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## Fruits Morphology of Annual Grasses from Egypt

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**Abstract:** The grasses caryopses of 33 taxa belong to 24 genera of 11 tribes of wild Gramineae from Egypt were examined by using light and scanning electron microscopy. Macro- and micro-morphological characters, including fruit shape, size, weight, coloring mode and colour shade, trichomes and their features and the seed surface topography are presented. The caryopses are distinct by three principal diagnostic characters; fruit shape, mode of coloring and seed surface topography. A key for the identification of the investigated taxa based on fruit characters is provided.

**Key words:** Morphology, fruits, Gramineae, trichomes, grasses caryopses

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### INTRODUCTION

Gaertner (1788, 1791) was the botanist who published the first works devoted to the identification of fruits and seeds. Although this work has never been surpassed in its usefulness for identifying unknown seeds. Barthlott (1984) gave also an account of seeds and small fruits morphology as important tool in plant taxonomy. Most systematists agree that data concerning the macro and microstructure of seeds are very significant for the classification of Angiosperm taxa (Abdel-Khalik, 2002). Martin and Barkley (1961) applied the term seed in its broad, popular sense i.e., not only to true seed, but also to equivalent structures which look like and function as seeds. Generally, Gramineae fruits, also called grains, can usually be considered as seeds. The shape of seeds is more or less specific to the species and may often serve as a diagnostic character (Werker, 1997). The surface of seeds exhibit several macro- and micro-morphological structures (Zareh, 2005). The pattern of the seed surface is often peculiar to species or to a higher taxon and can be of great taxonomic value.

Taia (2005) confirmed that the plant morphology in all its aspects is still hugely important. With proper weighting, morphological characteristics remain the most valuable tools for interpreting phylogenetic analyses. Moreover, Heywood (1971) drew attention to the importance and impact of scanning electron microscopy in the study of systematic problems, as very valuable information has been provided by using this technique. In addition to that general point, over the last few decades scholars have applied SEM to morphological study of seeds and small fruits (Dahlgren, 1980). Grass fruits or seeds proved highly significant for taxonomic studies

at different taxonomic levels in dependence on a morphological surveying by aiding of the most popular techniques LM, SM and/or SEM (Irving, 1983; Terrell, 1993; Seberg and Frederiksen, 2001; Liu *et al.*, 2005). Also other articles applied the same protocols investigating seeds of some dicotyledons resolving a systematic dispute (Barthlott, 1981, 1984; Segarra and Mateu, 2001; Tantawy *et al.*, 2004; Zareh, 2005; Hamed, 2006). This study aims to describe the morphological features for the caryopsis of each taxon available for study in the Egyptian grass seed collection at our University. Variation and diversity in characteristics is recorded from all available specimens using of Light, Stereo and Scanning electron microscopes to determine the importance of grain characters as a criterion for separating the taxa.

### MATERIALS AND METHODS

**Plant material:** Thirty three species for 24 genera of 11 tribes of wild grasses represented the Egyptian flora, dried and kept in the Botany Department Herbarium of South Valley University in Qena (QNA a proposed acronym) and named as mentioned by El Hadidi and Fayed (1995) and Boulos (2009, 2005). Dry mature fruits were selected and immersed in ethanol 70% for cleaning till be examined. They were then dried on filter paper before investigation.

**Microscopic investigations:** For Light Microscopic (LM) characters; fruit size dimensions obtained by ocular micrometer a light microscope MICROS-AUSTRIA MC-400 using the objective (x = 4/0.1-160/0.17), some dimensions were obtained using the centimeter-scaled ruler.

For stereomicroscopic (SM) characters; shape, colouring, colour type, trichomes types and their features were recorded by the aid of a stereomicroscope (SM); OLYMPUS VE-3 using the eyepiece (G20XT). Mass of fruits was determined for batches of 100 grains and divided by 100 to obtain the average milligrams per seed by using an electric balance apparatus; SARTORIUS BP-2215.

For Scanning Electron Microscopy (SEM); fruit samples were examined for seed coat cell types, in addition to, more illustration for the most mentioned characters. They were mounted on dry, xylene-cleaned aluminium stubs covered by double sided adhesive tape. The mounted samples were scanned and photographed using a JOEL JSM-5500 LV scanning electron microscopy.

## RESULTS AND DISCUSSION

A careful examination of the genera and species represented in the flora of Egypt revealed highly variant data summarized in Table 1. The tribes, genera and species of family Poaceae that are represented in the flora of Egypt are arranged alphabetically to facilitate consultation. For each species, the accepted scientific name is given followed by the citation of the authority (El Hadidi and Fayed, 1995; Boulos, 2005, 2009). Fruit macro- and micro-morphological characters description.

### Tribe: Andropogoneae

***Sorghum variegatum* Hack. (Fig. 1a, b):** The caryopsis is cordate in shape, mass 0.75 mg and 0.114×0.253 mm in size as (width×length). The fruit is glabrous; with no trichomes. The fruit surface exhibits two colors (bicolored fruit) gradient beige with light green and brown spot at the top. The ornamentation of the fruit surface appears as striate sculpturing.

### Tribe: Aristideae

***Aristida adscensionis* L. (Fig. 2a, b):** The caryopsis is long linear in shape, mass 0.38 mg and 0.129×8.0 mm in size as (width×length). The fruit is hairy with short colored simple hairs at the base of the fruit. The fruit is bicolored; beige with light violet sheath. The surface sculpture is striate to scabrate.

***Aristida funiculata* Trin. et Rupr. (Fig. 3a, b):** The caryopsis is long linear in shape, mass 0.63 mg and 0.042×0.752 mm in size as (width×length). The fruit is hairy with short colored simple hairs at the base of the fruit. The fruit surface exhibits two colors (bicolored fruit); brown with pale beige sheath. The surface ornamentation is reticulate with undulate cell walls.

***Aristida mutabilis* Trin. et Rupr. (Fig. 4a, b):** The caryopsis is short linear in shape, mass 0.22 mg and 0.043×0.459 mm in size as (width×length). The fruit is hairy with short colored simple hairs at the base of the fruit. The fruit is one colored by brown color. The ornamentation of the fruit surface appears as striate sculpturing.

***Stipagrostis ciliata* Desf. (Fig. 5a, b):** The caryopsis is short oblong in shape, mass 0.57 mg and 0.058×0.445 mm in size as (width×length). The fruit is hairy with short colored simple hairs at the base of the fruit. The fruit is single colored, brown. The fruit surface exhibits the ribbed pattern cell walls.

### Tribe: Arundineae

***Schismus arabicus* Nees. (Fig. 6a, b):** The caryopsis is oval in shape, mass 0.06 mg and 0.039×0.068 mm in size as (width×length). The fruits have no trichomes. Its surface is bicolored; shiny beige with light brown small spots and it is smooth sculptured.

### Tribe: Aveneae

***Avena barbata* Pott ex Link. (Fig. 7a, b):** The caryopsis is oblong in shape, mass 1.99 mg and 0.085×0.505 mm in size as (width×length). The fruit is hairy with short colored simple hairs condensed and scattered around the entire seed surface; which is one colored; light beige and striate sculptured.

***Avena fatua* L. (Fig. 8a, b):** The caryopsis is tall oblong, mass 6.65 mg and 0.239×9.33 mm in size as (width×length). The fruit is hairy with long colored simple hairs condensed and scattered around the entire seed surface; which is one colored; beige and striate sculptured.

***Phalaris minor* Retz. (Fig. 9a, b):** The caryopsis is cordate in shape, mass 1.42 mg and 0.144×0.278 mm in size as (width×length). The fruit is hairy with short shiny simple hairs around the seed surface; which is one colored; brown and scabrate sculptured.

***Polygonum maritimum* Willd. (Fig. 10a, b):** The caryopsis is cordate in shape, mass 0.11 mg and 0.046×0.088 mm in size as (width×length). The fruit is glabrous without any trichomes. The fruit surface exhibits one color; light brown and it is striate to scabrate in the ornamentation.

***Polygonum monspeliensis* L. (Fig. 11a, b):** The caryopsis is oblong in shape, mass 0.03 mg and 0.029×0.089 mm in size as (width×length). The fruit is glabrous without any trichomes. The fruit surface exhibits one color; light brown and it is rugose in the ornamentation.

Table 1: Tubular summary showing the fruits. Macro- and Micro-morphological Characters in examined taxa

Species	Tribe	Fruit shapes	M/100 fruits (mg)	Fruit size		Length (mm)	Fruit coloring mode	Color shade
				Wide (mm)	Height (mm)			
<i>Sorghum variegatum</i> spot	Andro.	Cordate	0.75	(0.112-0.119)	0.114	(0.245-0.266)	0.253	Gradient beige with light green and brown at the grain top
<i>Aristida adscensionis</i>	Arist.	Long linear	0.388	(0.038-0.049)	0.043	(0.7-0.9-0)	8.0	Beige with light violet sheath
<i>Aristida funiculata</i>	Arist.	Long linear	0.6384	(0.038-0.045)	0.042	(0.7-0.787)	0.752	Brown with pale beige sheath
<i>Aristida mutabilis</i>	Arist.	Short linear	0.226	(0.031-0.059)	0.043	(0.427-0.483)	0.459	Brown
<i>Stipogrostis ciliata</i>	Arist.	Short oblong	0.573	(0.052-0.063)	0.058	(0.392-0.472)	0.445	Light brown
<i>Schismus arabicus</i>	Arund.	Oval	0.062	(0.038-0.042)	0.039	(0.066-0.073)	0.068	Shiny beige with light brown small spots
<i>Avenca barbata</i>	Aven.	Oblong	1.993	(0.07-0.108)	0.085	(0.49-0.535)	0.505	Light beige
<i>Avenca fatua</i>	Aven.	Tall oblong	6.656	(0.227-0.245)	0.239	(9.0-10.0)	9.33	Beige
<i>Phalaris minor</i>	Aven.	Cordate	1.429	(0.143-0.147)	0.144	(0.27-0.28)	0.278	Brown
<i>Polypogon maritimus</i>	Aven.	Cordate	0.111	(0.045-0.049)	0.046	(0.080-0.094)	0.088	Light brown
<i>Polypogon monspeliensis</i>	Aven.	Oblong	0.0325	(0.024-0.031)	0.029	(0.087-0.094)	0.089	Light brown
<i>Brachypodium distachyon</i>	Brach.	Linear	3.897	(0.105-0.108)	0.106	(0.56-0.588)	0.569	Dark red
<i>Bromus rubens</i>	Brom.	Tall oblong with tapered ends	2.276	(0.122-0.122)	0.122	(0.987-1.039)	1.012	Dark red
<i>Bromus scoparius</i>	Brom.	Linear	0.766	(0.045-0.077)	0.059	(6.5-7.0)	6.66	Dark red
<i>Coelachyrum beryfolium</i>	Eragr.	Cordate with hollow part	0.188	(0.080-0.094)	0.086	(0.101-0.112)	0.107	Dark red
<i>Dactyloctenium aegyptium</i>	Eragr.	Oval	0.14	(0.059-0.7)	0.061	(0.07-0.073)	0.072	Beige with brown protrusions
<i>Eragrostis ciliatensis</i>	Eragr.	Circular	0.106	(0.049-0.052)	0.050	(0.066-0.066)	0.066	Brown
<i>Eragrostis minor</i>	Eragr.	Elliptic	0.043	(0.042-0.045)	0.043	(0.080-0.087)	0.084	Light brown
<i>Leptochloa fistica</i>	Eragr.	Elliptic	0.06	(0.031-0.045)	0.037	(0.077-0.101)	0.084	Brown and light orange
<i>Cenchrus ciliaris</i>	Panic.	Cordate	0.31	(0.098-0.105)	0.100	(0.196-0.199)	0.197	Beige and brown black spots
<i>Echinochloa colona</i>	Panic.	Cordate	0.547	(0.119-0.122)	0.120	(0.227-0.262)	0.239	Light beige with light green strips
<i>Panicum turgidum</i>	Panic.	Narrow cordate	0.31	(0.087-0.091)	0.269	(0.252-0.255)	0.253	Beige
<i>Dactylis glomerata</i>	Poae.	Oval with acute protrusions	0.094	(0.045-0.094)	0.064	(0.105-0.115)	0.109	Brown
<i>Lamarckia aurea</i>	Poae.	Elliptic with tapered ends	0.342	(0.059-0.087)	0.077	(0.178-0.213)	0.199	Light brown, the ends are dark brown
<i>Lolium perenne</i>	Poae.	Rectangular	2.883	(0.129-0.14)	0.134	(0.409-0.413)	0.411	Dark brown with light yellowish sheath
<i>Poa annua</i>	Poae.	Elliptic	0.196	(0.049-0.059)	0.052	(0.143-0.168)	0.158	Brown
<i>Oryzopsis miliacea</i>	Stipeae.	Oval	0.344	(0.08-0.087)	0.085	(0.199-0.21)	0.205	Dark beige
<i>Stipa capensis</i>	Stipeae.	Oblong	0.75	(0.059-0.059)	0.059	(0.402-0.452)	0.424	Light brown
<i>Stipa lagascae</i>	Stipeae.	Short oblong	0.986	(0.059-0.07)	0.065	(0.63-0.7)	0.676	Brown
<i>Stipa parviflora</i>	Stipeae.	Tall oblong	2.4825	(0.077-0.08)	0.078	(11.0-13.0)	12.33	Beige
<i>Aegilops kotschy</i>	Triti.	Oblong	5.944	(0.150-0.206)	0.176	(0.63-0.689)	0.649	Brown with light green sheath
<i>Aegilops ventricosa</i>	Triti.	Rectangular	12.608	(0.248-0.28)	0.263	(0.602-0.63)	0.618	Light brown
<i>Hordeum murinum</i> ssp., leporinum	Triti.	Oblong	2.21	(0.101-0.112)	0.106	(0.395-0.402)	0.400	Beige
<b>Species</b>	<b>Trichomes type</b>	<b>Hairs length</b>	<b>Hairs coloring</b>	<b>Position of hairs attaching</b>			<b>Fruit surface cells type</b>	
<i>Sorghum variegatum</i>	Absent	-	-	-			Striate	
<i>Aristida adscensionis</i>	Simple hairs	Short	Colored	At the base of fruit			Striate to scabrate	
<i>Aristida funiculata</i>	Simple hairs	Short	Colored	At the base of fruit			Reticulate with undulate cell walls	
<i>Aristida mutabilis</i>	Simple hairs	Short	Colored	At the base of fruit			Striate	
<i>Stipogrostis ciliata</i>	Simple hairs	Short	Colored	At the base of fruit			Ribbed pattern cell walls	

Table 1: Continue

Species	Trichomes type	Hairs length	Hairs coloring	Position of hairs attaching	Fruit surface cells type
<i>Sclerismus arabicus</i>	Absent	-	-	-	Smooth
<i>Avena barbata</i>	Simple hairs	Short	Colored	Around all the fruit surface condensed at top	Striate
<i>Avena fatua</i>	Simple hairs	Long	Colored	Around all the fruit surface	Striate
<i>Phalaris minor</i>	Simple hairs	Short	Shiny	Around all the fruit surface	Scabrate
<i>Polygonon maritimum</i>	Absent	-	-	-	Striate to scabrate
<i>Polygonon monspeliensis</i>	Absent	-	-	-	Rugose
<i>Brachypodium distachyum</i>	Simple hairs	Short	Shiny	At the edges of the fruit	Striate
<i>Bromus rubens</i>	Simple hairs	Short	Shiny	Around all the fruit surface	Compound reticulate with granulate
<i>Bromus scoparius</i>	Simple hairs	Short	Shiny	On the side margin of fruit sheath	Striate
<i>Coelachyrum brevifolium</i>	Absent	-	-	-	Reticulate with undulate cell walls
<i>Dactyloctenium aegyptium</i>	Absent	-	-	-	Compound reticulate with tuberculate
<i>Eragrostis cilianensis</i>	Absent	-	-	-	Scaly surface
<i>Eragrostis minor</i>	Absent	-	-	-	Reticulate with striate cell walls
<i>Leptochloa fusca</i>	Absent	-	-	-	Reticulate with striate cell walls
<i>Cenchrus ciliaris</i>	Absent	-	-	-	Reticulate with undulate cell walls
<i>Echinochloa colona</i>	Absent	-	-	-	Compound reticulate with foveolate
<i>Panicum turgidum</i>	Absent	-	-	-	Reticulate with striate cell walls
<i>Dactylis glomerata</i>	Absent	-	-	-	Reticulate with undulate cell walls
<i>Lamarckia aurea</i>	Simple hairs	Long	Colored	At the base of fruit	Reticulate with undulate cell walls
<i>Lolium perenne</i>	Absent	-	-	-	Striate
<i>Poa annua</i>	Simple hairs	Short	Colored	At the top of fruit	Scalariform
<i>Oryzopsis miliacea</i>	Simple hairs	Short	Colored	At the top of fruit	Rugose
<i>Stipa capensis</i>	Simple hairs	With different lengths	Colored	At the base of fruit	Striate at intermediate and reticulate with striate cell walls next to hilum
<i>Stipa lagascae</i>	Simple hairs	Short	Colored	Around all the fruit surface	Reticulate with striate to undulate cell walls
<i>Stipa parviflora</i>	Simple hairs	Short	Shiny	At the base of fruit	Striate
<i>Aegilops kotschy</i>	Simple hairs	Short	Colored	At the top of fruit	Striate
<i>Aegilops ventricosa</i>	Simple hairs	Short	Colored	At the top of fruit	Striate
<i>Hordeum murinum</i> ssp., <i>leporinum</i>	Absent	-	-	-	Reticulate with undulate granulate cell walls

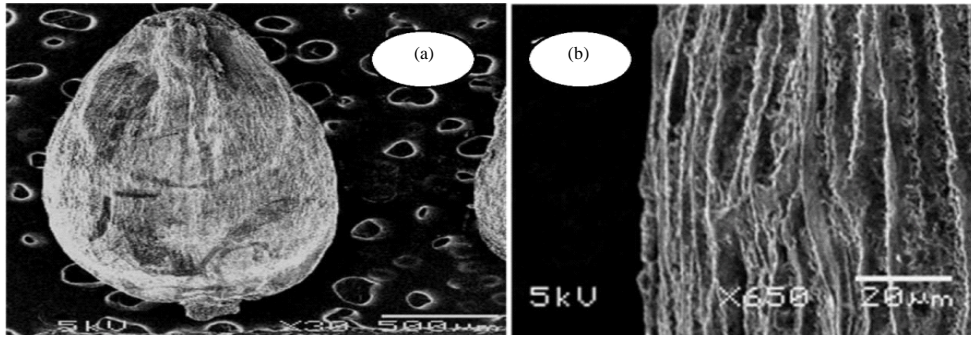


Fig. 1(a-b): SEM photographs of *Sorghum variegatum* (a) Entire fruit and (b) Enlarged part of fruit coat surface

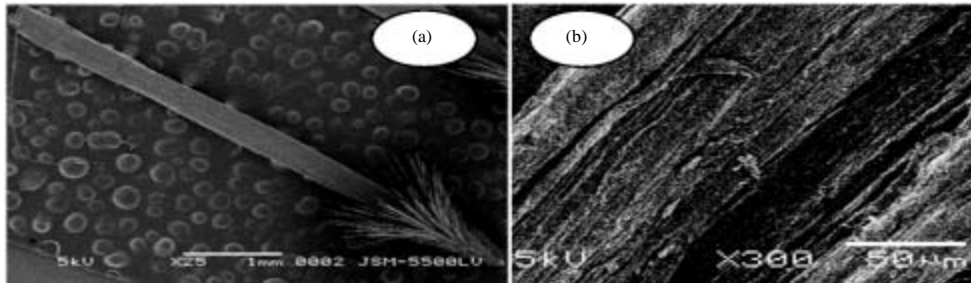


Fig. 2(a-b): SEM photographs of *Aristida adscensionis* (a) Entire fruit and (b) Enlarged part of fruit coat surface

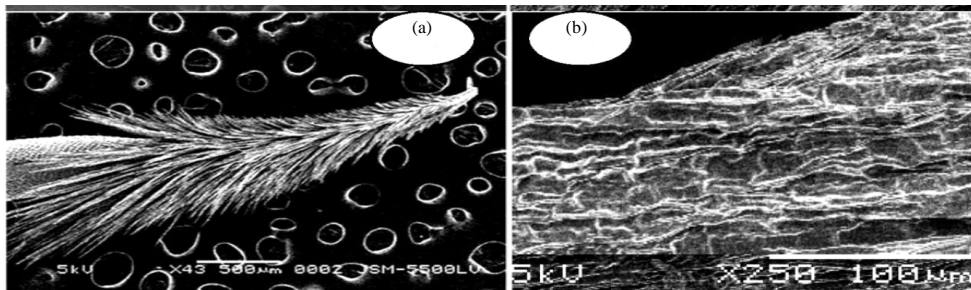


Fig. 3(a-b): SEM photographs of *Aristida funiculata* (a) Entire fruit and (b) Enlarged part of fruit coat surface

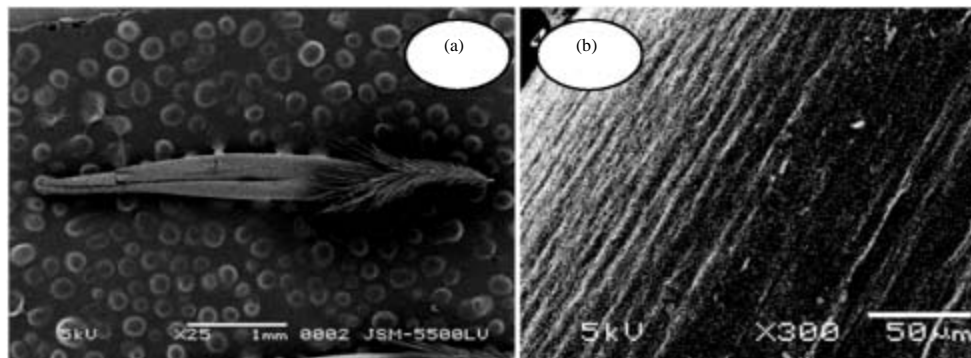


Fig. 4(a-b): SEM photographs of *Aristida mutabilis* (a) Entire fruit and (b) Enlarged part of fruit coat surface

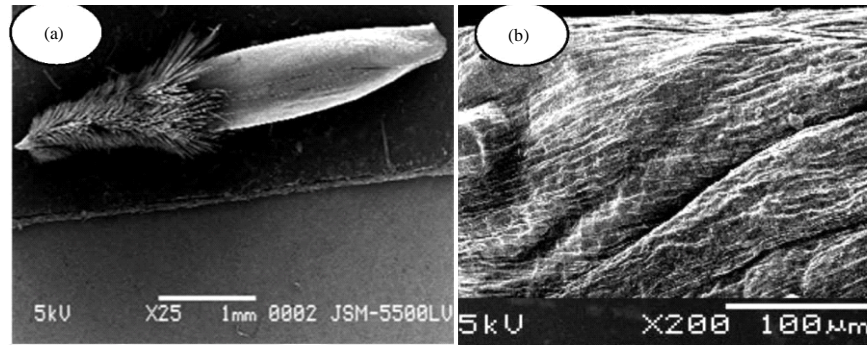


Fig. 5(a-b): SEM photographs of *Stipagrostis ciliate* (a) Entire fruit and (b) Enlarged part of fruit coat surface

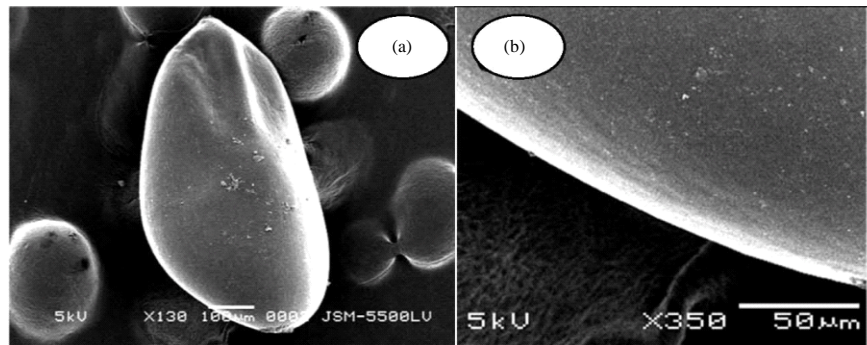


Fig. 6(a-b): SEM photographs of *Schismus arabicus* (a) Entire fruit and (b) Enlarged part of fruit coat surface

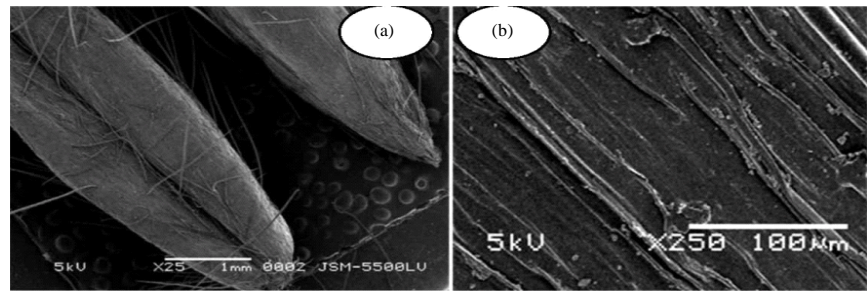


Fig. 7(a-b): SEM photographs of *Avena barbata* (a) Entire fruit and (b) Enlarged part of fruit coat surface

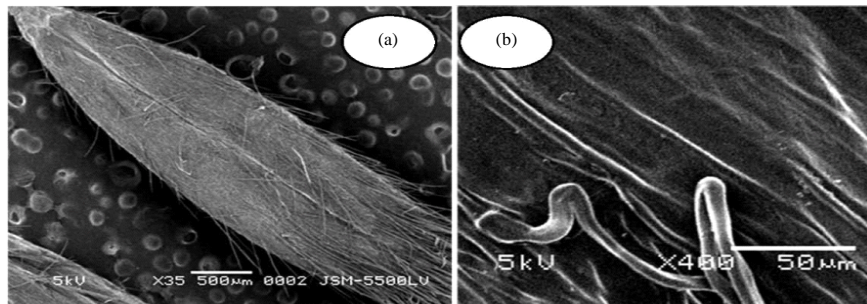


Fig. 8(a-b): SEM photographs of *Avena fatua* (a) Entire fruit and (b) Enlarged part of fruit coat surface

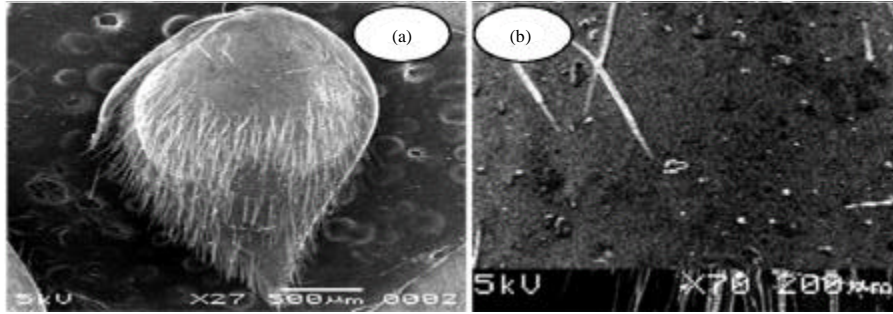


Fig. 9(a-b): SEM photographs of *Phalaris minor* (a) Entire fruit and (b) Enlarged part of fruit coat surface

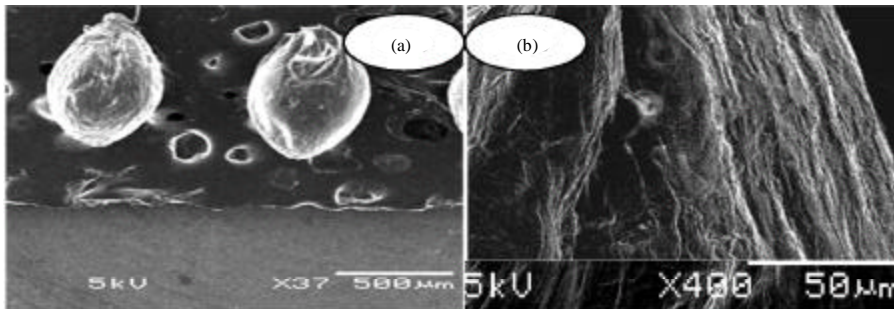


Fig. 10(a-b): SEM photographs of *Polypogon maritimus* (a) Entire fruit and (b) Enlarged part of fruit coat surface

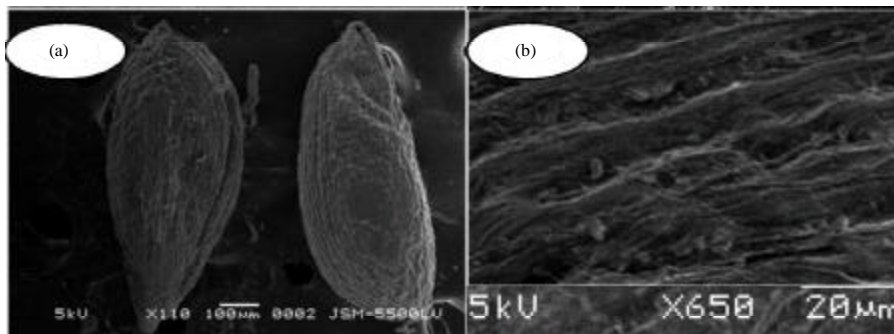


Fig. 11(a-b): SEM photographs of *Polygon monspeliensis* (a) Entire fruit and (b) Enlarged part of fruit coat surface

**Tribe: Brachypodieae**

***Brachypodium distachyum* L. (Fig. 12a, b):** The caryopsis is linear in shape, mass 3.89 mg and 0.106×0.569 mm in size as (width×length). The fruit is hairy with short shiny simple hairs positioned at the edges of the fruit. The seed surface exhibits one color; dark red; and is striate in sculpturing.

**Tribe: Bromeae**

***Bromus rubens* L. (Fig. 13a, b):** The caryopsis is tall oblong with tapered ends in shape, mass 2.27 mg and 0.122×1.012 mm in size as (width×length). The fruit is hairy

with short shiny simple hairs positioned around the entire seed surface. The seed surface exhibits one color; dark red; and is compound reticulate with granulate in sculpturing.

***Bromus scoparius* L. (Fig. 14a, b):** The caryopsis is linear in shape, mass 0.76 mg and 0.059×6.66 mm in size as (width×length). The fruit is hairy with short shiny simple hairs positioned around the side margin of the fruit sheath. The seed surface exhibits one color; dark red; and is striate in sculpturing.



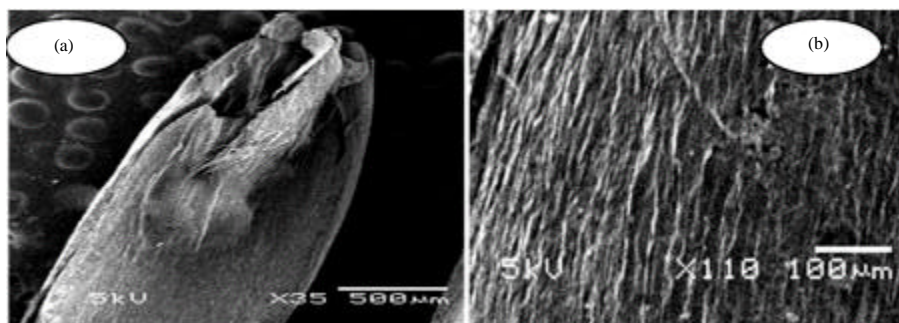


Fig. 12(a-b): SEM photographs of *Brachypodium distachyum* (a) Entire fruit and (b) Enlarged part of fruit coat surface

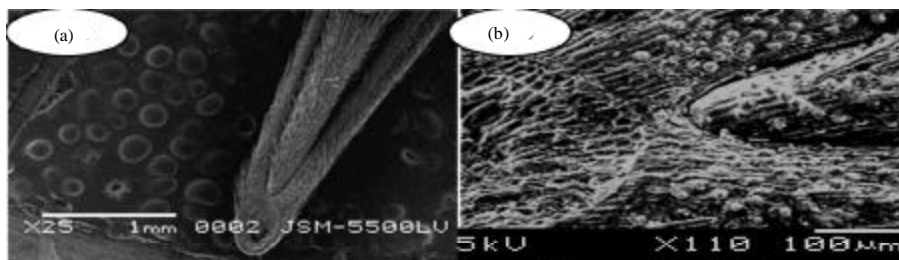


Fig. 13(a-b): SEM photographs of *Bromus rubens* (a) Enlarged part of fruit and (b) Enlarged part of fruit coat surface

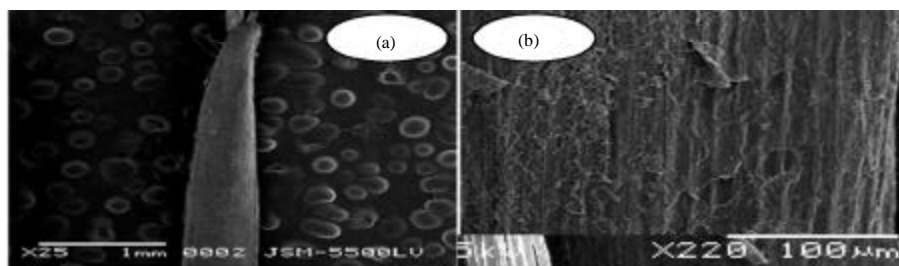


Fig. 14(a-b): SEM photographs of *B. scoparius* (a) Enlarged part of fruit and (b) Enlarged part of fruit coat surface

**Tribe: Eragrostideae**

***Coelachryum bervifolium* Hochst. and Nees. Fig. 15a, b):**

The caryopsis is cordate with hollow part in shape, mass 0.18 mg and 0.086×0.107 mm in size as (width×length). The fruit is glabrous with no hairs. The seed surface exhibits one color; dark red and is reticulate with undulate cell walls in sculpturing.

***Dactyloctenium aegyptium* L. (Fig. 16a, b):**

The caryopsis is oval in shape, mass 0.14 mg and 0.061×0.072 mm in size as (width×length). The fruit is glabrous with no hairs. The seed surface exhibits two colors; beige with brown protrusions; and is compound reticulate with tuberculation in sculpturing.

***Eragrostis cilianensis* All. (Fig. 17a, b):**

The caryopsis is circular in shape, mass 0.10 mg and 0.050×0.066 mm in size as (width×length). The fruit is glabrous with

no hairs. The seed surface is of one colored mode; brown colored and the surface is scaly like.

***Eragrostis minor* Host, Icon. (Fig. 18a, b):**

The caryopsis is elliptic in shape, mass 0.43 mg and 0.043×0.084 mm in size as (width×length). The fruit is glabrous with no hairs. The seed surface is of one colored mode; light brown colored and the surface is reticulate with striate cell walls.

***Leptochloa fusca* L. (Fig. 19a, b):**

The caryopsis is elliptic in shape, mass 0.06 mg and 0.037×0.084 mm in size as (width×length). The fruit is glabrous with no hairs. The seed surface is of bicolored mode; brown and light orange colors; while it is reticulate with striate cell walls.

**Tribe: Paniceae**

***Cenchrus ciliaris* L. (Fig. 20a, b):**

The caryopsis is cordate in shape, mass 0.31 mg and 0.100×0.197 mm

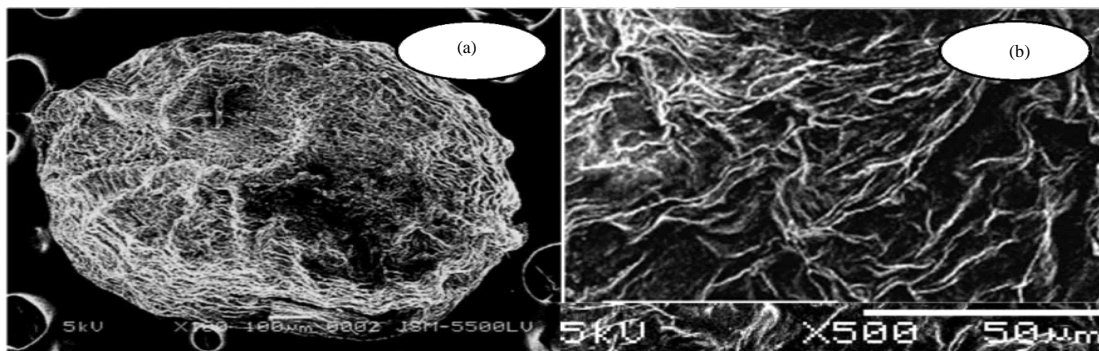


Fig. 15(a-b): SEM photographs of *Coelachyrum bervifolium* (a) Enlarged part of fruit and (b) Enlarged part of fruit coat surface

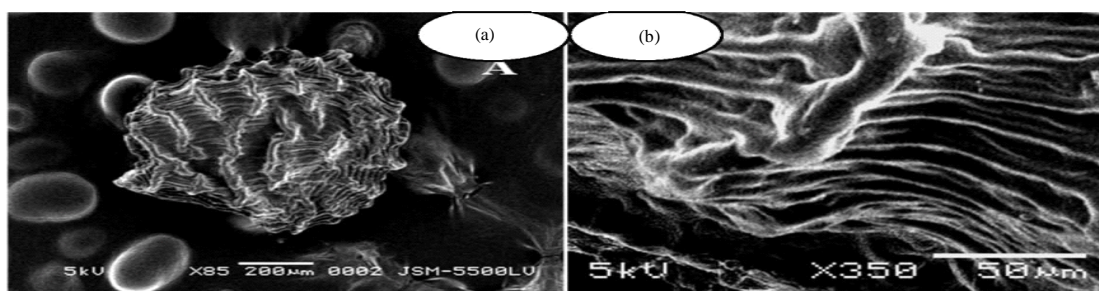


Fig. 16(a-b): SEM photographs of *Dactyloctenium aegyptium* (a) Entire fruit and (b) Enlarged part of fruit coat surface

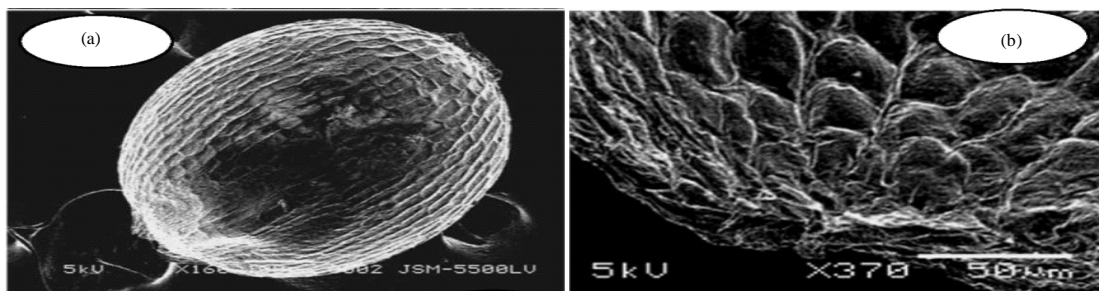


Fig. 17(a-b): SEM photographs of *Eragrostis cilianensis* (a) Entire fruit and (b) Enlarged part of fruit coat surface

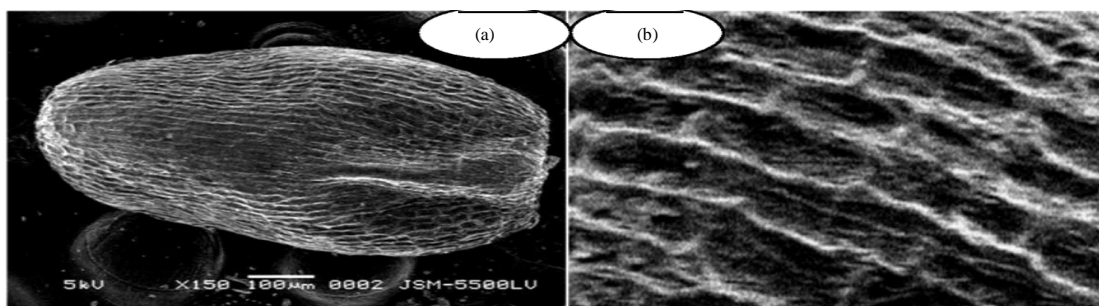


Fig. 18(a-b): SEM photographs of *Eragrostis minor* (a) Entire fruit and (b) Enlarged part of fruit coat surface

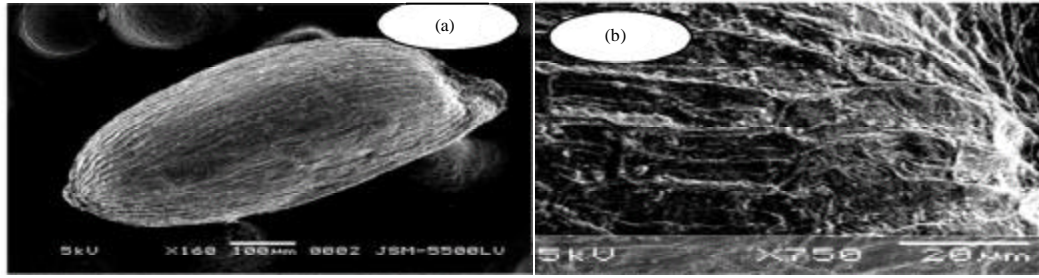


Fig. 19(a-b): SEM photographs of *Leptochloa fusca* (a) Entire fruit and (b) Enlarged part of fruit coat surface

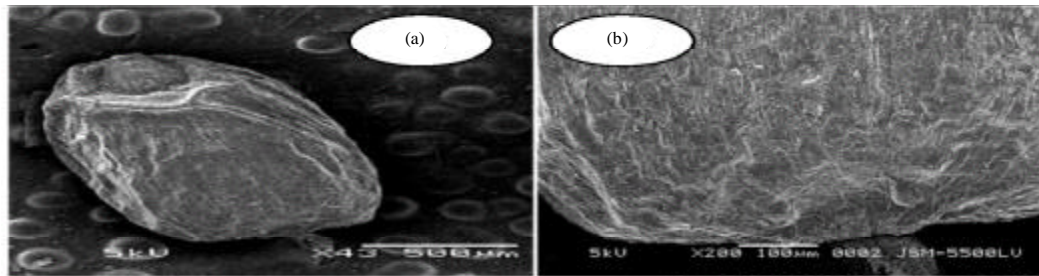


Fig. 20(a-b): SEM photographs of *Cenchrus ciliaris* (a) Entire fruit and (b) Enlarged part of fruit coat surface

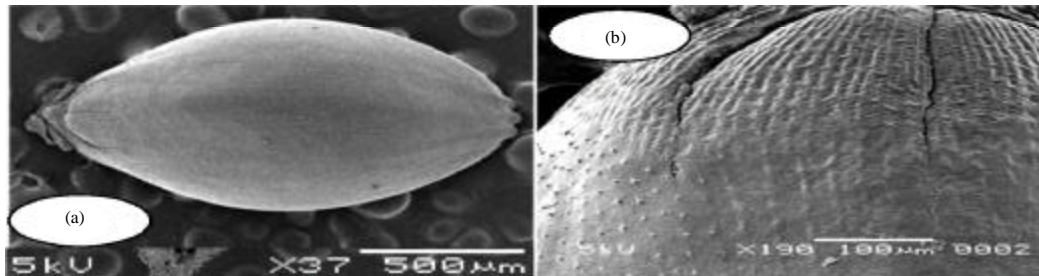


Fig. 21(a-b): SEM photographs of *Echinochloa colona* (a) Entire fruit and (b) Enlarged part of fruit coat surface

in size as (width×length). The fruit is glabrous with no hairs. The seed surface is of bicolored mode; beige and brown black spots; while it is reticulate with undulate cell walls.

***Echinochloa colona* L. (Fig. 21a, b):** The caryopsis is cordate in shape, mass 0.54 mg and 0.120×0.239 mm in size as (width×length). The fruit is glabrous with no hairs. The seed surface is of bicolored mode; light beige with light green strips; while it is compound reticulate with faveolate in sculpturing.

***Panicum turgidum* L. (Fig. 22a, b):** The caryopsis is narrow cordate, mass 0.31 mg and 0.269×0.253 mm in size as (width×length). The fruit is glabrous with no hairs. The seed surface is of one colored; beige; while it is striate with cell walls in sculpturing.

**Tribe: Poae**

***Dactylis glomerata* L. (Fig. 23a, b):** The caryopsis is oval with acute protrusion, mass 0.09 mg and 0.064×0.109 mm in size as (width×length). The fruit is glabrous with no hairs. The seed surface is of one colored; brown; while it is reticulate with undulate cell walls in sculpturing.

***Lamarckia aurea* L. (Fig. 24a, b):** The elliptic with tapered ends, mass 0.34 mg and 0.077×0.199 mm in size as (width×length). The fruit is hairy with long colored simple hairs positioned at the base of the fruit. The seed surface is of two colored mode; light brown and the ends are dark brown. The surface is reticulate with undulate cell walls in sculpturing.

***Lolium perenne* L. (Fig. 25a, b):** The caryopsis is rectangular in shape, mass 2.88 mg and 0.134×0.411 mm in

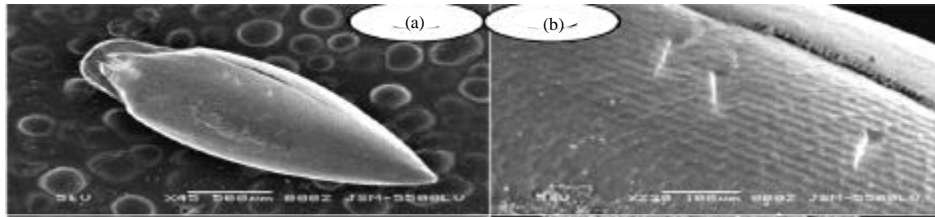


Fig. 22(a-b): SEM photographs of *Panicum turgidum* (a) Entire fruit and (b) Enlarged part of fruit coat surface

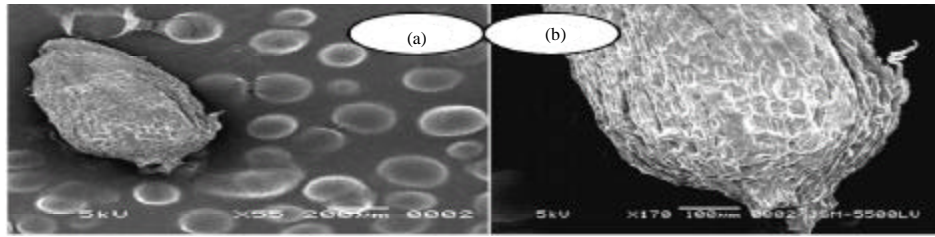


Fig. 23(a-b): SEM photographs of *Dactylis glomerata* (a) Entire fruit and (b) Enlarged part of fruit coat surface

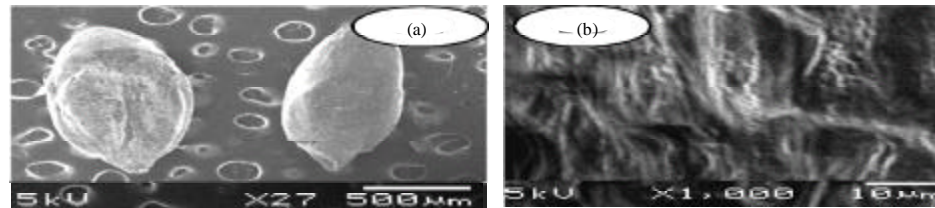


Fig. 24(a-b): SEM photographs of *Lamarckia aurea* (a) Entire fruit and (b) Enlarged part of fruit coat surface

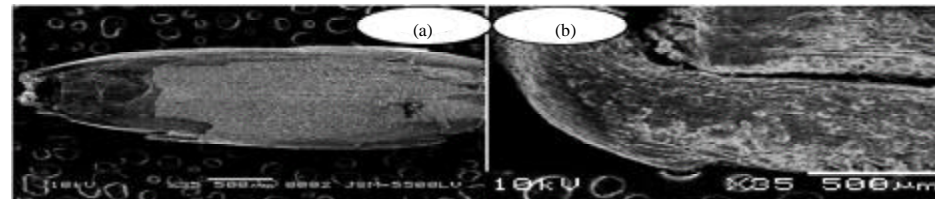


Fig. 25(a-b): SEM photographs of *Lolium perenne* (a) Entire fruit and (b) Enlarged part of fruit coat surface

size as (width×length). The fruit is glabrous without any trichomes. The seed surface is of two colored mode; dark brown with light yellowish sheath. While the surface is striate in sculpturing.

***Poa annua* L. (Fig. 26a, b):** The caryopsis is elliptic in shape, mass 0.19 mg and 0.052×0.158 mm in size as (width×length). The fruit is hairy with short colored simple hairs positioned at the top of the fruit. The seed surface is of one colored mode; brown color. The surface sculpturing of the type scalariform.

**Tribe: Stipeae**

***Oryzopsis miliacea* L. (Fig. 27a, b):** The caryopsis is oval, mass 0.34 mg and 0.085×0.205 mm in size as

(width×length). The fruit is hairy with short colored simple hairs positioned at the top of the fruit. The seed surface is of one colored mode; dark beige. The surface sculpturing of the type rugose.

***Stipa capensis* Thumb. (Fig. 28a, b):** The caryopsis is oblong in shape, mass 0.75 and 0.059×0.424 mm in size as (width×length). The fruit is hairy, colored simple hairs with different lengths positioned at the base of the fruit. The fruit color is light brown. The seed surface exhibits variant sculpturing type whereas it is striate at intermediate region and reticulate with striate cell walls at region next to hilum.

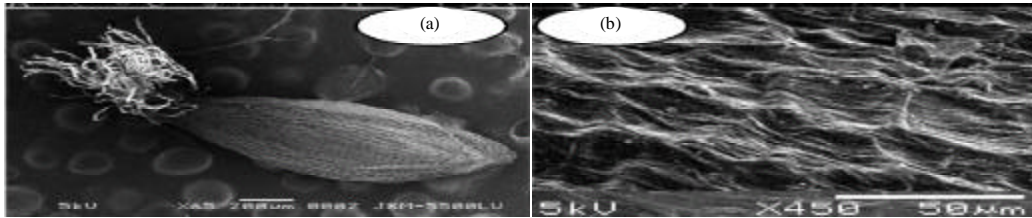


Fig. 26(a-b): SEM photographs of *Poa annua* (a) Entire fruit and (b) Enlarged part of fruit coat surface

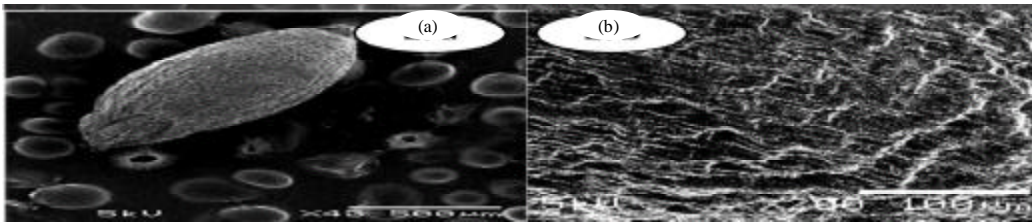


Fig. 27(a-b): SEM photographs of *Oryzopsis miliacea* (a) Entire fruit and (b) Enlarged part of fruit coat surface

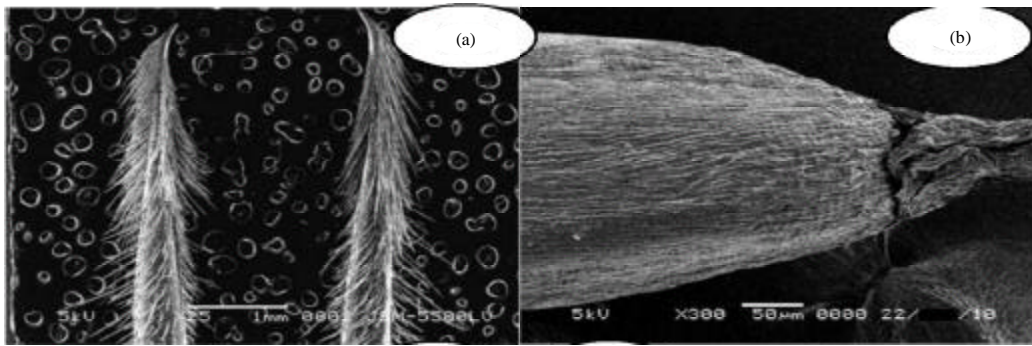


Fig. 28(a-b): SEM photographs of *Stipa capensis* (a) Entire fruit and (b) Enlarged part of fruit coat surface

***Stipa lagascae* Roem. et Schult. (Fig. 29a, b):** The caryopsis is short oblong in shape, mass 0.98 mg and 0.065×0.676 mm in size as (width×length). The fruit is hairy with short colored simple hairs scattered around the entire the fruit surface. The fruit color is brown. The sculpturing type is of reticulate type with striate to undulate cell walls.

***Stipa parviflora* Desf. (Fig. 30a, b):** The caryopsis is tall oblong in shape, mass 2.48 mg and 0.078×1.233 mm in size as (width×length). The fruit is hairy with short shiny simple hairs at the base of the fruit. The fruit is one colored of beige appearance. The surface sculpturing of the type striate.

**Tribe: Triticeae**

***Aegilops kotschy* Boiss. (Fig. 31a, b):** The caryopsis is oblong in shape with striate sculpturing, mass 5.94 mg and 0.176×0.649 mm in size as (width×length). The fruit is

hairy with short colored simple hairs at the top of the fruit. It is bicolored by brown with light green sheath.

***Aegilops ventricosa* Tausch. (Fig. 32a, b):** The caryopsis is rectangular in shape with striate sculpturing, mass 12.60 mg and 0.263×0.618 mm in size as (width×length). The fruit is hairy with short colored simple hairs at the top of the fruit. It is one colored with light brown color.

***Hordeum murinum* L. ssp. *leporinum* Link. (Fig. 33a, b):** The caryopsis is oblong in shape, mass 2.21 mg and 0.106×0.400 mm in size as (width×length). The fruit is glabrous without any trichomes. The fruit is one colored with beige color. The sculpturing type is reticulate with undulate to granulate cell walls.

The caryopses of weed taxa included in this study are examined through different macro- and micro-morphological characters; shape, size, weight, coloring

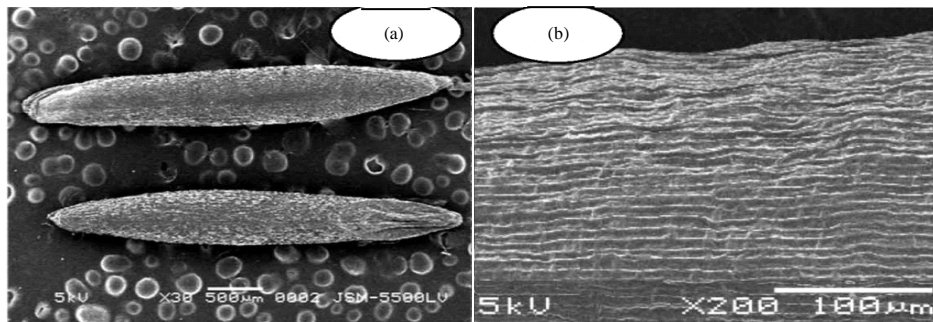


Fig. 29(a-b): SEM photographs of *Stipa lagascae* (a) Entire fruit and (b) Enlarged part of fruit coat surface

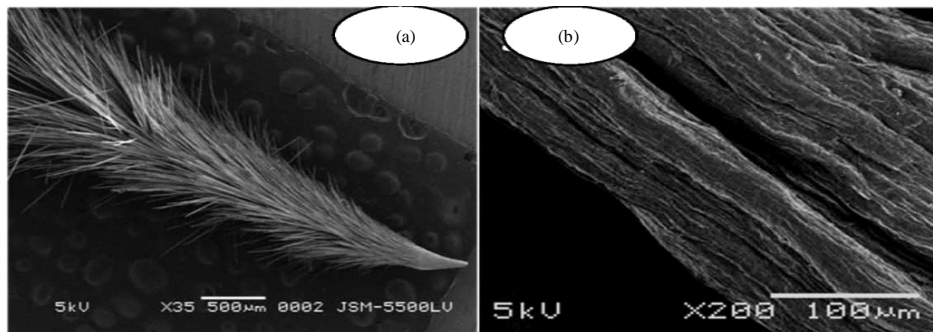


Fig. 30(a-b): SEM photographs of *Stipa parviflora* (a) Entire fruit and (b) Enlarged part of fruit coat surface

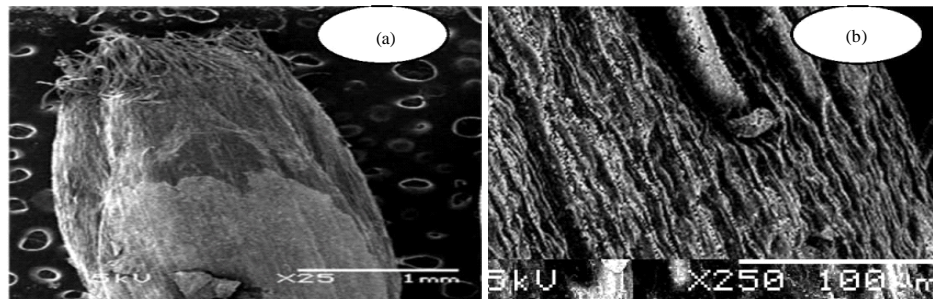


Fig. 31(a-b): SEM photographs of *Aegilops kotshyi* (a) Enlarged part of fruit and (b) Enlarged part of fruit coat surface

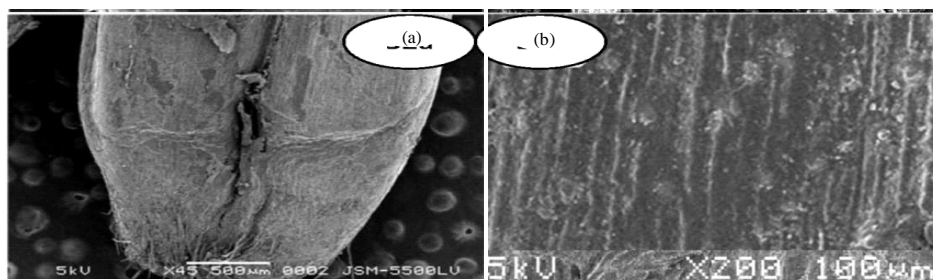


Fig. 32(a-b): SEM photographs of *Aegilops ventricosa*, (a) Enlarged part of fruit and (b) Enlarged part of fruit coat surface

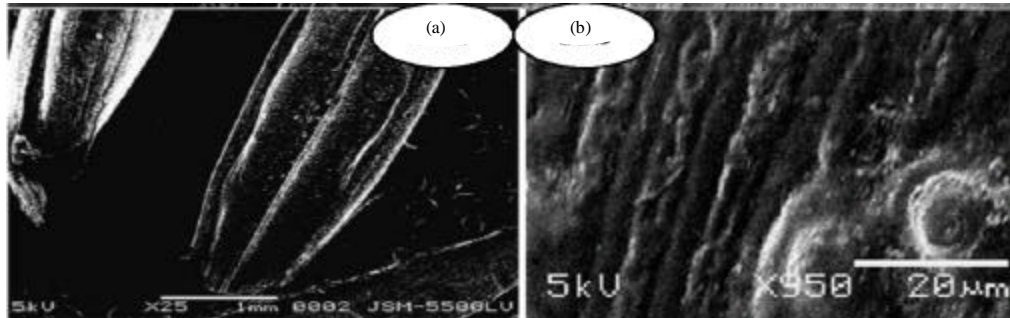


Fig. 33(a-b): SEM photographs of *Hordeum murinum* ssp., *leporinum* (a) Enlarged part of fruit and (b) Enlarged part of fruit coat surface

mode and colour shade, trichomes and their features and the seed surface topography. Of the general characters mentioned, the caryopses are distinct by three principal diagnostic characters; (1) fruit shape, (2) mode of coloring and (3) seed surface topography.

**Fruit shape:** The shape of fruits among the investigated taxa showed a large variation. It exhibits different types; cordate, oval, oblong, circular, elliptic, rectangular and linear. In addition to some modified types from the proper shapes; long and short linear, short and tall oblong, oblong with tapered ends, narrow cordate and other shapes that appeared to be characteristic to certain species. Cordate with hollow part in *Coelachrym bervifolium*, elliptic with tapered ends in *Lamarckia aurea*, oval with acute protrusions in *Dactylis glomerata* and tall oblong with tapered ends in *Bromus rubens*. The shape of seeds can serve as a diagnostic character; between different genera and species within a tribe, also the seed shape has been detected to be specific to species by Carlquist *et al.* (1997). The fruit shape showed a great variation that can aid in differentiating between taxa within each tribe; at the generic and specific levels in the Aveneae, Eragrostideae and Stipeae while in Bromaeae, fruit shape is differentiating between species and the fruit shape is helpful in separating genera within tribe Poeae.

**Fruit size:** Fruit dimensions vary greatly among the examined taxa, the fruit lengths ranged from the shortest length, 0.066 mm; in *Eragrostis cilianensis* to the tallest length, 12.33 mm; in *Stipa parviflora*. Also the wide of fruits varies in different values, the smallest wide, 0.042 mm; in *Aristida funiculata* while the largest wide, 0.269 mm; in *Panicum turgidum*. The rest taxa have slightly varied dimensions; (0.072-9.33 mm) in length and (0.043-0.263 mm). The fruit dimensions found then to be useful to separate between two species of *Aristida*, three genera in tribe Paniceae where as they have relatively the

same fruit shape and between two species of *Avena* where their length values can separate them confirming the fruits shape difference.

**Fruit mass:** The seeds of weed plants in Gramineae are characterized by the small mass. The mass of fruits exhibits different values among taxa even between genera and species. The minimum mass, 0.06 mg in *Leptochloa fusca* (Eragrostideae) while the maximum mass, 6.65 mg in *Avena fatua* (Aveneae). The fruit mass is a significant tool to separate between the investigated species and genera, we can observed that in species of both *Avena* and *Polypogon* of tribe Aveneae, in two species of *Bromus* in tribe Bromaeae, in two species of *Aegilops* in tribe Triticeae; also in both *Aegilops kotschyi* and *Hordeum murinum* ssp. *leporinum*; and finally in species of *Dactylis glomerata*, *Lamarckia aurea*, *Lolium perenne* and *Poa annua* of tribe Poeae.

Thus the previous indications imply the importance of the fruit shape, size and mass; as useful macromorphological features; in aiding the differentiation between taxa. Moreover, they are highly related characters to each other in a plant group. That is regarding the conclusion which reveals that the total mass of a seed is determined primarily by its size. Also the general shape of the fruit can be in some way related to the size of the fruit. The final shape and size of seeds have another relation of their importance effect on their dispersal and this fact which is correlated to Gramineae where the fruit and the seed constitute one unit for dispersing. Finally, the variation in seed size and mass can exist also between different populations of a species was recorded by other investigators (Black, 1957, 1958; Harper, 1977; Stanton, 1984; Venable, 1985; Venable and Levin, 1985; Ellison, 1987).

**Mode of colouring:** Seeds may be uniformly colored or bicolor. The colour of seeds may be uniform within a

Table 2: Combination between several morphological characters aiding in taxonomy

Taxa	Tribes	Shape	Coloring mode	Trichomes presence	Surface sculpture
<i>Sorghum variegatum</i>	Andro.	cordate	bi-colored	Absent	Striate
<i>Schismus arabicus</i>	Anund.	oval	bi-colored	Absent	Smooth
<i>Dactyloctenium aegyptium</i>	Eragro.	oval	bi-colored	Absent	Compound reticulate with tuberculate
<i>Leptochloa fusca</i>	Eragro.	elliptic	bi-colored	Absent	Compound reticulate with striate
<i>Cenchrus ciliaris</i>	Panic.	cordate	bi-colored	Absent	Compound reticulate with undulate
<i>Echinochloa colona</i>	Panic.	cordate	bi-colored	Absent	Compound reticulate with faveolate
<i>Lamarckia aurea</i>	Poeae	elliptic tapering ends	bi-colored	Present	Compound reticulate with undulate

Andro: Andropogoneae, Arund: Arundineae, Eragro: Eragrostideae, Panic: Paniceae

taxon, combined with shape and size, have a diagnostic and taxonomic value. The seed color may be specific of subfamilies, species and cultivars (Carlquist *et al.*, 1997). Gramineae seeds included in the present investigation confirmed the two modes of coloring, that at maturity some species seeds exhibit one color, some others exhibit two colors. Also a large variation of color shades appear in Gramineae caryopses; that variation seems to be a unique group of colors that range from light beige, beige, light brown, brown and dark red. Some other different colors appear to participate the main colors in seeds of two coloring mode; the more brighten colors; light violet, light green, light yellow and light orange. The manner of coloration is a criterion for differentiating taxa at various levels. In Aristideae, at the species level; between three species of *Aristida* and at the generic level; between the differently colored *Aristida adscensionis*, *A. funiculata*, *A. mutabilis* and *Stipagrostis ciliata*. Among Eragrostideae, the coloring mode can be useful for characterizing four genera; *Coelachryum bervifolium*, *Dactyloctenium aegyptium*, *Eragrostis* sp. and *Leptochloa fusca*. Between two species of *Aegilops*, the coloring mode and the color shade can be helpful character to separate *Aegilops kotschyi* and *A. ventricosa*. At the species level, also the color shade can differentiate between the three *Stipa* sp., *S. capensis*, *S. lagascae* and *S. parviflora*. While the coloring mode and color shade are uniform among Bromaceae within the two *Bromus*; *B. rubens* and *B. scoparius*.

**Trichomes appearance:** Gramineae seeds of some taxa are characterized by the presence of such projections. The trichomes defined in the tribes; Aristideae, Aveneae, Brachypodieae, Bromaceae, Poeae, Stipeae and Triticeae; are simple hairs which may be shiny or colored; mostly white creamy; long or short or even with different lengths. The position of attaching hairs on the caryopsis also can be a characteristic feature. The trichomes appearance; presence or absence and their features of length, coloring and attaching position; is a differentiation tool can be used in characterizing between taxa. Among Aveneae, two species of *Polypogon* are glabrous i.e. without hairs while the rest genera and species the tribe are hairy. In Poeae, *Lamarckia aurea* and *Poa annua* are hairy while

*Dactylis glomerata* and *Lolium perenne* are glabrous and so as in Triticeae whereas *Aegilops* sp. are hairy while *Hordeum murinum* ssp. *leporinum* is glabrous.

**Surface topography:** Seeds surface of Gramineae represent highly variant types of surface sculpturing which can be an identifier for some taxa even at the specific level. Surface topography of seeds and of larger dispersal units can be in many cases of diagnostic significance (Brisson and Peterson, 1976). In tribes of Gramineae weeds studied, the seed surface exhibit differently sixteen surface sculpturing types, they ranged from striate and its modified types, reticulate and reticulate with different cell wall constructions, smooth, scabrate, rugose and ripped pattern also are defined. In the Aristideae, the surface sculpturing exhibits four different types of ornamentation those are helpful for separating between four species within the same group. In Paniceae, the seed surface sculpture type is an aid in characterizing the taxa included at the generic level. Thus the seed surface sculpturing alone can be of great taxonomic significance. Moreover, the combination with one or more of the seed macro- and micro-morphological characters, also can create more satisfying criteria for distinguishing different taxa both at generic and specific levels and hence can evaluate some distinct features for a certain plant group even at the tribal level. That can be summarized and exemplified in Table 2. In this table, it is clear that the fruit shape and the surface sculpture type can separate between two genera in one tribe (Eragro. = Eragrostideae); when the colouring mode and trichomes presence are similar in *Dactyloctenium aegyptium* and *Leptochloa fusca*. So as in Paniceae whereas the shape, colouring mode and trichomes presence are uniformed characters between *Cenchrus ciliaris* and *Echinochloa colona*; while the two genera are obviously different in the surface sculpturing type. In addition to, separated genera; *Sorghum variegatum*, *Schismus arabicus* and *Lamarckia aurea* of different tribes; Andropogoneae, Arundineae and Poeae, respectively; can be distinct by their shapes, trichomes presence and surface sculpturing, though their similarity in the colouring mode.



Table 3: Key to the investigated seeds.

1: Fruits bicolored	2
Fruits one colored	12
2: Fruit surface sculpture smooth	<i>Schismus arabicus</i>
Fruit surface sculpture otherwise	3
3: Fruit surface sculpture compound reticulate	4
Fruit surface sculpture otherwise	5
4: Reticulation with tuberculate and fruit oval in shape	<i>Dactyloctenium aegyptium</i>
Reticulation with faveolate and fruit cordate in shape	<i>Echinochloa colona</i>
5: Fruit surface sculpture striate or sometimes striate to scabrate	6
Fruit surface sculpture reticulate with undulate to striate cell walls	9
6: Fruits trichomes absent	7
Fruits trichomes simple hairs	8
7: Fruit cordate in shape	<i>Sorghum variegatum</i>
Fruit rectangular in shape	<i>Lolium perenne</i>
8: Trichomes at the base of fruit	<i>Aristida adscensionis</i>
Trichomes at the top of the fruit	<i>Aegilops kotschy</i>
9: Fruit trichomes absent	10
Fruit trichomes simple hairs	11
10: Fruit elliptic in shape	<i>Leptochloa fusca</i>
Fruit cordate in shape	<i>Cenchrus ciliaris</i>
11: Simple hairs long in length	<i>Lamarckia aurea</i>
Simple hairs short in length	<i>Aristida funiculata</i>
12: Fruit surface sculpture ribbed pattern cell walls	<i>Stipagrostis ciliata</i>
Fruit surface sculpture otherwise	13
13: Fruit surface sculpture scabrate	<i>Phalaris minor</i>
Fruit surface sculpture otherwise	14
14: Fruit surface sculpture compound reticulate with granulate	<i>Bromus rubens</i>
Fruit surface sculpture otherwise	15
15: Fruit surface sculpture scaly-like	<i>Eragrostis cilianensis</i>
Fruit surface sculpture otherwise	16
16: Fruit surface sculpture scalariform	<i>Poa annua</i>
Fruit surface sculpture otherwise	17
17: Fruit surface sculpture striate at intermediate and reticulate with striate cell walls next to hilum	<i>Stipa capensis</i>
Fruit surface sculpture otherwise	18
18: Fruit surface sculpture rugose	19
Fruit surface sculpture otherwise	20
19: Fruits with simple hairs	<i>Oryzopsis miliacea</i>
Fruits without hairs	<i>Polypogon monspeliensis</i>
20: Fruit surface sculpture striate or striate to scabrate	21
Fruit surface sculpture reticulate with undulate or striate cell walls	28
21: Fruits without simple hairs	<i>Polypogon maritimus</i>
Fruits with simple hairs	22
22: Fruit color dark red	23
Fruit color otherwise	24
23: Fruit simple hairs at the edges of the fruit	<i>Brachypodium distachyum</i>
Fruit simple hairs on the side margin of fruit	<i>Bromus scoparius</i>
24: Fruit color brown to light brown	25
Fruit color light beige to beige	26
25: Fruit with short linear shape	<i>Aristida mutabilis</i>
Fruit with rectangular shape	<i>Aegilops ventricosa</i>
26: Trichomes at the base of fruit	<i>Stipa parviflora</i>
Trichomes are around all the fruit surface	27
27: Simple hairs short in length	<i>Avena barbata</i>
Simple hairs long in length	<i>Avena fatua</i>
28: Fruit with short simple hairs	<i>Stipa lagascae</i>
Fruit without hairs	29
29: Fruit is elliptic in shape	<i>Eragrostis minor</i>
Fruit shape is otherwise	30
30: Fruit shape is oval with acute protrusions	<i>Dactylis glomerata</i>
Fruit shape is otherwise	31
31: Fruit shape is oblong	<i>Hordeum murinum</i> ssp. <i>leporinum</i>
Fruit shape is cordate to narrow cordate	32
32: Fruit shape is cordate with hollow part	<i>Coelachryum bervifolium</i>
Fruit shape is narrow cordate	<i>Panicum turgidum</i>

From data in Table 1, a very useful key can be used for the identification of different taxa based on the caryopsis morphological characters (Table 3).

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