (*s.str.*). This subgroup is characterized by the presence of seeds usually with marginal, lateral or sub-central hilum. Within this group the 3 taxa viz., *Alternanthera paronychioides*, *Celosia argentea* and *Nothosaerva brachiata* show close affinity with each other on the basis of orbicular-sub orbicular seeds but remain distinct with each other on the basis of different seed colour and hilum. While, *Amaranthus graecizans* ssp. *graecizans*, *A. graecizans* ssp. *silvestris*, *A. hybridus* ssp. *cruentus*, *A. tricolor* fall within a same cluster as all the taxa share black seeds but remain distinct due to different seed surfaces. The last cluster of this subgroup includes 4 taxa viz., *Aerva javanica* var. *javanica*, *A. javanica* var. *bovei*, *Alternanthera sessilis* and *Amaranthus viridus* and usually characterized by having dark brown seeds. Among them *Alternanthera sessilis* remains distinguished by having seeds with lateral hilum. While *Aerva javanica* and *Amaranthus viridus* have seeds with marginal or sub-central hilum. Both the above taxa could be distinguished with each other as *Aerva*

javanica have colliculate seeds, whereas *Amaranthus viridus* is characterized with verrucate seeds.

The second main group is characterized by the presence of mostly halophytes and rarely glycophytes (Townsend, 1974; Freitag *et al.*, 2001) along with obovate, orbicular, elliptic pyriform, oblong, oblanceolate, ovoid, cuneate, transversely cuneate, reniform or sub-reniform seeds. This group represents 31 taxa out of which 4 are Amaranths (Former Amaranthaceae) and 27 are Chenopods (Former Chenopodiaceae). The second group is the broadest group and further separated into 3 subgroups. The first subgroup includes 14 taxa viz., *Gomphrena celosioides*, *G.globosa*, *Arthrocnemum macrostachyum*, *Alternanthera pungens*, *Atriplex dimorphostegia*, *A. lasiantha*, *Holostachys belangerana*, *Kochia indica*, *K.scoparia*, *Spinacia oleracea*, *Suaeda arcuata*, *S.fruticosa*, *Chenopodium korshinskyi* and *C.litwinowii*. The placement of 3 taxa viz., *Gomphrena celosioides*, *G.globosa* and *Chenopodium korshinskyi* is supported by oblong-transversely cuneate seeds, but having distinctive seed colours and surface patterns. Furthermore, *Arthrocnemum macrostachyum*, *Alternanthera pungens* and *Holostachys belangerana* form a common cluster by having obovate seeds. Among them *Arthrocnemum macrostachyum* and *Holostachys belangerana* are more closely related by having seeds with inconspicuous hilum. Whereas, *Alternanthera pungens* is characterized by having seeds with lateral hilum. Moreover, the 4 taxa viz., *Atriplex lasiantha*, *Kochia indica*, *Suaeda arcuata* and *S. fruticosa* are grouped within a next cluster by having black seeds. Among them *S.fruticosa* makes its position distinct due to reniform seeds with sub-central hilum, while rest of the taxa have elliptic pyriform or sub-reniform seeds and can be further distinguished on the basis of different seed surfaces. Likewise, the placement of *Atriplex dimorphostegia*, *K.scoparia*, *Spinacia oleracea* and *Chenopodium litwinowii* is strongly supported by the presence of obovate or elliptic pyriform-obovate seeds. Among them *Atriplex dimorphostegia* and *Spinacia oleracea* showing more affinity with each other on the basis of rugose seeds with different colours. The remaining 8 taxa viz., *Atriplex leuoclada*, *A.schugnanica*, *A.stocksii*, *Girgensohnia oppositiflora*, *Halogeton glomeratus*, *Haloxylon salicornicum*, *Salsola nitraria* and *S.tragus* include in second subgroup which may be distinguished by the presence of succulent chenopods (Freitag *et al.*, 2001) with rugose, favulariate, striate, or lineate seed surface. Among them the 3 taxa viz., *Girgensohnia oppositiflora*, *Halogeton salicornicum* and *Salsola tragus* fall within a same cluster by having lineate or rugose-lineate surface. While, *Atriplex leuoclada*, *A.stocksii* and *Halogeton glomeratus* show close affinity by having elliptic pyriform seeds. *Atriplex leuoclada* can be further separated by having dark brown seeds, while black seeds are observed in *A.stocksii* and *Halogeton glomeratus*. The taxa *Atriplex schugnanica* and *Salsola nitraria* show strong affinity as both share orbicular seeds.

Moreover, the third subgroup is delimited by having rugose, striate, reticulate-favulariate, tuberculate or lepidote seeds. This group comprises 9 taxa viz., *Anabasis haussknechtii*, *Axyris hybrida*, *Beta vulgaris*, *Ceratocarpus arenarius*, *Digera muricata*, *Haloxylon griffithii*, *Kochia iranica*, *K.prostrata* and *Salsola drummondii*. Within the first cluster *Haloxylon griffithii*, *Salsola drummondii* and *Axyris hybrida* show close affinity with each other by

sharing black seeds. While rest of the taxa of this cluster viz., *Kochia iranica* and *Digera muricata* are characterized with cream, light brown or greenish brown seeds. *Digera muricata* and *Salsola drummondii* arise from a common point as both share orbicular seeds but remains distinct due to reticulate-foveate seeds in *Salsola drummondii*, while *Digera muricata* have lepidote seeds. Within the next cluster *Anabasis haussknechtii* remains distinct and does not show affinity with other taxa by having colliculate seeds. Whereas, rest of the 2 taxa viz., *Beta vulgaris* and *Ceratocarpus arenarius* remain close as both share rugose seeds. However, *Kochia prostrata* appears to be more close to *Beta vulgaris* by sharing similar seed shape and surface.

The third main group shows terminal position in the dendrogram and considered as advance group. The advancement of this group is supported by having smaller seeds. This group is delimited by having orbicular, obovate or elliptic seeds. It includes 14 species of the genus *Chenopodium* viz., *C.album*, *C. ambrosioides*, *C. badachshanicum*, *C.ficifolium* ssp. *blomianum*, *C. foliosum*, *C. glaucum*, *C. karoii*, *C. murale*, *C.nepalensis*, *C.novopokrovskyana*, *C. pamiricum*, *C. schraderianum*, *C. strictum* and *C. vulvaria*. This group is further separated in 3 subgroup. The first subgroup comprises 3 taxa *C. schraderianum*, *C. nepalense* and *C. foliosum* and characterized with rugose or rugose and tuberculate seeds. Among them *C. schraderianum* and *C. foliosum* arise from the common point by sharing common seed surface. While *C. nepalense* shows more affinity with *C. foliosum* as both share same seed colour but remain distinguished by having rugose seeds in *C.foliosum*, whereas *C.nepalense* shows psilate seeds. Likewise in the second subgroup *C.badachshanicum* and *C.murale* have common point of origin due to the presence of orbicular seeds. The last cluster and third subgroup of dendrogram is differentiated on the basis of smooth, lineate, falsifoveate, ruminant or punctuate-ruminant seeds. This group is represented by 9 taxa viz., *C.ambrosioides*, *C.atrupliciforme*, *C.karoii*, *C.album*, *C.glaucum*, *C.ficifolium* ssp. *blomianum*, *C.strictum*, *C.vulvaria* and *C.novopokrovskyanum*. Among them 3 taxa viz., *C.ambrosioides*, *C.karoii* and *C.album* fall within a common cluster by sharing obovate-obovate or obovate seeds, while rest of the taxa have orbicular and rarely obovate seeds. The 2 taxa *C.glaucum* and *C.ficifolium* ssp. *blomianum* show similarity in seed surface, but remain separated on the basis of seed colour. Likewise, *C.atrupliciforme*, *C.vulvaria* and *C.novopokrovskyanum* are closely related as they share almost smooth seeds. While *C.strictum* remain distinct with ruminant seeds.

Thus it is concluded that the family Amaranthaceae is more or less stenospermous family as most of the species of different genera showing same seed morphological characters with slight differentiation and these findings are also supported with the palynological findings (Perveen & Qaiser, 2002, 2012).

Acknowledgment

This research work is a part of the project "The Seed Atlas of Pakistan", sponsored by HEC which is sincerely acknowledged. Thanks are also for Chairperson, Department of Botany, University of Karachi for providing the departmental facilities. We are also thankful to the Director, Karachi University Herbarium for the providing the herbarium and scanning facilities.

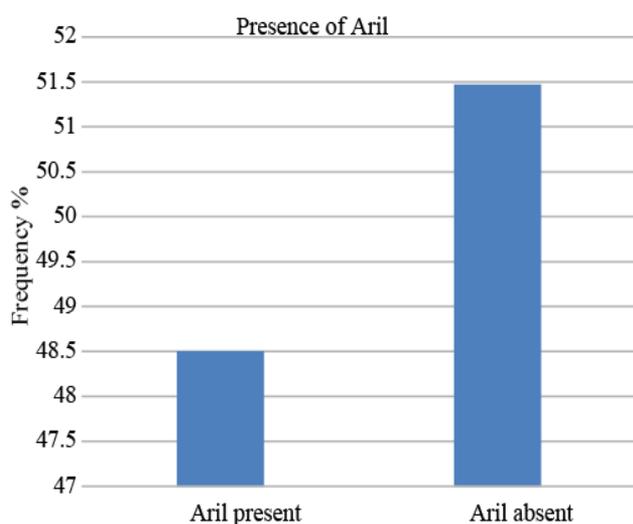


Fig.4. Bar diagram showing variation in presence of aril within the family Amaranthaceae.

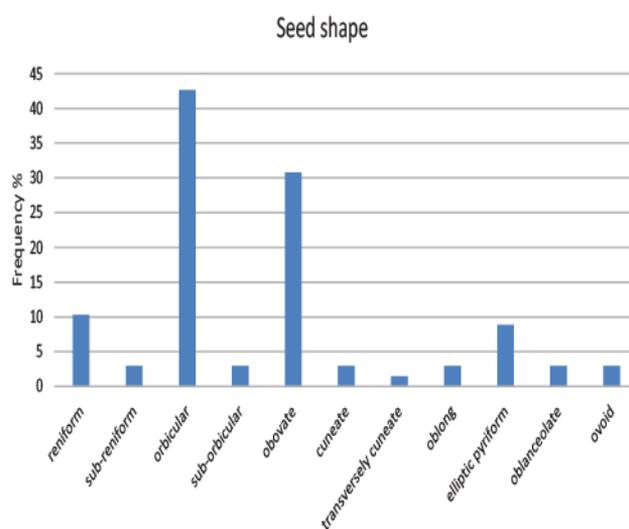


Fig.7. Bar diagram showing variation in seed shape within the family Amaranthaceae.

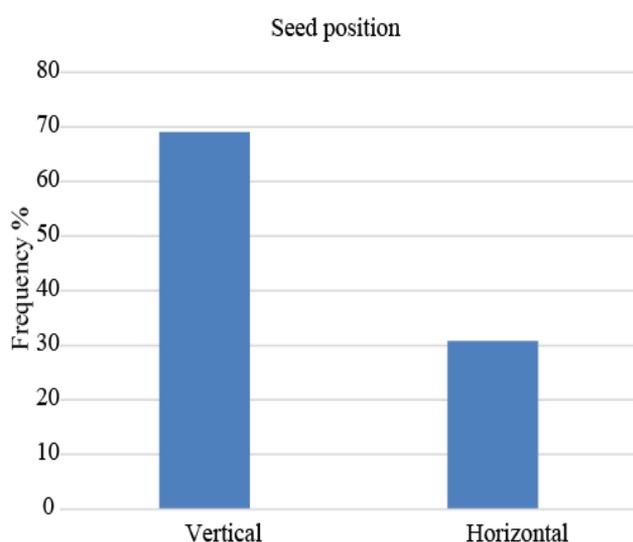


Fig.5. Bar diagram showing variation in seed position within the family Amaranthaceae.

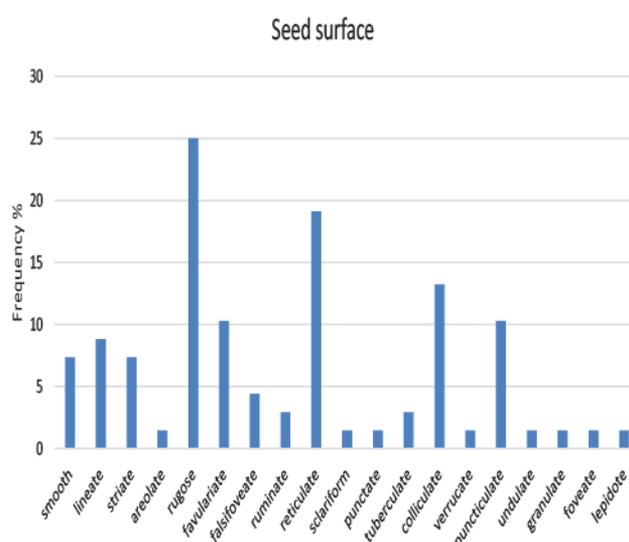


Fig.8. Bar diagram showing variation in seed surface within the family Amaranthaceae.

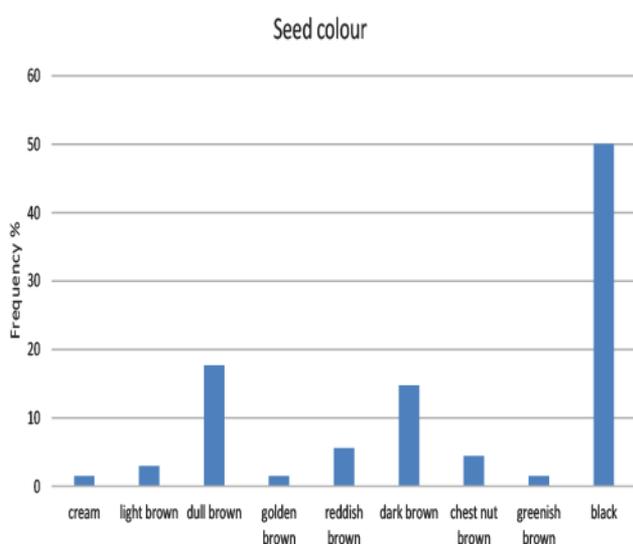


Fig.6. Bar diagram showing variation in seed colour within the family Amaranthaceae.

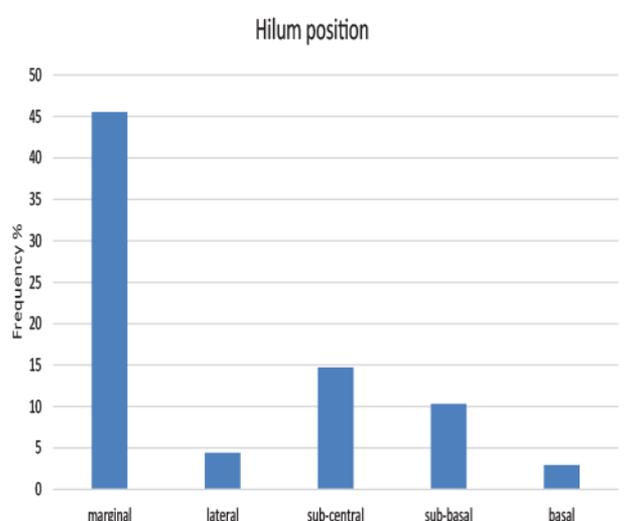
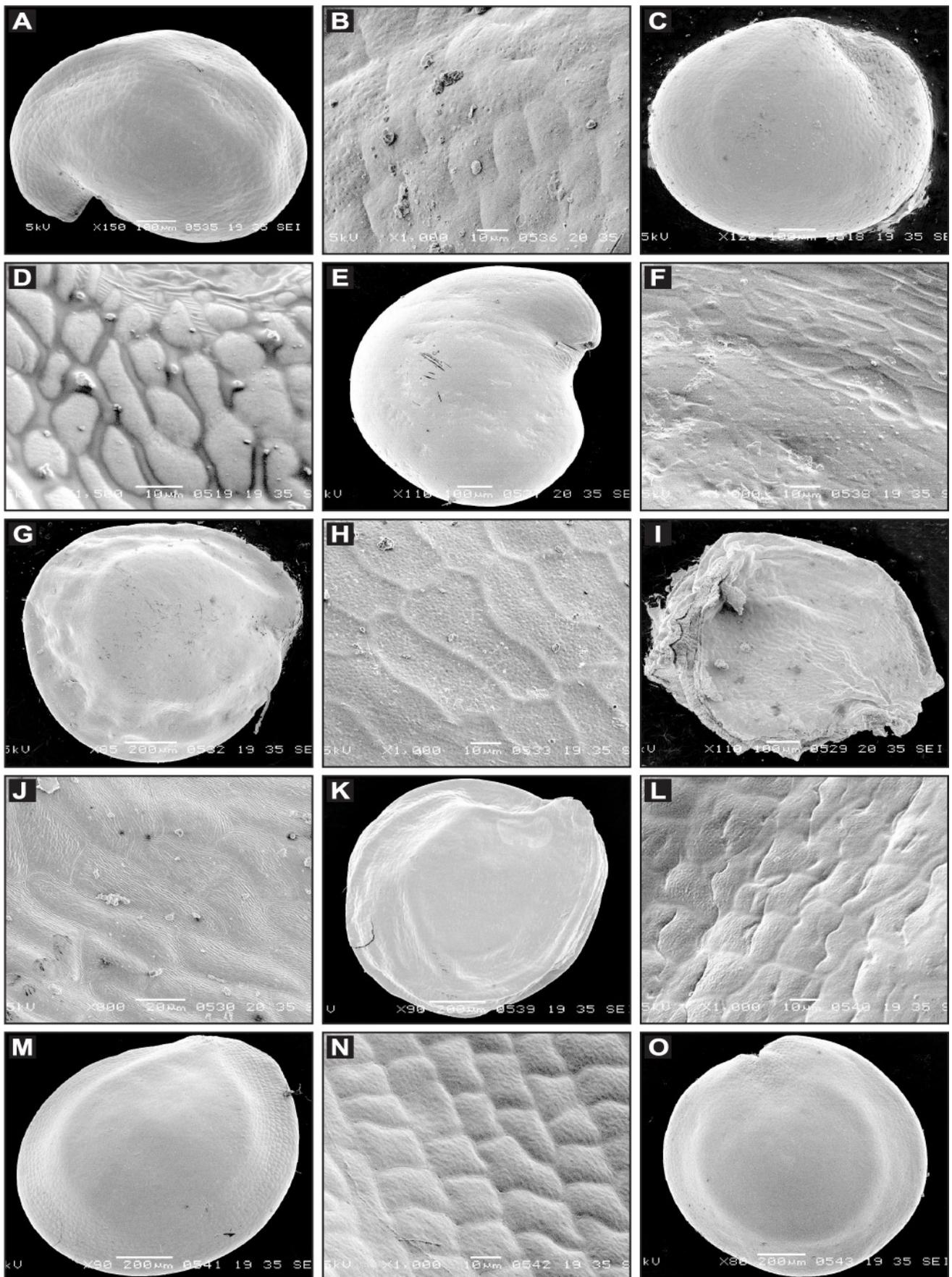
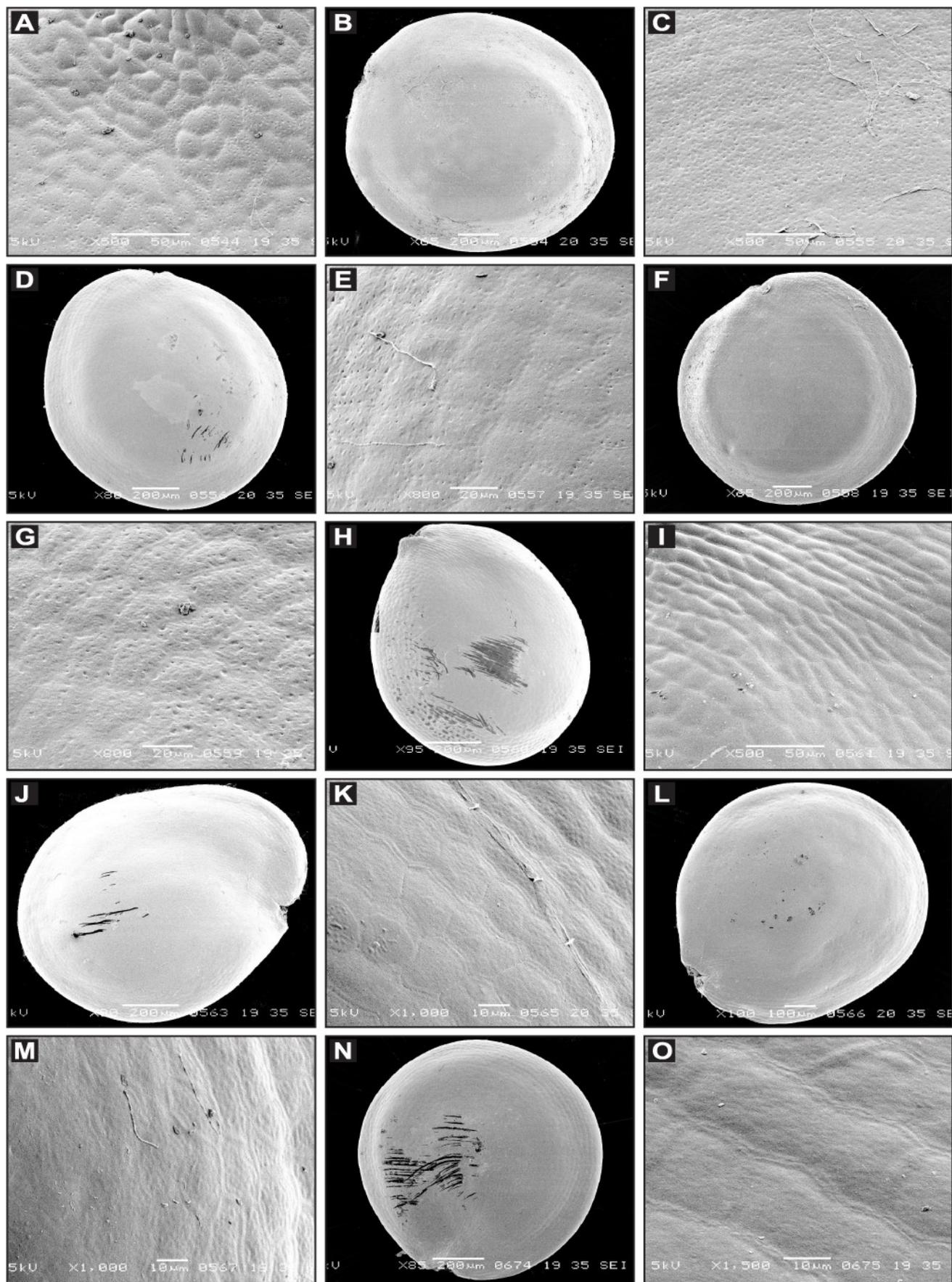


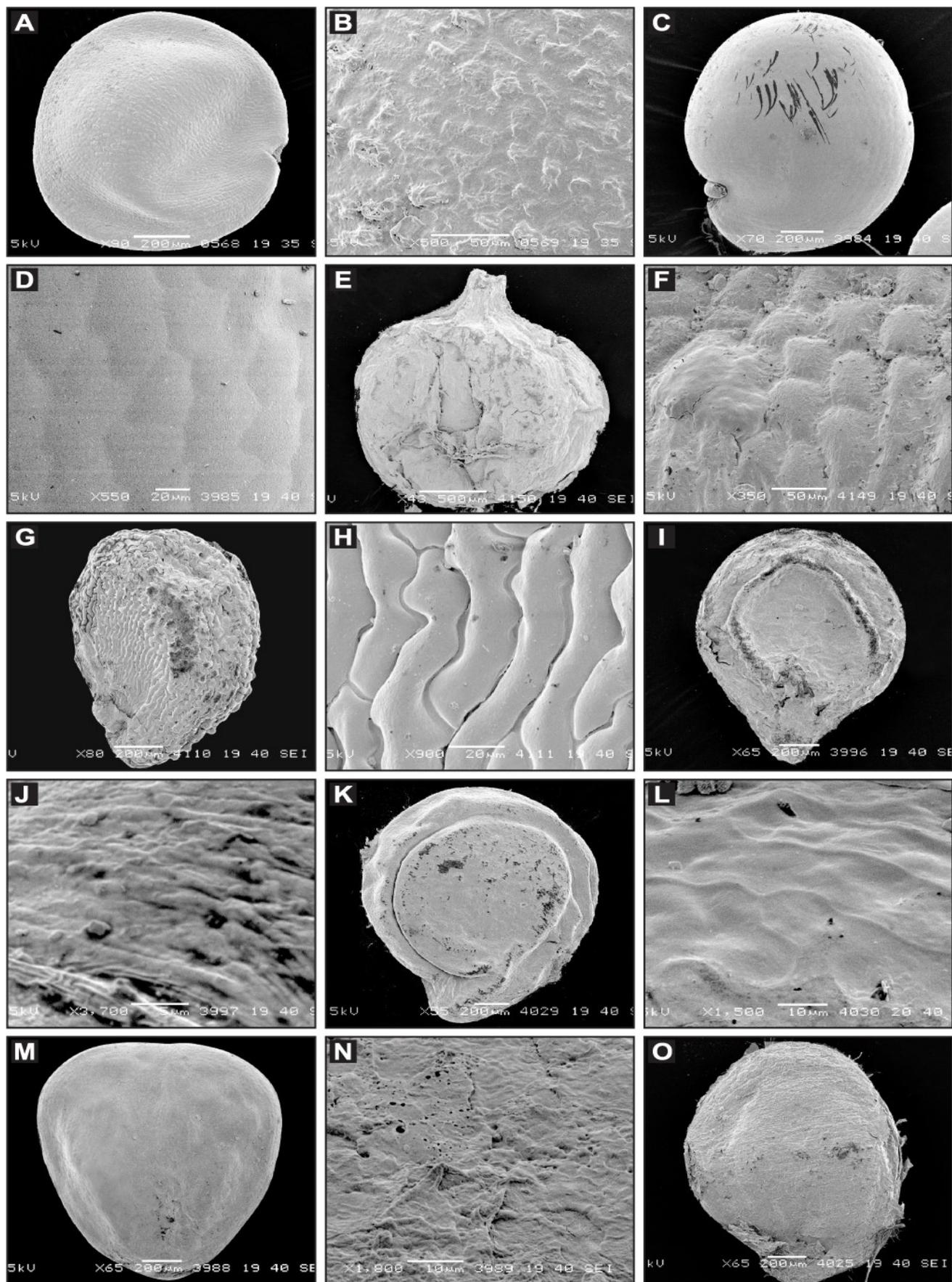
Fig.9. Bar diagram showing variation in Hilum position within the family Amaranthaceae.



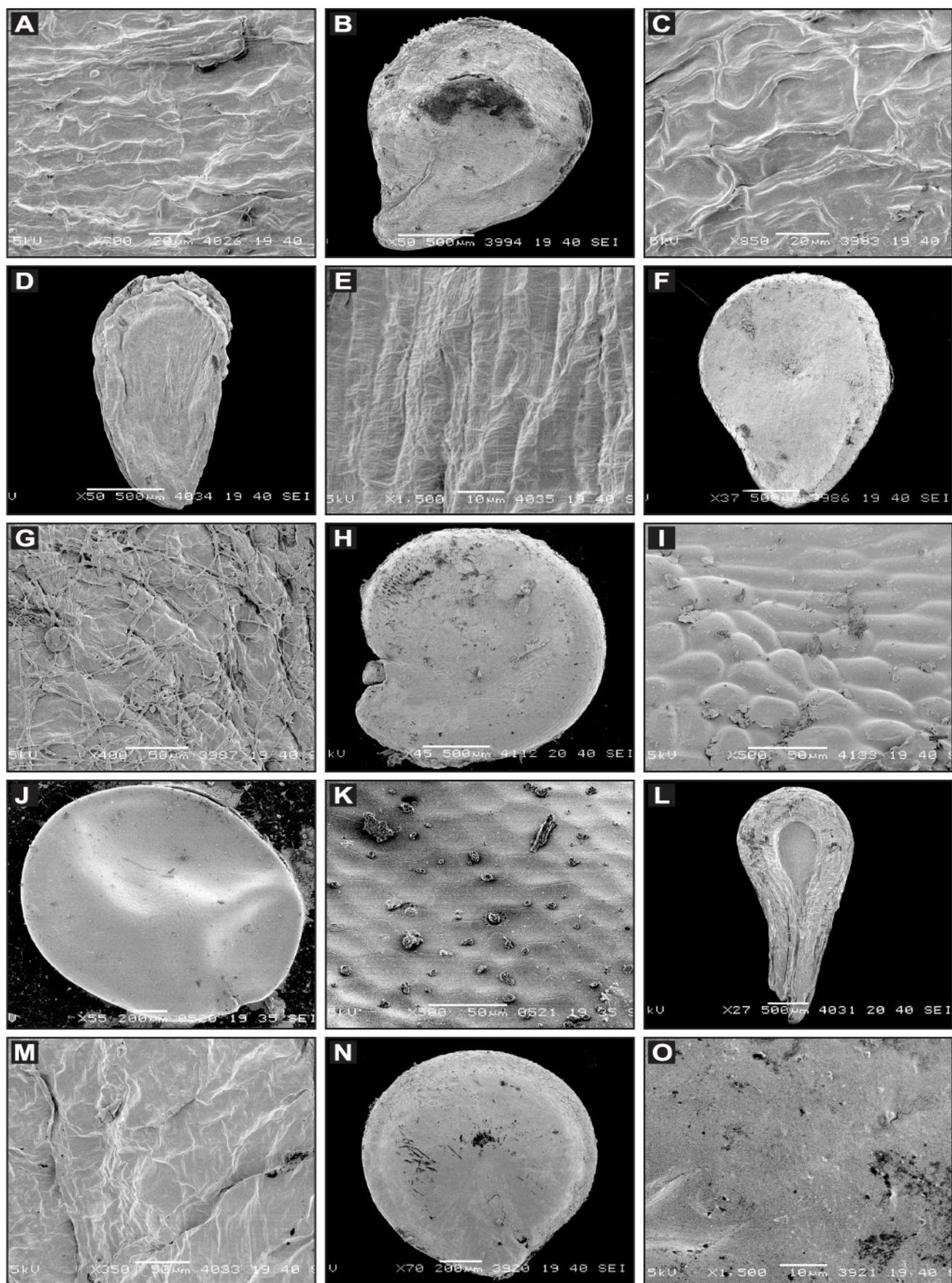
Plt. 1. Scanning electron micrographs. *Aerva javanica* var. *javanica*: A, seed; B, surface. *A. javanica* var. *bovei*: C, seed; D, surface. *A. sanguinolenta*: E, seed; F, surface. *Alternanthera paronychioides*: G, seed; H, surface. *A. pungens*: I, seed; J, surface. *A. sessilis*: K, seed; L, surface. *Amaranthus caudatus*: M, seed; N, surface. *A. graecizans* ssp. *graecizans*: O, seed. (Scale bars: G,K,M,O=200; A,C,E,I=100; J=20; B,D,F,H,L,N=10).



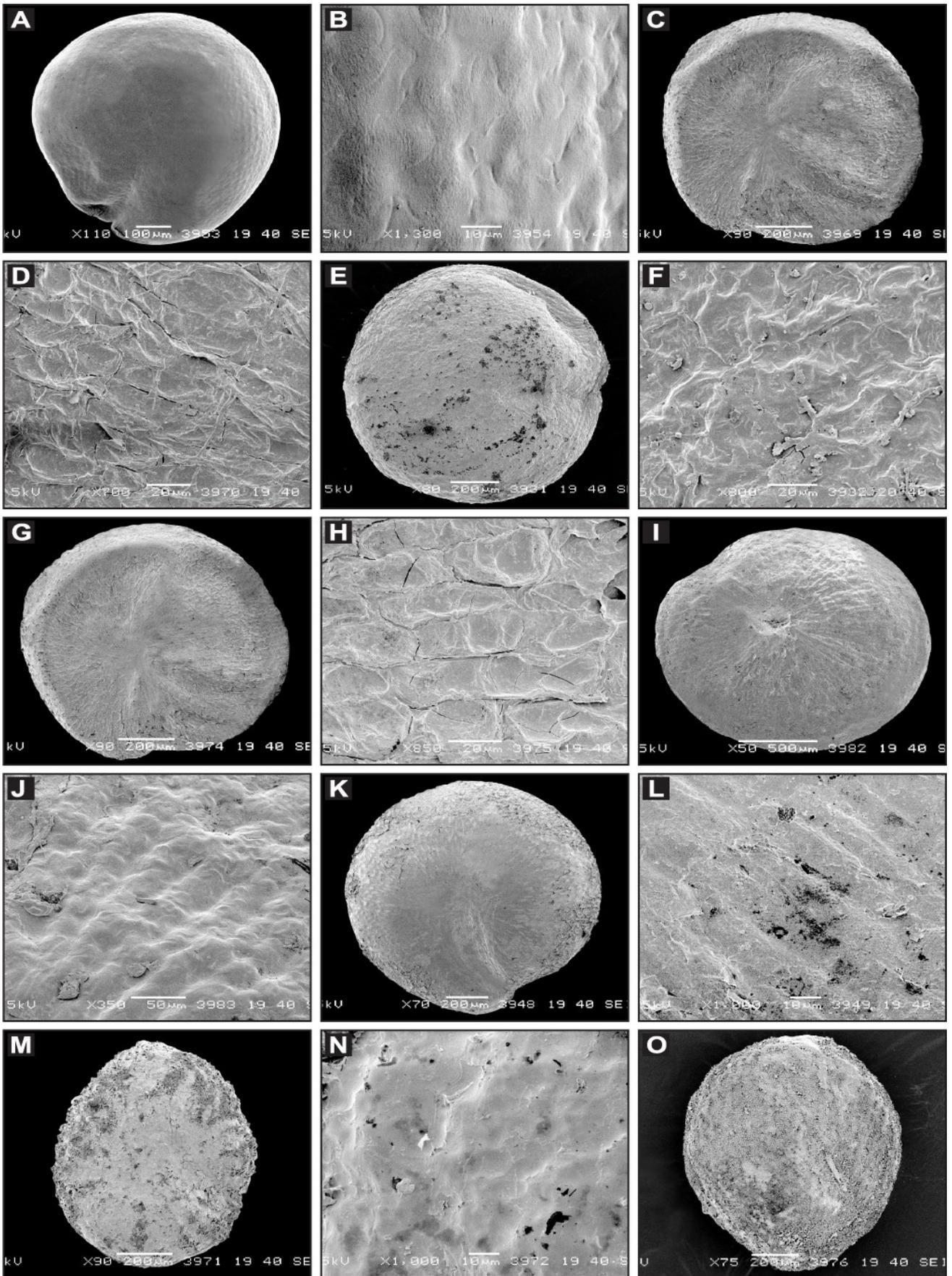
Plt. 2. Scanning electron micrographs. *A. graecizans* ssp. *graecizans*: A, surface. *A. graecizans* ssp. *silvestris*: B, seed; C, surface. *A. graecizans* ssp. *thellungianus*: D, seed; E, surface. *A. hybridus* ssp. *cruentus*: F, seed; G, surface. *A. hybridus* ssp. *hybridus*: H, seed; I, surface. *A. retroflexus*: J, seed; K, surface. *A. spinosus*: L, seed; M, surface. *A. tricolor*: N, seed; O, surface. (Scale bars: B,D,F,H,J,N=200; L=100; A,C,I=50; E,G=20; K,M,O=10).



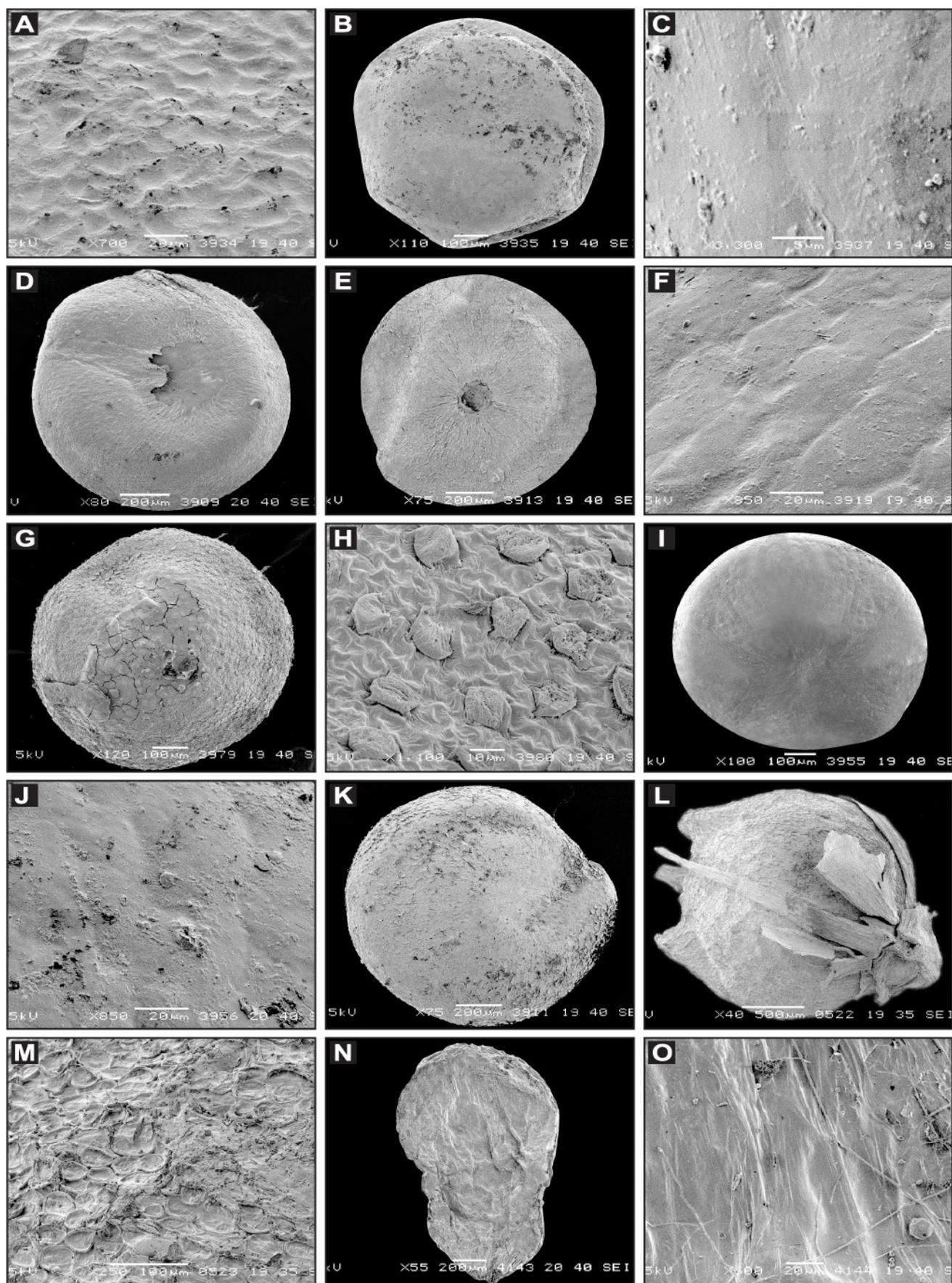
Plt. 3. Scanning electron micrographs. *A. viridus*: A, seed; B, surface. *Acroglochin persicarioides*: C, seed; D, surface. *Anabasis haussknechtii*: E, seed; F, surface. *Arthrocnemum macrostachyum*: G, seed; H, surface. *Atriplex dimorphostegia*: I, seed; J, surface. *A. lasiantha*: K, seed; L, surface. *A. leucoclada*: M, seed; N, surface. *A. schugnanica*: O, seed. (Scale bars: E=500; A,C,G,I,K,M,O=200; B,F=50; D,H=20; L,N=10; J=5).



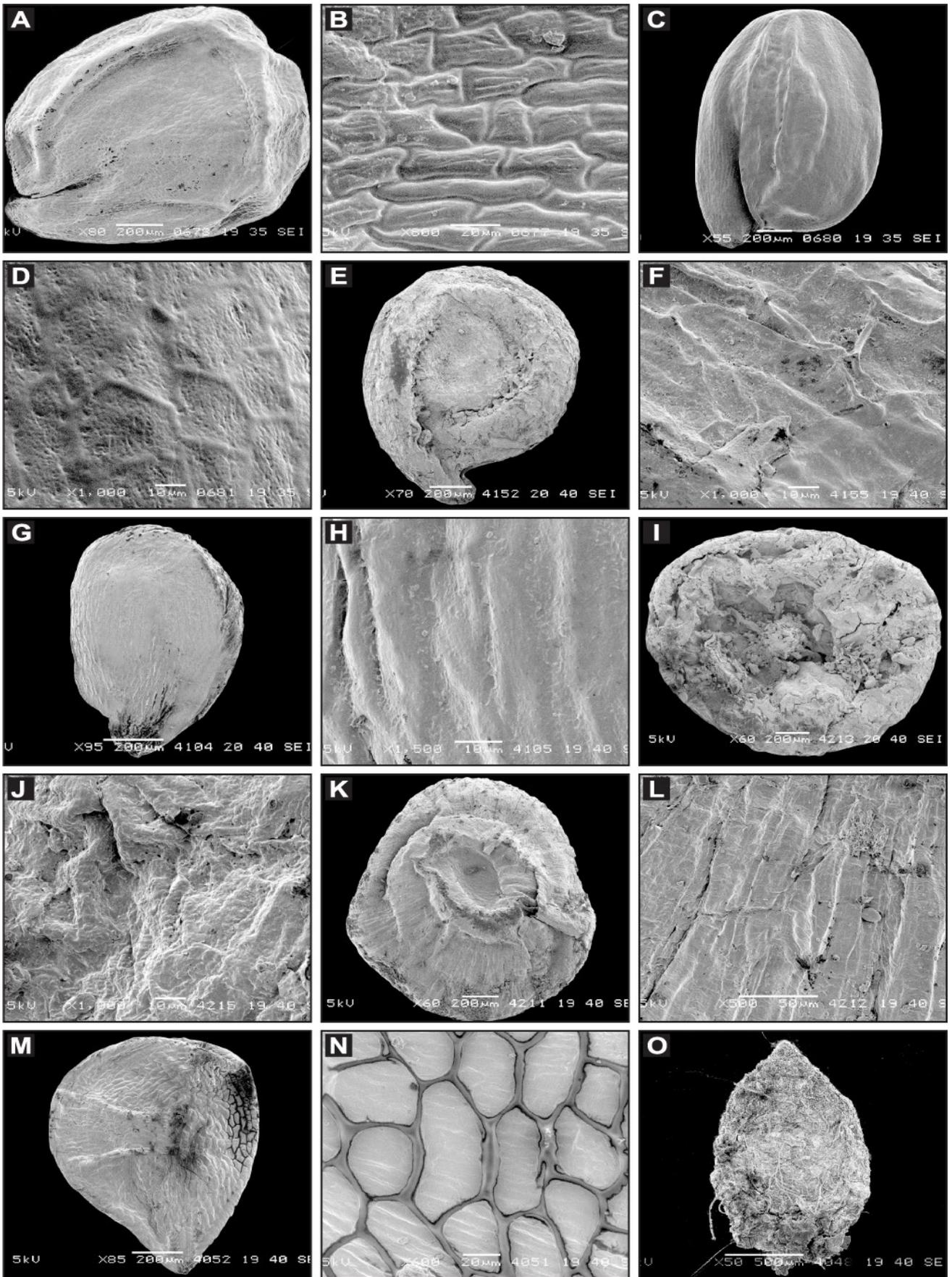
Plt. 4. Scanning electron micrographs. *A. schugnanica*: A, surface. *A. stocksii*: B, seed; C, surface. *Axyris hybrida*: D, seed; E, surface. *Beta vulgaris*: F, seed; G, surface. *Bienertia cycloptera*: H, seed; I, surface. *Celosia argentea*: J, seed; K, surface. *Ceratocarpus arenarius*: L, seed; M, surface. *Chenopodium album*: N, seed; O, surface. (Scale bars: B,D,F,H,L=500; J,N=200; G,I,K,M=50; A,C=20; E,O=10).



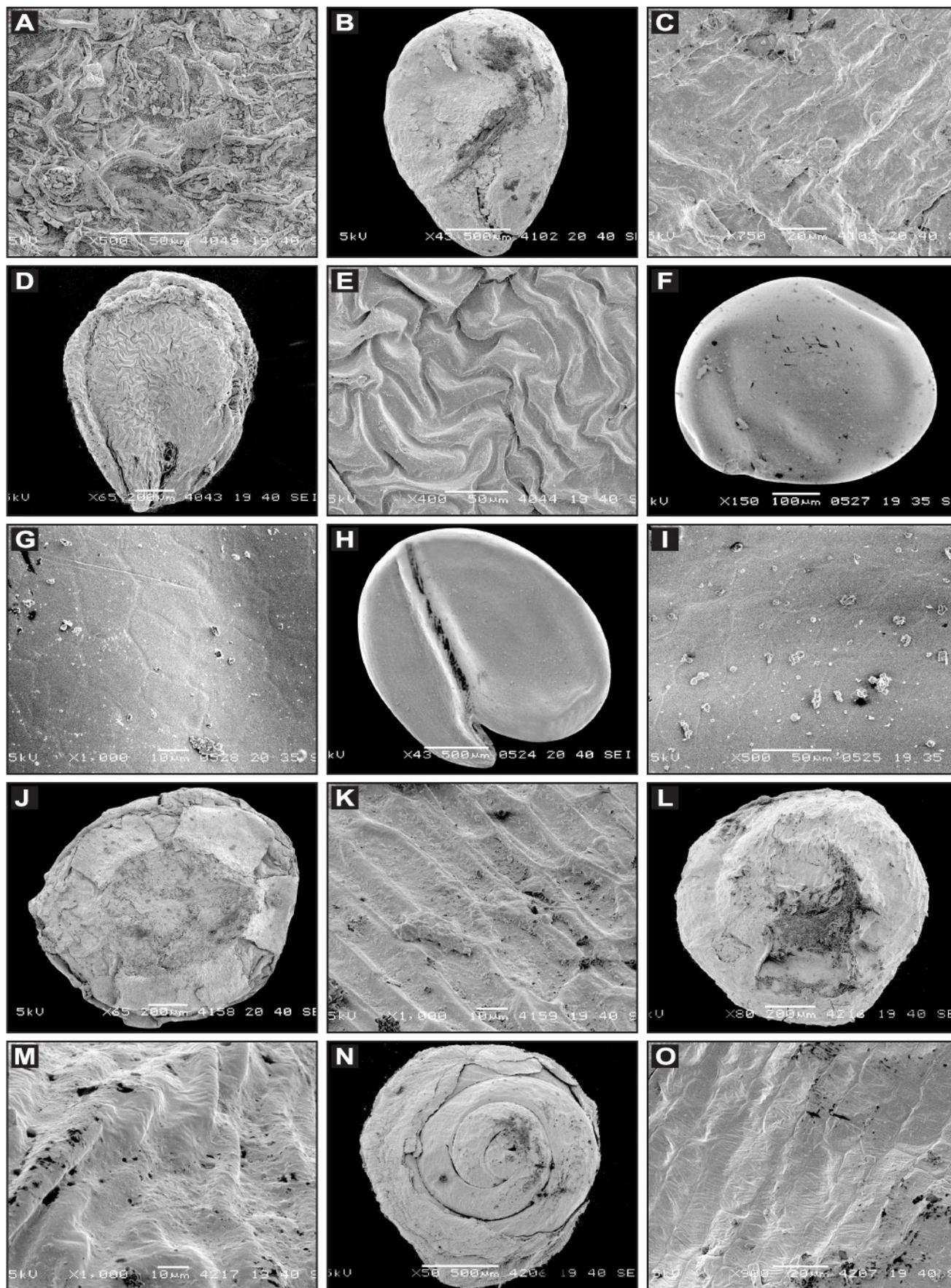
Plt. 5. Scanning electron micrographs. *C. ambrosioides*: A, seed; B, surface. *C. ficifolium* ssp. *blomianum*: C, seed; D, surface. *C. foliosum*: E, seed; F, surface. *C. glaucum*: G, seed; H, surface. *C. badachschanicum*: I, seed; J, surface. *C. karoi*: K, seed; L, surface. *C. korshinskyi*: M, seed; N, surface. *C. litwinowii*: O, seed. (Scale bars: I=500; C,E,G,K,M,O=200; A=100; J=50; D,F,H=20; B,L,N=10).



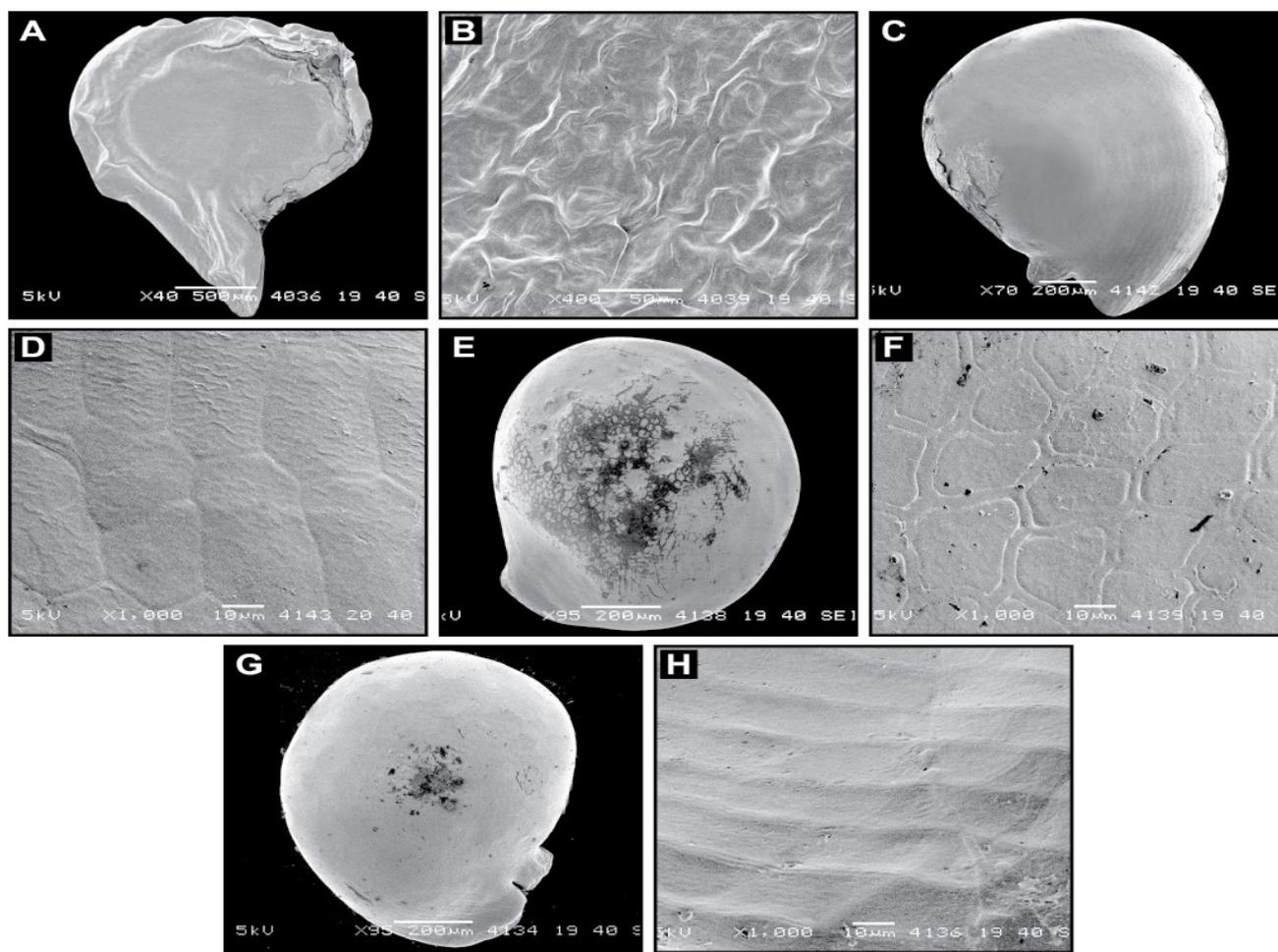
Plt. 6. Scanning electron micrographs. *C. murale*: A, surface. *C. nepalense*: B, seed; C, surface. *C. novopokrovskyanum*: D, seed. *C. pamiricum*: E, seed; F, surface. *C. schraderianum*: G, seed; H, surface. *C. strictum*: I, seed; J, surface. *C. vulvaria*: K, seed. *Digera muricata*: L, seed; M, surface. *Girgensohnia oppositiflora*: N, seed; O, surface. (Scale bars: L=500; D,E,K,N=200; B,G,I,M=100; A,F,J,O=20; H=10; C=5).



Plt. 7. Scanning electron micrographs. *Gomphrena celosioides*: A, seed; B, surface. *G. globosa*: C, seed; D, surface. *Halogeton glomeratus*: E, seed; F, surface. *Halostachys belangerana*: G, seed; H, surface. *Haloxylon griffithii*: I, seed; J, surface. *H. selicornicum*: K, seed; L, surface. *Kochia indica*: M, seed; N, surface. *K. iranica*: O, seed; B, surface. (Scale bars: O=500; A,C,E,G,I,K,M=200; L=50; B,N=20; D,F,H,J=10).



Plt. 8. Scanning electron micrographs. *K. iranica*: A, surface. *K. prostrata*: B, seed; C, surface. *K. scoparia*: D, seed; E, surface. *Nothosaerva brachiata*: F, seed; G, surface. *Pupalia lappacea*: H, seed; I, surface. *Salsola drummondii*: J, seed; K, surface. *S. nitraria*: L, seed; M, surface. *S. tragus*: N, seed; O, surface. (Scale bars: B,H,N=500; D,J,L=200; F=100; A,E,I=50; C,O=20; G,K,M=10).



Plt. 9. Scanning electron micrographs. *Spinacia oleracea*: A, seed; B, surface. *Suaeda aegyptiaca*: C, seed; D, surface. *S. arcuata*: E, seed; F, surface. *S. fruticosa*: G, seed; H, surface. (Scale bars: A=500; C,E,G=200; B=50; D,F,H=10).

References

- Anonymous. IBM SPSS 19. 2012 for windows XP 2002.
- APG (Angiosperm Phylogeny Group) III. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants. *Bot. J. Linn. Soc.*, 161: 105-121.
- Berggren, G. 1981. *Atlas of seeds, and small Fruit of Northwest European plant species*, Salicaceae-Cruciferae. Part 3. Swedish Museum of Natural History, Stockholm.
- Cronquist, A. 1981. *An integrated system of classification of flowering plants*. New York: Columbia University Press.
- Frank-De-Carvalto, S.M., M.R.A. Gomes, P.Í.T. Silva and S.N. Bao. 2010. Leaf surfaces of *Gomphrena* spp. (Amaranthaceae) from Cerrado biome. *Biocell*, Vol.34 (1): 23-35.
- Freitag, H., I. C. Hedge, S. M. H. Jafri, G. K. Othe-Heinrich, S. Omer and P. Uotilu. 2001. Chenopodiaceae. Vol.204:1-213. In: *Fl. W. Pak*. S. I. Ali and M. Qaiser (Eds.). Dept. Bot. Univ. Karachi, Karachi.
- Heywood, V.H. 1993. *Flowering plants of the world*. Oxford University press, New York.
- Irving, D.W., A.A. Betschart and R.M. Saunders. 1984. Morphological studies on *Amaranthus cruentus* J. *Food Sc.*, 46(4): 1170-1174.
- Jain, S.K. and H. Hauptli. 1980. Grain Amaranth. A new crop for California. Agronomy progress report. No.107. Cooperative extension service, university of California, USA.
- Khalid, S. and R.A. Shad. 1990. Importance of structure and shape in the spread and adaptability of weed seed. *Pak. J. Agri. Res.* Vol. 11(2):111-132.
- Malekloo, M., S.M.M. Handi, M. Assadi and T. Nejadstari. 2010. Morphological, micromorphological and anatomical studies of *Chenopodium album* in Iran. *Iran. J. Bot.*, Vol.16 (1): 69-75.
- Perveen, A. and M. Qaiser, 2002. Pollen Flora of Pakistan-XVIII-Amaranthaceae. *Pak. J. Bot.*, 34(4): 375-383.
- Perveen, A. and M. Qaiser, 2012. Pollen Flora of Pakistan-LXX-Chenopodiaceae. *Pak. J. Bot.*, 44(4): 1325-1333.
- Rendle, A.B. 1925. *The classification of flowering plants*. Cambridge University press, Euston road, London.
- Sage, R.F., T.L. Sage, R.W. Percy and T. Borsch. 2007. The taxonomic distribution of C4 photosynthesis in *Amaranthus Sensu strict*. *Amr. J. Bot.*, 94: 1992-2003.
- Saunders, R.M. and R. Becker. 1984. *Amaranthus*. A potential food and fees resource. In: Advances in cereal science technology, Y. Pomeranz (ed.). *Am. Assoc. Cereal. Chem.*, 5: 357.
- Soliman, M.A. 2006. Cytological studies on *Aerva javanica* (Amaranthaceae). *Fl. Medit.*, 16: 333-339.
- Stearn, T.W. 1983. *Botanical Latin*, 3rd edition. David & Charles. Britain.
- Takhtajan, A. 1966. *Systema et phylogenia Magnoliophytorum*. Moscow: Nauka.
- Townsend, C.C. 1974. *Fl. W. Pak.*, Amaranthaceae. Vol.71:1-49. In: E. Nasir and S.I. Ali. (Eds.). Dept. Bot. Univ. Karachi and Stewart Herbarium, Gorden College, Rawalpindi.
- Yao, S., H. Lan, and F. Zhang. 2010. Variation of seed heteromorphism in *Chenopodium album* and the effect of salinity stress on the descendants. *Ann. Bot.*, Vol.105 (6): 1015-1025.

(Received for publication 15 January 2016)