

## COMPARATIVE ANATOMICAL STUDY ON FRUITS OF SOME TRIBES OF FAMILY GRAMINEAE FROM EGYPT

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### Abstract

Anatomical study surveyed 11 tribes of family Gramineae provided by 31 species of 22 genera. Fruit anatomy is one of the significant taxonomic tools that recently used. Caryopsis fruit of grasses represents an important source of starch-rich food. Sections of each taxa fruit were examined, measured, photographed and line drawings supported. The main parts of a section are seed coat cells, aleurone layer and the starch endosperm. The cotyledon cells, scutellum, are also defined in various types. Different section dimensions were measured, generally the section dimensions found to be related in some means to the fruit size.

### Introduction

Among the various aspects of seed anatomy of the angiosperms, a taxonomic approach is presented by the classical book of Netolitzky (1926). The ever increasing information on seed anatomy is being compiled and extended systematically by Takhtajan and his co-workers (1985, 1988, 1991, and 1992). Seeds also exhibit a great diversity in shape, color, size, surface sculpturing, hairness, appendages, anatomical structure, chemical structure, etc. typical to the species. Some features, like the external and internal seed coat structure, are more stable in a species and may be used as an aid in classification and identification, while others, like color, may be more variable (Carlquist *et al.*, 1997; Khaniki, 2003 and Kanwal *et al.*, 2010).

The seed coat can constitute various proportions of the seed, depending on the species (Jacks, 1990). On the other hand, the structure of the seed coat in a species is determined genetically and has certain genetic trends typical of the family, but it is also modified by other factors, like the type of the fruit, density of seeds in the fruit and external conditions (Shaffer-Fehre, 1991b). Also Carlquist *et al.*, (1997) have stated that seed coat anatomy is species-specific and can serve as an aid in identification and taxonomy. In some families the seed coat is more uniform while in others more variable. Detailed systematic anatomical descriptions of the seed coat are represented in the books of Netolitzky (1926), Corner (1976) and Takhtajan (1985, 1988, 1991, and 1992). Whereas Corner (1976) has concluded that orders and super orders should be based on the structure of the seed coat, as one of the peculiar and intrinsic characters of angiosperms. The seed coat has also been reviewed by Barthlott & Ehler (1977), Barthlott (1981) and Boesewinkel & Bouman (1984).

In angiosperms, in contrast to gymnosperms, the endosperm is formed, together with the zygote, by the process of double fertilization. In the majority of species endosperm continues to develop until a well differentiated endosperm is formed (Carlquist *et al.*, 1997). Endosperm functions as an intermediary tissue, absorbing nutrients from the outer tissues, the seed coat and nucleus, and

accumulating them. It might occupy a considerable volume in the aluminous seed, as in many Gramineae like wheat, barley and maize (Gunn, 1981).

The endosperm, like other reserve tissues in the seed, includes more than one type of reserve materials, within its cells or also in its walls. Its cells may contain protein bodies, oil and starch in their lumina, and may contain reserve polysaccharides in thickened walls. Alkaloids may be also present in the oil of the endosperm (Netolitzky, 1926). Moreover, endosperm has been suggested to have a morphogenetic role in regulation of embryo development since it includes, in addition to nutrient, growth hormones Cutter & Wilson (1954), Alpi *et al.*, (1975) and Vijayaraghavan & Prabharar (1984).

An investigation for the ultrastructure features of pearl millet and grain sorghum caryopses made by Zeleznak & Varriano-Marston (1982) revealing that the pericarp of those grains is comprised of three distinct layers; epicarp, mesocarp and endocarp. While the major constituent of sorghum and millet aleurone cells are aleurone grains (protein bodies) and lipid bodies. In the grass Channel Millet (*Echinochloa turnerana*), the starchy endosperm contained nearly spherical starch granules, lipids and protein (Irving, 1983).

The main point of this article is to study the anatomical structure for every taxon to help evaluating the similarities and dissimilarities among them which in turn help in extracting good taxonomic criteria for the tribes and genera studied within the family Gramineae.

### Materials and Methods

**Plant material:** The dry mature caryopses of 31 species for 22 genera of Gramineae were selected and collected from plants kept in QNA Herbarium; a proposed acronym for the herbarium of Botany Department of South Valley University in Qena. Their nomenclature was agreed with Boulus (2005, 2009). The plants were collected from different phytogeographical regions of the Egyptian flora, all species have been illustrated in Table 1. The stereomicroscope (SM) OLYMPUS VE-3 with the eyepiece (G20XT) was an aid in examining and collecting the fruits from the plant samples.

**Table 1. List for the investigated taxa with their geographical region.**

No.	Species	Tribes	Herbarium	Collecting region	Year	Collector
1.	<i>Sorghum variegatum</i>	Andro	QNA	N	2004	A.K. OSMAN
2.	<i>Aristida adscensionis</i>	Arist	QNA	GE	2004	A.K. OSMAN
3.	<i>Aristida funiculata</i>	Arist	QNA	GE	2004	A.K. OSMAN
4.	<i>Aristida mutabilis</i>	Arist	QNA	GE	2004	A.K. OSMAN
5.	<i>Stipagrostis ciliata</i>	Arist	QNA	R	2004	A.K. OSMAN
6.	<i>Schismus arabicus</i>	Arund	QNA	M	2006	A.K. OSMAN
7.	<i>Avena barbata</i>	Aven	QNA	N	2005	A.K. OSMAN
8.	<i>Avena fatua</i>	Aven	QNA	N	2005	A.K. OSMAN
9.	<i>Phalaris minor</i>	Aven	QNA	M	2006	A.K. OSMAN
10.	<i>Polypogon maritimus</i>	Aven	QNA	N	2006	A.K. OSMAN
11.	<i>Polypogon monspeliensis</i>	Aven	QNA	N	2006,07	A.K. OSMAN
12.	<i>Brachypodium distachym</i>	Brachy	QNA	M	2006	A.K. OSMAN
13.	<i>Bromus rubens</i>	Brom	QNA	M	2005	A.K. OSMAN
14.	<i>Bromus scoparius</i>	Brom	QNA	M	2006	A.K. OSMAN
15.	<i>Coelachyrum bervifolium</i>	Eragro	QNA	GE	2004	A.K. OSMAN
16.	<i>Dactyloctenium aegyptium</i>	Eragro	QNA	N	2006	A.K. OSMAN
17.	<i>Eragrostis cilianensis</i>	Eragro	QNA	S	2005	A.K. OSMAN
18.	<i>Eragrostis minor</i>	Eragro	QNA	M	2005	A.K. OSMAN
19.	<i>Leptochloa fusca</i>	Eragro	QNA	S	2005	A.K. OSMAN
20.	<i>Cenchrus ciliaris</i>	Panic	QNA	GE	2004	A.K. OSMAN
21.	<i>Echinochloa colona</i>	Panic	QNA	N	2006	A.K. OSMAN
22.	<i>Dactylis glomerata</i>	Poeae	QNA	M	2006	A.K. OSMAN
23.	<i>Lolium perenne</i>	Poeae	QNA	N	2009	N. RABIA
24.	<i>Poa annua</i>	Poeae	QNA	N	2005	A.K. OSMAN
25.	<i>Oryzopsis miliacea</i>	Stipeae	QNA	M	2006	A.K. OSMAN
26.	<i>Stipa capensis</i>	Stipeae	QNA	M	2006	A.K. OSMAN
27.	<i>Stipa lagascae</i>	Stipeae	QNA	M	2006	A.K. OSMAN
28.	<i>Stipa parviflora</i>	Stipeae	QNA	M	2006	A.K. OSMAN
29.	<i>Aegilops kotshyi</i>	Triti	QNA	M	2006	A.K. OSMAN
30.	<i>Aegilops ventricosa</i>	Triti	QNA	M	2006	A.K. OSMAN
31.	<i>Hordium murinum</i> ssp. <i>Leporinum</i>	Triti	QNA	S	2005	A.K. OSMAN

QNA = Qena Faculty of Science Herbarium (QNA a proposed Agronym); M = Mediterranean region; N = Nile region; R = Red sea coastal region; S = Sinai; GE= Gebel Elba; Andro= Andropogoneae; Arist= Aristideae; Arund= Arundineae; Aven= Aveneae; Brachy= Brachypodieae; Brom= Bromeae; Eragro= Eragrostideae; Panic= Paniceae; Triti= Triticeae

**Handling and microscopic investigations:** Fruits anatomical characters; mature dry fruits were soaked in water (12-72 hrs.) and then sectioned by the rotary microtome at 10-15  $\mu$  after being embedded in paraffin wax as described by Johansen (1940). The sections were stained using safranin (2% in ethanol 50%) and light green (1% in absolute ethanol and clove oil) and then permanently mounted in canda Balsam. Anatomical sections were investigated by the light microscope MICROS-AUSTRIA MC-400 using the objectives with different magnifications; the investigation was supported by line drawings for a diagram and a sector for each section. A section dimensions; wide and length ( $\mu$ m); were measured using the ocular-metric supported the light microscope. Sections photographed with a digital photographing unit of a LEICA-DM1000 light microscope provided by a digital video camera of LEICA-EC3. The terminology follow Jackson (1928).

The following abbreviations are used for the details of fruit sections studied: Al.: aleurone cells, Ain.: aleurone initials, Ed.: endosperm, Em.: embryo, Fl.d.: fluidly endosperm, H.: hull, N.: nucleus, P.: pericarp, T.: testa, Sc.: scutellum, SCo.: seed coat, Und.: undifferentiated endosperm.

## Results

Describing fruit section from the outside to inside for each taxon of tribes selected. The tribes, genera and species of family Gramineae that are represented in the flora of Egypt are arranged alphabetically to facilitate consultation. For each species, the valid scientific name is given followed by the citation of the authority and the date of publication. Synonymy is at a minimum level to avoid complications. For full synonymy of the species see El-Hadidi & Fayed (1994/1995) and Boulos (2005, 2009) (Tables 2 and 3).

Table 2. Tabular summary showing the dimensions of sections ( $\mu\text{m}$ ) for taxa studied.

No.	Species	Tribes	Shape in out line	Section dimensions	
				Length ( $\mu\text{m}$ )	Wide ( $\mu\text{m}$ )
1.	<i>Sorghum varigatum</i>	Andro	Rect. acut.	123.33	44.66
2.	<i>Aristida adscensionis</i>	Arist	Oval	47	23
3.	<i>Aristida funiculata</i>	Arist	Circled lin.	55	48
4.	<i>Aristida mutabilis</i>	Arist	Sem. Circular	51	43.66
5.	<i>Stipagrostis ciliata</i>	Arist	Circular	52	46.66
6.	<i>Schismus arabicus</i>	Arund	Triang. Obts.	51	37.33
7.	<i>Avena barbata</i>	Aven	Oval to cordate	112.66	101.33
8.	<i>Avena fatua</i>	Aven	Rect.	204.16	87.66
9.	<i>Phalaris minor</i>	Aven	Oval	95	46.3
10.	<i>Polypogon maritimus</i>	Aven	Circular	50.33	49
11.	<i>Polypogon monspeliensis</i>	Aven	Circular to cordt.	34	31
12.	<i>Brachypodium distachym</i>	Brachy	C- shaped	137.33	44.33
13.	<i>Bromus rubens</i>	Brom	Rectangulae, obtuse to oval	108.33	35
14.	<i>Bromus scoparius</i>	Brom	C- shaped	89	24.66
15.	<i>Coelachyrum bervifolium</i>	Eragro	C- shaped	73.66	49.33
16.	<i>Dactyloctenium aegyptium</i>	Eragro	Polygonal	65.66	41
17.	<i>Eragrostis cilianensis</i>	Eragro	Circular	56	49
18.	<i>Eragrostis minor</i>	Eragro	Circular to cordate	50.33	48.66
19.	<i>Leptochloa fusca</i>	Eragro	Circular	33.33	31.66
20.	<i>Cenchrus ciliaris</i>	Panic	Oval	112.5	56.66
21.	<i>Echinochloa colona</i>	Panic	Triangular	59	36
22.	<i>Dactylis glomerata</i>	Poeae	Circular to triangular, obtuse.	69	60.33
23.	<i>Lolium perenne</i>	Poeae	Oval to rectangular, obtuse.	121.33	62
24.	<i>Poa annua</i>	Poeae	Circular to oval	61.33	47.33
25.	<i>Oryzopsis miliacea</i>	Stipeae	Circular	63.66	56
26.	<i>Stipa capensis</i>	Stipeae	Rectangular, obtuse.	53.33	28
27.	<i>Stipa lagascae</i>	Stipeae	Rectangular, obtuse.	43.66	42
28.	<i>Stipa parviflora</i>	Stipeae	Linear with folded ends	95.33	5.33
29.	<i>Aegilops kotschy</i>	Triti	Cordate	207.5	141.66
30.	<i>Aegilops ventricosa</i>	Triti	Oval to rectangular	265	132.5
31.	<i>Hordium murinum</i> subsp. <i>Leporinum</i>	Triti	Oval to rectangular, curved.	163.33	158.33

Acut. = acute; lin. = linear; sem. = semi; rect. = rectangular; triang. = triangular; obts. = obtuse; cordt. = cordate

### Andropogoneae

#### *Sorghum Moench.*

*Sorghum varigatum* (Hack.) Stapf In Prain, Fl. Trop. Afr.9:111 (1917); Figs. (1, 32: a, b).

Cross section is rectangular in outline, semi-acute at the corners, 44.66 x 123.33  $\mu\text{m}$  in size. The section covered by a hull; one layer of palisade rectangular; obtuse at corners; parenchymatous cells, the layer is 9.36  $\mu\text{m}$  in thickness. Seed coat tegmens; exo-, and endo-tegmens are of thick walls with dark materials. Seed coat is 9.88  $\mu\text{m}$  in thickness. Aleurone cells of one layer of living cells, rectangular in shape and arranged transversally. The aleuronic layer is 5.17  $\mu\text{m}$  in thickness. The cotyledon tissue; scutellum; appeared lower to aleurone. Scutellum is a mass celled part that is elliptic in outline with acuminate ends. The massed part is 273.95 x 65.83  $\mu\text{m}$  in size. The main storage tissue; starchy endosperm; enclosed the rest section space after the layers of aleurone and the scutellum. Endosperm is 108.24  $\mu\text{m}$  in thickness.

### Aristideae

#### *Aristida L.*

*Aristida adscensionis* L., Sp.Pl., ed 1, 82 (1753); Figs. (2, 33: a, b).

Cross section is oval in outline, 47 x 23  $\mu\text{m}$  in size. The section covered by a hull; one layer of palisade

parenchymatous cells, the layer is 13.86  $\mu\text{m}$  in thickness. Seed coat tegmens; exo-, and endo-tegmens are of thick walls with dark materials. Seed coat is 6.03  $\mu\text{m}$  in thickness. The living rectangular aleuronic cells arranged transversally. The layer of aleurone is 4.53  $\mu\text{m}$  thickness. The scutellum tissue is also massed in an elliptic bulk sizes 194.96 x 88.55  $\mu\text{m}$ . The starchy endosperm; enclosed the rest section space after the layers of aleurone and the scutellum. Endosperm exhibit differently regions of thickness, averages as 70.62  $\mu\text{m}$ .

*Aristida funiculata* Trin. & Rupr., sp. Gram. Stipac. 159 (1842); Figs. (3, 34: a, b).

Cross section circled linear with two folded pointed ends in outline, 55 x 48  $\mu\text{m}$  in size. The section is centered with a massive bulk of cells filled with storage materials; this bulk appears as a part of the embryo, taking the size 176.85 x 137.81  $\mu\text{m}$  and is surrounded by a row of compressed epithelial cells with the thickness 14.51  $\mu\text{m}$ . The layers of the section begin with the seed coat; its parts are compressed and take relatively small thickness 2.95  $\mu\text{m}$ . The aleurone layer is not differentiated as same as the scutellum. The whole endosperm is well differentiated and takes the thickness 44.91  $\mu\text{m}$ , this part of endosperm includes the starchy endosperm and some fluidly endosperm in which the cell walls are usually not formed and the central part remain fluidly.

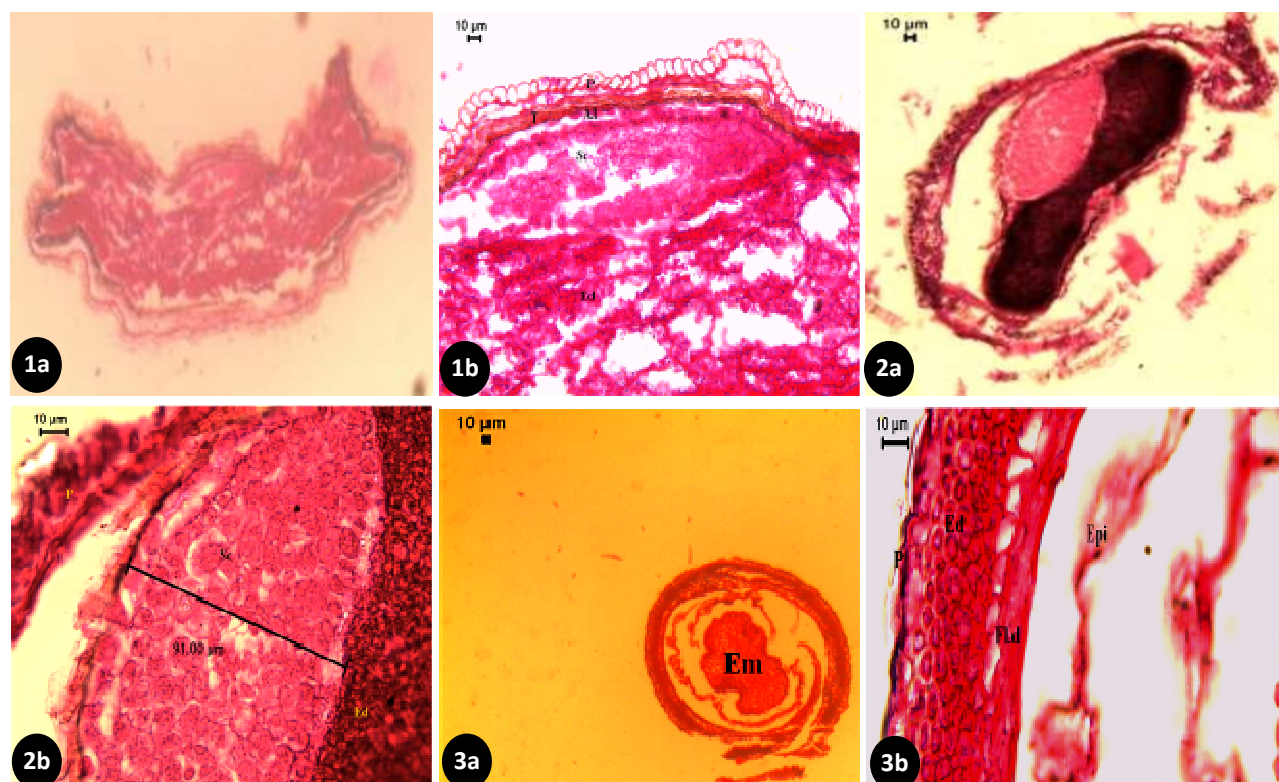
Table 3. Section layers and cells identification for taxa studied.

No.	Species	Hull		Seed coat thickness (µm)	Aleurone			Scutellum		Endosperm		
		Cells type	Thickness (µm)		Cells shape	Orin.	Thick. (µm)	Shape	Dimension (µm)	Differentin.	Type	Thickness (µm)
1.	<i>Sorghum variegatum</i>	Parch.	9.36 (9.27-10.09)	9.88 (8.18-10.94)	Rect.	Horz.	5.17 (5-5.53)	Elip. mass cells	273.95x65.83	differentid.	Starchy	108.24 (103.38-111.67)
2.	<i>Aristida adscensionis</i>	Parch.	13.68 (12.01-15.42)	6.03 (4.57-8.38)	Rect.	Horz.	4.53 (3.75-5.27)	Elip. mass cells	194.96x88.55	differentid.	Starchy	70.62 (34.67-94.02)
3.	<i>Aristida funiculata</i>	no	-	2.95 (2.33-4.19)	no	no	-	no	-	differentid.	Starchy & fluidly	44.91 (44.41-45.60)
4.	<i>Aristida mutabilis</i>	Epith.	12.86 (11.32-14.65)	3.94 (3.76-4.15)	Rect.	Horz. & vert.	8.36 (11.36-14.65)	Elip. mass cells	271.93x81.01	differentid.	Starchy	146.84 (109.22-191.85)
5.	<i>Stipagrostis ciliata</i>	Epith.	14.30 (13.77-14.65)	4.97 (4.02-6.03)	Rect.	Horz.	3.3 (2.58-4.18)	Strip of cells	16.97 (12.55-19.98)	differentid.	Starchy	415.20 (411.68-418.37)
6.	<i>Schismus arabicus</i>	no	-	9.86 (7.74-10.94)	Rect.	Horz.	4.10 (3.76-4.34)	Strip of cells	28.58 (24.83-35.92)	differentid.	Starchy	309.80 (304.48-312.72)
7.	<i>Avena barbata</i>	no	-	7.79 (7.1-9)	Rect.	Vert.	38.82 (31.68-44.77)	Quing mass cells	439.71x272.01	differentid.	Starchy	437.35 (328.07-518.664)
8.	<i>Avena fatua</i>	no	-	24.28 (21.01-27.39)	Rect.	Vert.	33.13 (31.27-35.43)	Strip of cells	44.04 (29.518-54.95)	differentid.	Starchy	619.14 (609.94-630.25)
9.	<i>Phalaris minor</i>	no	-	9.45 (8.7-10.28)	Rect. & plg.	Vert.	20.58 (16.89-26.05)	Strip of cells	8.87 (6.2-11.09)	differentid.	Starchy	358.01 (343.65-369.67)
10.	<i>Polypogon maritimus</i>	no	-	5.20 (6.2-11.09)	Rect. & qudt.	Vert.	15.47 (12.0-17.71)	Strip of cells	21.48 (14.56-27.58)	differentid.	Starchy	354.55 (315.46-377.27)
11.	<i>Polypogon monspeliensis</i>	Parch.	16.25 (14.09-18.33)	4.90 (4.26-6.11)	Rect.	Vert.	12.86 (11.77-13.52)	no	-	differentid.	Starchy	203.71 (162.7-255.04)
12.	<i>Brachypodium distachym</i>	no	-	9.84 (9.45-10.46)	Rect.	Horz.	6.76 (5.92-7.62)	no	-	differentid. + undifferd.	Starchy	174.50 (146.16-206.0)
13.	<i>Bromus rubens</i>	no	-	6.32 (5.32-7.76)	Qudt. & rect.	Vert.	21.11 (19.17-24.50)	no	-	differentid.	Starchy	156.51 (152.86-158.69)
14.	<i>Bromus scoparius</i>	no	-	9.79 (9.36-10.49)	Rect.	Vert.	17.76 (16.32-19.24)	no	-	differentid.	Starchy	83.71 (76.01-87.8)
15.	<i>Coelachyrum berrifolium</i>	Parch.	24.58 (23.04-26.10)	10.39 (8.33-14.28)	Rect.	Horz.	5.15 (4.76-5.23)	Strip of cells	16.34 (13.81-19.52)	differentid.	Starchy	120.98 (93.03-148.26)
16.	<i>Dactyloctenium aegyptium</i>	no	-	9.07 (7.44-10.23)	Rect.	Horz.	4.64 (4.19-5.34)	Train. Mass cells	261.23 x 247.6	differentid.	Starchy	180.65 (152.73-221.88)
								Strip of cells	27.59 (20.7-34.65)			

Table 3. (Cont'd.).

No.	Species	Hull		Seed coat thickness (µm)	Aleurone			Scutellum		Endosperm		
		Cells type	Thickness (µm)		Cells shape	Orin.	Thick. (µm)	Shape	Dimension (µm)	Differentin.	Type	Thickness (µm)
17.	<i>Eragrostis ciliaris</i>	no	-	8.36 (7.32-9.14)	Rect.	Horz.	8.25 (7.32-9.71)	Oval mass cells	234.74x139.47	differentid.	Starchy	243.68 (217.54-276.95)
18.	<i>Eragrostis minor</i>	no	-	9.0 (8-10.77)	no	no	no	Strip of cells	22.71 (21.81-23.7)	differentid.	Starchy	412.68 (406.27-420.01)
19.	<i>Leptochloa fusca</i>	no	-	2.43 (2.37-2.5)	Rect.	Horz.	1.92 (1.65-2.31)	Strip of cells	11.58 (10.27-12.41)	differentid.	Starchy	278.16 (274.08-282.08)
20.	<i>Cenchrus ciliaris</i>	no	-	7.83 (7.17-8.64)	Rect.	Horz.	6.77 (6.52-7.22)	Strip of cells	16.13 (12.92-17.92)	differentid.	Starchy	430.41 (387.02-453.48)
21.	<i>Echinochloa colona</i>	Parch.	31.66 (21.54-39.44)	3.25 (2.5-5)	Rect.	Horz.	10.75 (10-12.5)	Strip of cells	59.74 (46.14-70.19)	differentid.	Starchy	332.5 (282.5-380)
22.	<i>Dactylis glomerata</i>	no	-	6.67 (5.63-7.61)	no	no	no	no	-	differentid.	Starchy	407.57 (362.08-444.07)
23.	<i>Lolium perenne</i>	no	-	25.47 (22.55-31.48)	Rect.	Vert.	34.67 (30.61-40.51)	no	-	differentid.	Starchy	243.27 (221.41-284.11)
24.	<i>Poa annua</i>	no	-	39.37 (38.44-41.03)	Quadt	Horz.	16.52 (13.23-19.66)	no	-	differentid.	Starchy	271.38 (239.46-305.79)
25.	<i>Oryzopsis miliacea</i>	no	-	34.14 (21.36-44.52)	Quadt	Horz.	9.51 (8.44-10.94)	no	-	differentid.	Starchy	241.51 (212.14-260.64)
26.	<i>Stipa capensis</i>	no	-	8.12 (7.01-8.79)	Rect.	Horz.	5.54 (4.68-7.01)	Strip of cells	32.91 (26.72-40.19)	differentid.	Starchy	506 (470-540)
27.	<i>Stipa lagascae</i>	no	-	9.79 (9.15-10.54)	Rect. & quadt.	Horz.	6.81 (5.90-7.72)	no	-	differentid.	Starchy	238.6 (227.14-258.63)
28.	<i>Stipa parviflora</i>	no	-	9.02 (8.24-9.530)	no	no	no	no	-	differentid.	Starchy	21.52 (15.87-25.00)
29.	<i>Aegilops kotschy</i>	no	-	19.21 (18.09-20.64)	Rect.	Horz.	32.05 (31.39-32.88)	Rect. to cordt. Mass cells	296 (260-370)	differentid.	Starchy	493.8 (148.64-709.10)
30.	<i>Aegilops ventricosa</i>	no	-	37.36 (35.82-38.46)	Rect. & quadt.	Vert.	28.38 (23.94-31.11)	no	-	differentid.	Starchy	631.67 (602.41-784.98)
31.	<i>Hordium murinum</i> subsp. <i>Leporum</i>	no	-	30.90 (26.05-36.84)	Rect.	Vert.	44.16 (42.89-45.21)	no	-	differentid.	Starchy	303.26 (293.56-314.66)

Orin. = orientation; thkness. = thickness; Differentin. = differentiation; differentid. = differentiated; undifferd. = undifferentiated; parch. = parenchyma; epith. = epithelial cells; rect. = rectangular; quadt. = quadrate; train. = triangular; quinq. = quinquepartite; elip. = elliptic; horz. = horizontal; vert. = vertical; certical and no. = not observed



Figs. 1–3. Cross section LM photos; a– outline shape and b – enlarged part. Bar= 10 $\mu$ m; 1 – *Sorghum variegatum*, 2 – *Aristida adscensionis* and 3 – *A. funiculata*.

*Aristida mutabilis* Trin. & Rupr., sp. Gram. Stipac. 150 (1842); Figs. (4, 35: a, b).

Cross section is semi-circular, 51 x 43.66  $\mu$ m in size. The section covered by a hull; a layer of condensed epithelial cells thickened in 12.86  $\mu$ m. The seed coat tegmens are near to each other and take small thickness; 3.94  $\mu$ m. The aleuronic cells are rectangular with different sizes and orientations; they are thickening in 8.36  $\mu$ m. The scutellum tissue masses an elliptic bulk sizes 271.93 x 81.01 $\mu$ m. The starchy endosperm; enclosed the rest section space after the layers of aleurone and the scutellum. Endosperm exhibit differently regions of thickness, averages as 146.84  $\mu$ m.

#### ***Stipagrostis* Nees**

*Stipagrostis ciliata* (Desf.) De Winter, Kirkia 3:133 (1963); Figs. (5, 36: a, b).

Cross section is circular, 52 x 46.66 in size. The section covered by a hull; a layer of condensed epithelial cells thickened in 14.30  $\mu$ m. Seed coat tegmens; exo-, and endo-tegmens are of thick walls with dark materials. They seemly are be not distinguished and together exhibit smaller thickness; 4.97  $\mu$ m. The aleuronic cells are thin rectangular arranged transversally with small thickness; 3.3  $\mu$ m. The scutellum cells are in one row circulating the whole section outline in the thickness 16.97  $\mu$ m. The endosperm occupies a large density in the section that is thickening as 415.20  $\mu$ m.

#### **Arundineae**

##### ***Schismus* P. Beauv.**

*Schismus arabicus* Nees, Fl. Afr. Austral. III. 1:422 (1841); Figs. (6, 37: a, b).

Cross section is triangular in outline, with obtuse convex borders. The section sizes 51 x 37.33  $\mu$ m. The

seed coat layers are with deposition of dark materials. They appear more compressed, 9.86  $\mu$ m in thickness. The aleurone cells are rectangular and very thin layer in which the cells arranged transversally. The cells thickness is 4.10  $\mu$ m. Scutellum cells are one strip surrounding the whole outline section shape, its cells differentiated from the endosperm that the scutellum is denser than the endosperm. That cotyledon cells thickened in 28.58  $\mu$ m. Endosperm covers the most space in the section; it lies beneath the scutellum and takes more wide; 309.80  $\mu$ m.

#### **Aveneae**

##### ***Avena* L.**

*Avena barbata* Pott ex Link, J. Bot (Schrader) 2:315 (1799); Figs. (7, 38: a, b).

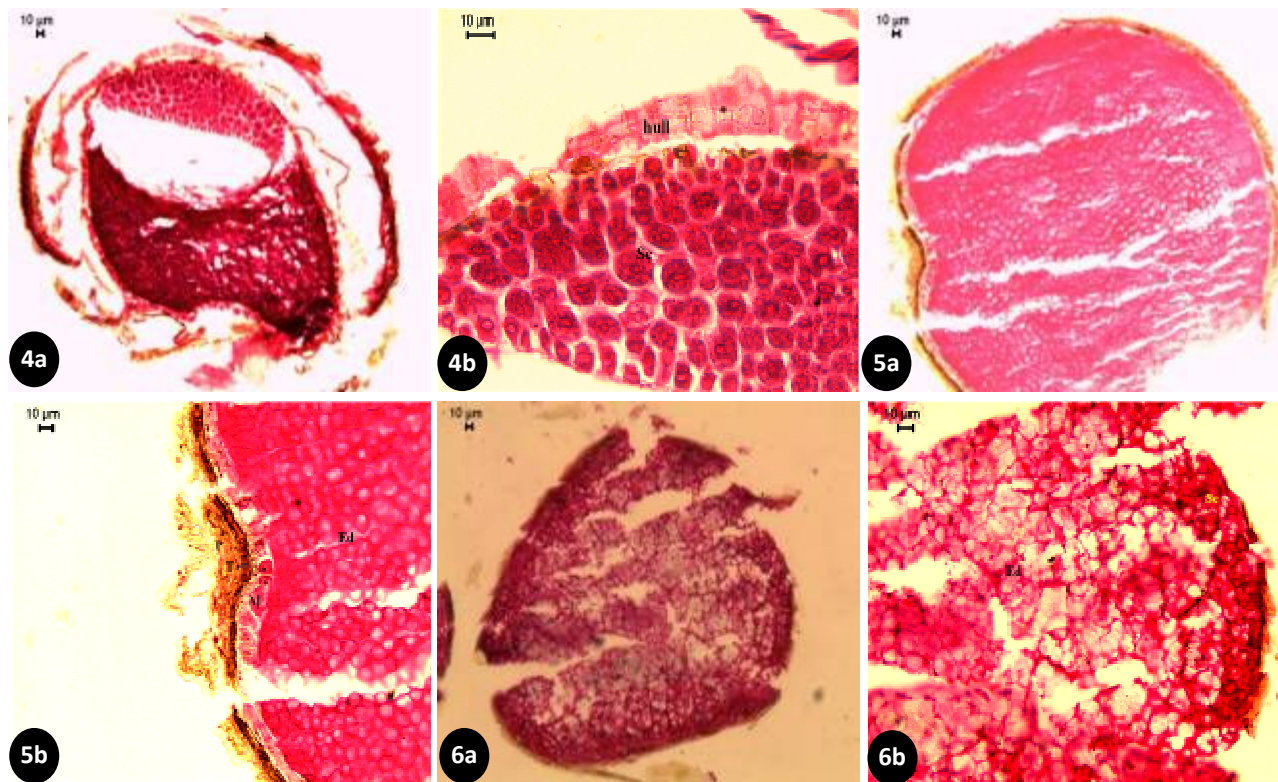
Cross section is oval to cordate in outline shape, 112.66 x 101.33  $\mu$ m in size. The seed coat layers are with deposition of dark materials. They appear also thinner, 7.79  $\mu$ m thickness. The aleurone cells are large rectangular, with distinct nucleus and they are arranged vertically. Their thickness is 38.82  $\mu$ m. The scutellum within the embryo; that is large and takes quinquangular shape; with curved borders toward the endosperm; in the size 439.71 x 272.01  $\mu$ m. Endosperm cells are less condensed than the scutellum cells. It occupies the rest area of the section and widens in 437.35  $\mu$ m as an average for different widths.

*Avena fatua* L., Sp.Pl., ed. 1, 80 (1753); Figs. (8, 39: a, b).

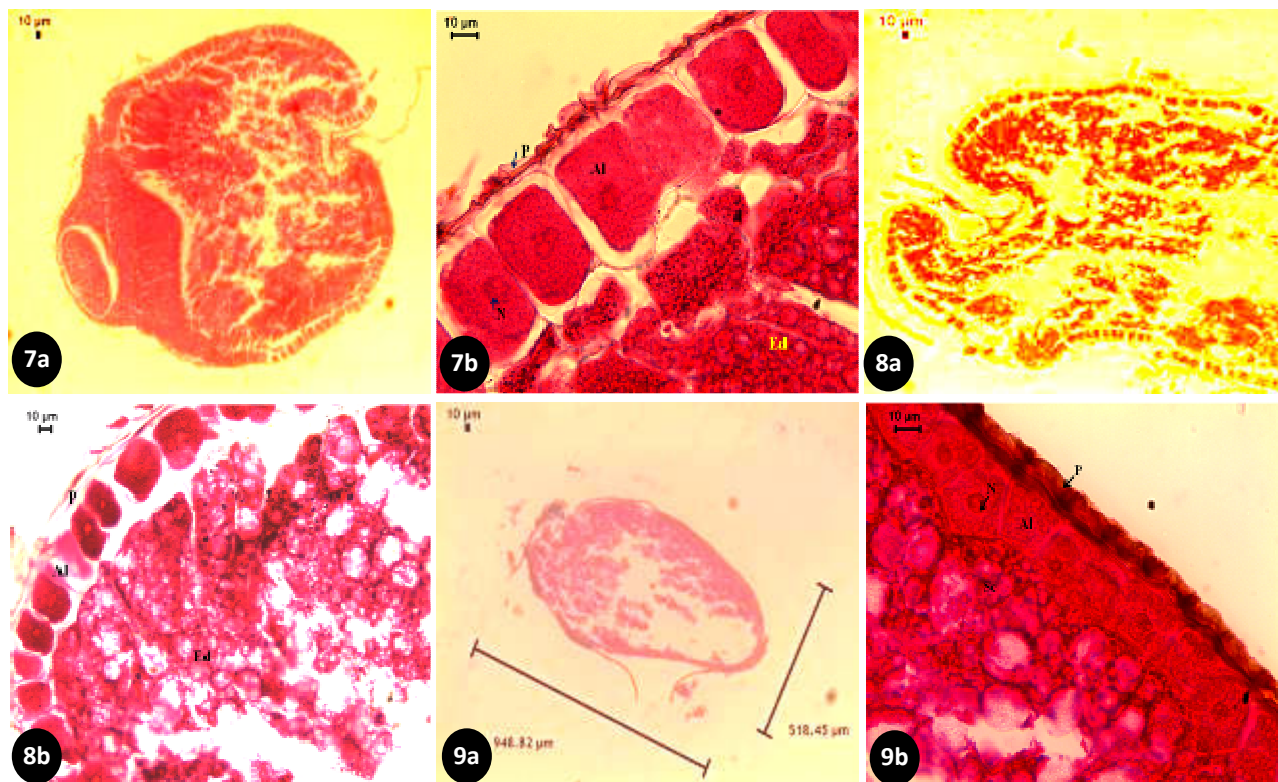
Cross section is rectangular in outline, 204.16 x 87.66  $\mu$ m in size. The seed coat or pericarp is well developed and its configuration as epithelial cells that are thick walled. The pericarp thickness is 24.28  $\mu$ m. The aleuronic

cells are large thickened, rectangular in shape and arranged vertically. The aleurone layer is 33.13  $\mu\text{m}$  in thickness. The scutellum cells surrounding the section outline beneath the aleurone, they vary in thickness; taking the average 44.04  $\mu\text{m}$ . The cotyledon cells can be

differentiated from the endosperm by their darker color. The starchy endosperm cells appear lighter than the scutellum cells. Endosperm takes the shape of the section outline, its wide 619.14  $\mu\text{m}$ .



Figs. 4–6. Cross section LM photos; a– outline shape and b – enlarged part. Bar= 10 $\mu\text{m}$ ; 4 – *Aristida mutabilis*, 5 – *Stipagrostis ciliate* and 6 – *Schismus arabicus*.



Figs. 7–9. Cross section LM photos; a– outline shape and b – enlarged part. Bar= 10 $\mu\text{m}$ ; 7 – *Avena barbata*, 8 – *Avena fatua* and 9 – *Phalaris minor*.

***Phalaris L.***

*Phalaris minor* Retz., *Observ. Bot.* 3: 8 (1788); Figs. (9, 40: a, b).

Cross section is oval in outline, 95 x 46.3 in size dimensions. The fruit section starts by the seed coat which is distinct with exo-tegmen; thickened walled by dark materials; and endo-tegmen that appears by its epithelial cells. Together comprise the thickness 9.45  $\mu\text{m}$ . Aleurone cells vary in shape; rectangular and polygonal in one row; they arranged vertically. The thickness is 20.58  $\mu\text{m}$ . The scutellum tissue is small condensed cells with small thickness; 8.87  $\mu\text{m}$ . Endosperm storage cells are lighter in staining and widen in 358.01  $\mu\text{m}$ .

***Polypogon Desf.***

*Polypogon maritimus* Willd., *Ges. Naturf. Freunde Berlin Neue Schriften* 3:422 (1801); Figs. (10, 41: a, b).

Cross section is typical circular in outline, 50.33 x 49  $\mu\text{m}$  in size. The fruit section starts by the seed coat which is distinct with exo-tegmen; thickened walled by dark materials; and endo-tegmen that appears by its epithelial cells. Together comprise the thickness 5.20  $\mu\text{m}$ . Aleurone cells vary in shape; rectangular and quadrate in one row; they arranged horizontally. The thickness is 15.47  $\mu\text{m}$ . The scutellum tissue is condensed cells with the thickness; 21.48  $\mu\text{m}$ . Endosperm storage cells are lighter in staining and widen in 354.55  $\mu\text{m}$ .

*Polypogon monspeliensis* (L.) Desf., *Fl. Atlant.* 1:67 (1798); Figs. (11, 42: a, b).

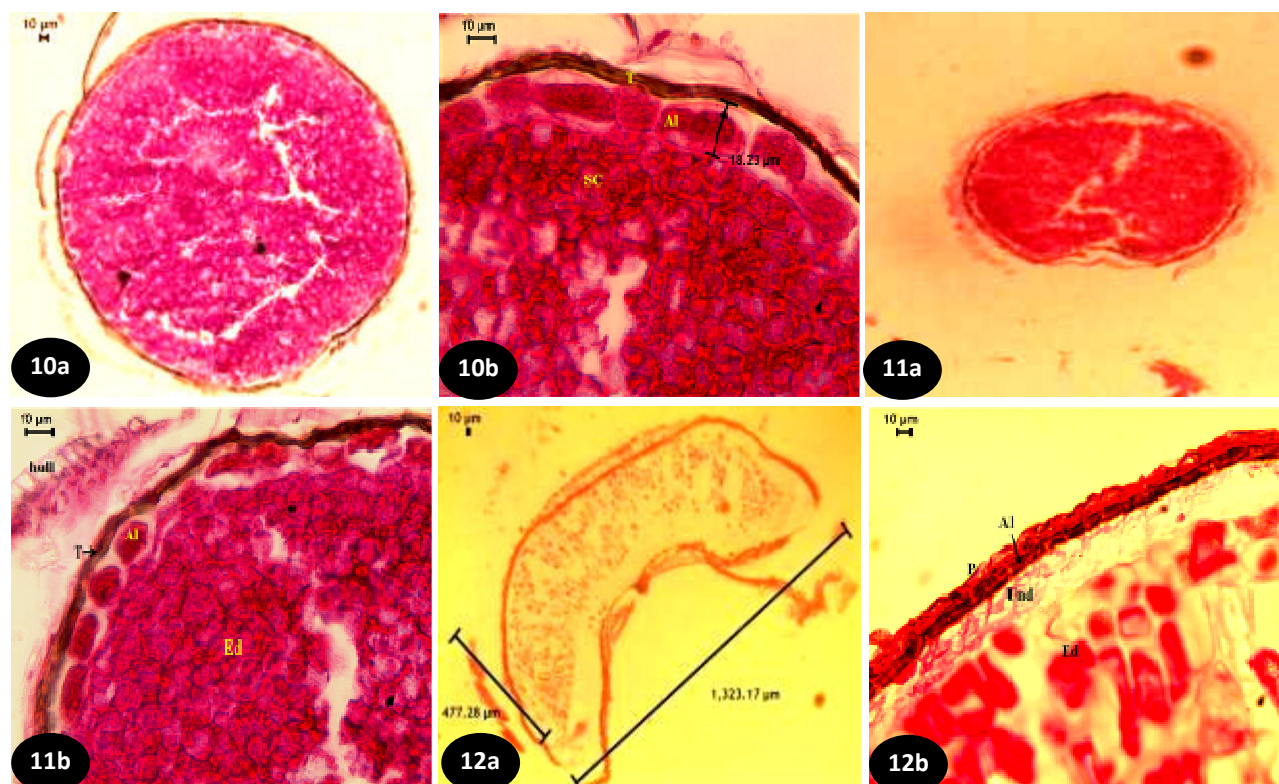
Cross section is circular to cordate in outline, 34 x 31  $\mu\text{m}$  in size. The fruit section begins with a covering

sheath; hull; of a rectangular parenchyma cells in vertical direction. The hull thickness is 16.25  $\mu\text{m}$ . Seed coat walls are thickened by dark materials. The thickness of the pericarp is relatively small; 4.90  $\mu\text{m}$ . Aleurone cells are rectangular with different sizes, arranged horizontally and the aleuronic layer thickening in 12.86  $\mu\text{m}$ . The scutellum tissue is not clearly conspicuous. Endosperm storage cells are massing within the rest section shape, taking the wide 203.71  $\mu\text{m}$ .

***Brachypodieae******Brachypodium P. Beauv.***

*Brachypodium distachyum* (L.) P. Beauv., *Ess. Agrostogr.* 101,155 (1812); Figs. (12, 43: a, b).

Cross section takes the C- shaped in outline, 137.33 x 44.33  $\mu\text{m}$  in size. Seed coat walls are thickened by dark materials. The thickness of the pericarp is 9.84  $\mu\text{m}$ . Aleurone cells are rectangular, arranged in horizontal row and deposited dark materials of the storage proteins or oils. The aleurone layer thickens in 6.76  $\mu\text{m}$ . The scutellum is not identified. The whole endosperm mass divided into two regions; the outermost region beneath the aleurone cells that is not differentiated into distinct cells, this region appears as lighter layers without deposition, they can be identified as undifferentiated endosperm and thickens in 27.58  $\mu\text{m}$ ; the inner endosperm surrounding the embryo and starch storage modified cells. This region which takes different widths among the section outline and thickened in 174.50  $\mu\text{m}$  as an average.



Figs. 10–12. Cross section LM photos; a– outline shape and b – enlarged part. Bar= 10 $\mu\text{m}$ ; 10 – *Polypogon maritimus*, 11 – *Polypogon monspeliensis* and 12 – *Brachypodium distachyum*.



**Bromeae*****Bromus* L.**

*Bromus rubens* L., Cent. Pl. 1:5 (1755); Figs. (13, 44: a, b).

Cross section is rectangular with obtuse borders to oval,  $108.33 \times 35 \mu\text{m}$  in size. Seed coat walls are thickened by dark materials. The thickness of the pericarp is  $6.32 \mu\text{m}$ . Distinct parenchyma with thickened walls and present in different thickness; are being as aleurone initials. Their thickness average is  $28.71 \mu\text{m}$ . The aleurone layer surrounds the rest section. Aleuronic cells are quadrate to rectangular in shape and arranged vertically. This living storage layer is  $21.11 \mu\text{m}$  in thickness. The scutellum cells were not clear. The starchy endosperm mass covers most section space. Its width is  $156.51 \mu\text{m}$ .

*Bromus scoparius* L., Cent.Pl. 1:6 (1755); Figs. (14, 45: a, b).

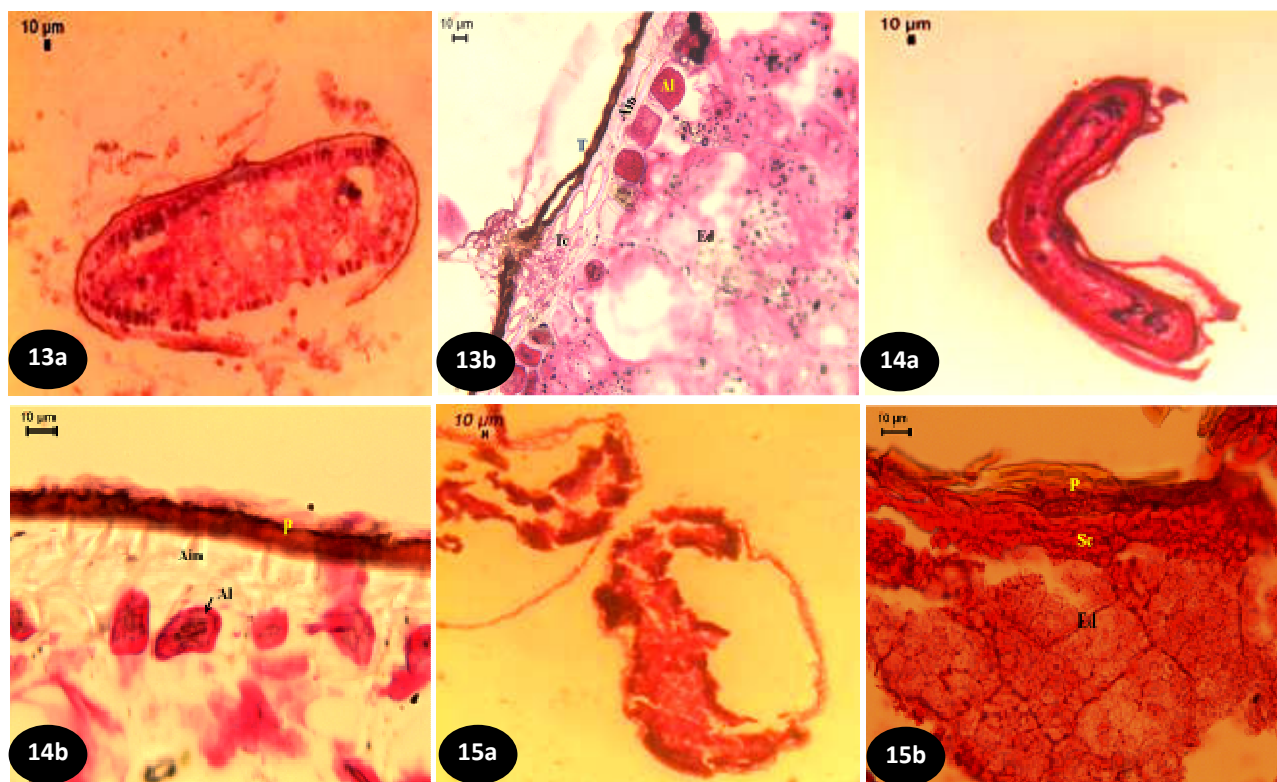
Cross section is C- shaped and  $89 \times 24.66 \mu\text{m}$  in size. Seed coat layers are deposited by dark materials; the parts of the pericarp are relatively compressed. Pericarp takes the thickness  $9.79 \mu\text{m}$ . A layer of thin walled cells lies after the pericarp; they are rectangular cells which lighter

in staining. This undifferentiated layer is called the aleurone initials; its thickness is  $17.28 \mu\text{m}$ . Some aleurone cells were developed; they are not yet distributed among the whole section, they appeared to be rectangular cells arranged vertically. Their thickness is  $17.76 \mu\text{m}$  as an average. Scutellum is not defined. The endosperm is not yet completely modified; it comprises the thickness  $83.71 \mu\text{m}$ .

**Eragrostideae*****Coelachyrum***

*Coelachyrum bervifolim* ; Figs. (15, 46: a, b).

Cross section is C- shaped and  $73.66 \times 49.33 \mu\text{m}$  in size. The hull cells thickened in  $13.41 \mu\text{m}$  and take polygonal shape arranging vertically. The seed coat layers are not completely compressed with a thickness average  $10.39 \mu\text{m}$ . An aleuronic layer can be distinct with dark parts in the thickness  $5.15 \mu\text{m}$ . The scutellum is well differentiated from the endosperm; distributed in different thicknesses and take the average  $16.34 \mu\text{m}$ . The endosperm cells are grouped in masses of polygonal shapes; in which; the cells containing starch granules are lighter in color. The endosperm containing area is  $120.98 \mu\text{m}$  in thickness.



Figs. 13–15. Cross section LM photos; a– outline shape and b – enlarged part. Bar=  $10\mu\text{m}$ ; 13 – *Bromus rubens*, 14 – *Bromus scoparius* and 15 – *Coelachyrum bervifolim*.

***Dactyloctenium* Willd.**

*Dactyloctenium aegyptium* (L.) Willd., enum.pl. 1029 (1809); Figs. (16, 47: a, b).

Cross section is polygonal in outline,  $65.66 \times 41 \mu\text{m}$  in size. The seed coat layers are distinguished in two parts comprise together the average  $8.50 \mu\text{m}$  in thickness. The aleurone layer is very thin of rectangular cells that appeared in dark color according to their contents of proteins and oils. The aleuronic layer is  $3.25 \mu\text{m}$  in

thickness. The scutellum appears in two manners; a triangular mass of the cotyledon cells within the embryo; that takes the wide  $225.86 \mu\text{m}$ ; other scuttled cells beneath the aleurone cells layer and takes the average thickness  $22.82 \mu\text{m}$ . The starchy endosperm is well developed cells distinguished by its starch granules contents that appeared by light granules within the cell contents. The endosperm is occupying a space with  $277.28 \mu\text{m}$  in width.

**Eragrostis**

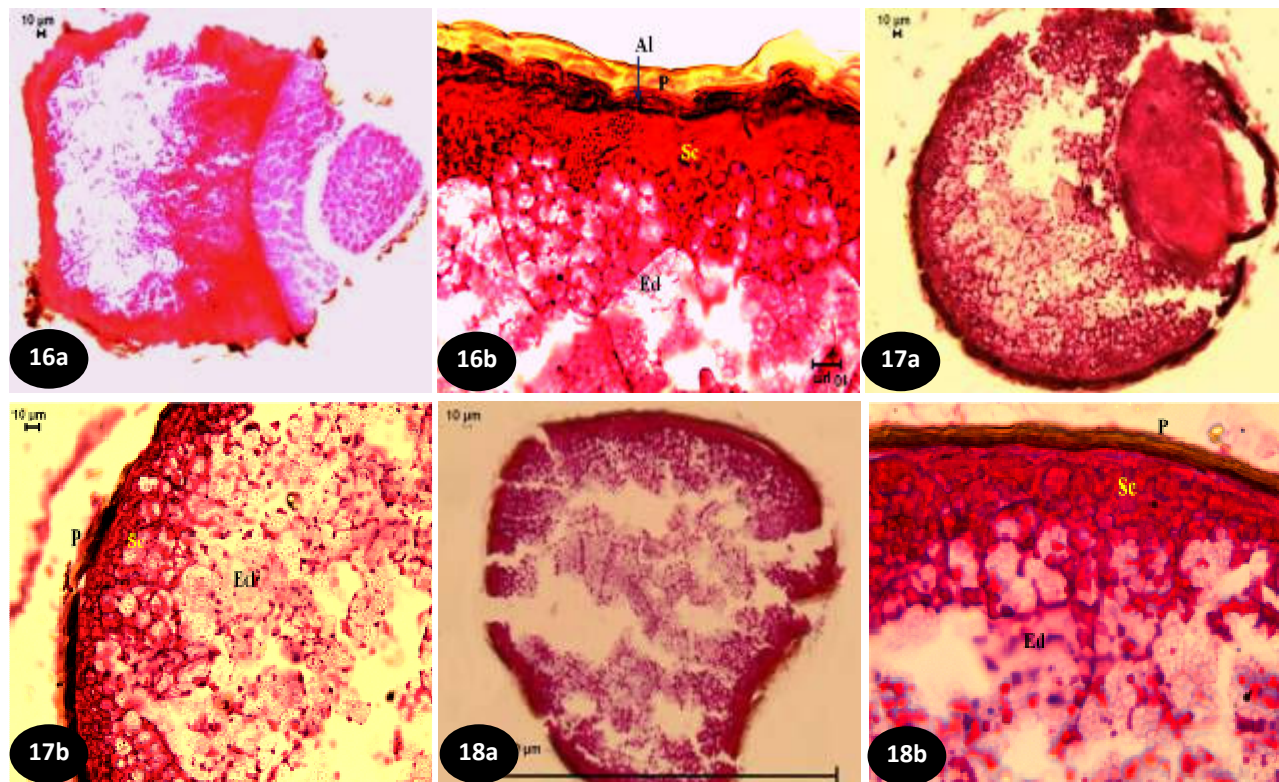
*Eragrostis cilianensis*; Figs. (17, 48: a, b).

Cross section is circular in outline, 56 x 49  $\mu\text{m}$  in size. The seed coat layers are relatively compressed taking the thickness 8.36  $\mu\text{m}$ . The aleuronic cells are dark due to their large content of protein bodies. They are rectangular cells arranged horizontally with an average thickness 8.25  $\mu\text{m}$ . the scutellum appeared at two sites; an oval bulk at one side of the section with the wide 177.05  $\mu\text{m}$  and as a strip of cells lies beneath the aleurone layer with the wide 22.71  $\mu\text{m}$ . in both sites, the scutellum cells appear more densely and darker in staining than the endosperm. The starch containing endosperm is lighter in

staining including white starch granules. Its mass takes the width 253.68  $\mu\text{m}$  in thickness.

*Eragrostis minor*; Figs. (18, 49: a, b).

Cross section is circular to cordate in outline, 50.33 x 48.66  $\mu\text{m}$  in size. The seed coat layers are compressed taking the thickness 9.00  $\mu\text{m}$ . The aleurone cells are not well distinguished. The cotyledon cells; scutellum; are surrounding the whole section outline as a strip of cells that are distinct by their darker view. Their thickness in 20.77  $\mu\text{m}$  as an averages. The starchy endosperm covering the rest of the section and takes the wide 412.68  $\mu\text{m}$  as an averages.



Figs. 16–18. Cross section LM photos; a– outline shape and b – enlarged part. Bar= 10 $\mu\text{m}$ ; 16 – *Dactyloctenium aegyptium*, 17 – *Eragrostis cilianensis* and 18 – *Eragrostis minor*.

**Leptochloa P. Beauv.**

*Leptochloa fusca* (L.) Kunth, Révis. Gramin. 1:91 (1829); Figs. (19, 50: a, b).

Cross section is circular in outline; 33.33 x 31.66  $\mu\text{m}$  in size. The pericarp layers are so compressed and exhibit very small thickness; 2.43  $\mu\text{m}$  is the pericarp layers thickness. Also the aleuronic cells are very thin rectangular cells arranged horizontally; appear relatively dark stained due to their contents. They exhibit the width 1.92  $\mu\text{m}$ . The scutellum takes less quantity of cells; it also appeared in dark view and thickened in 11.58  $\mu\text{m}$ . The endosperm can be distinct by its content of starch granules which appear white or; generally; lighter than the protein granules in scutellum or even in the endosperm itself. It takes 278.16  $\mu\text{m}$  in thickness.

**Panicaceae****Cenchrus**

*Cenchrus ciliaris*; Figs. (20, 51: a, b).

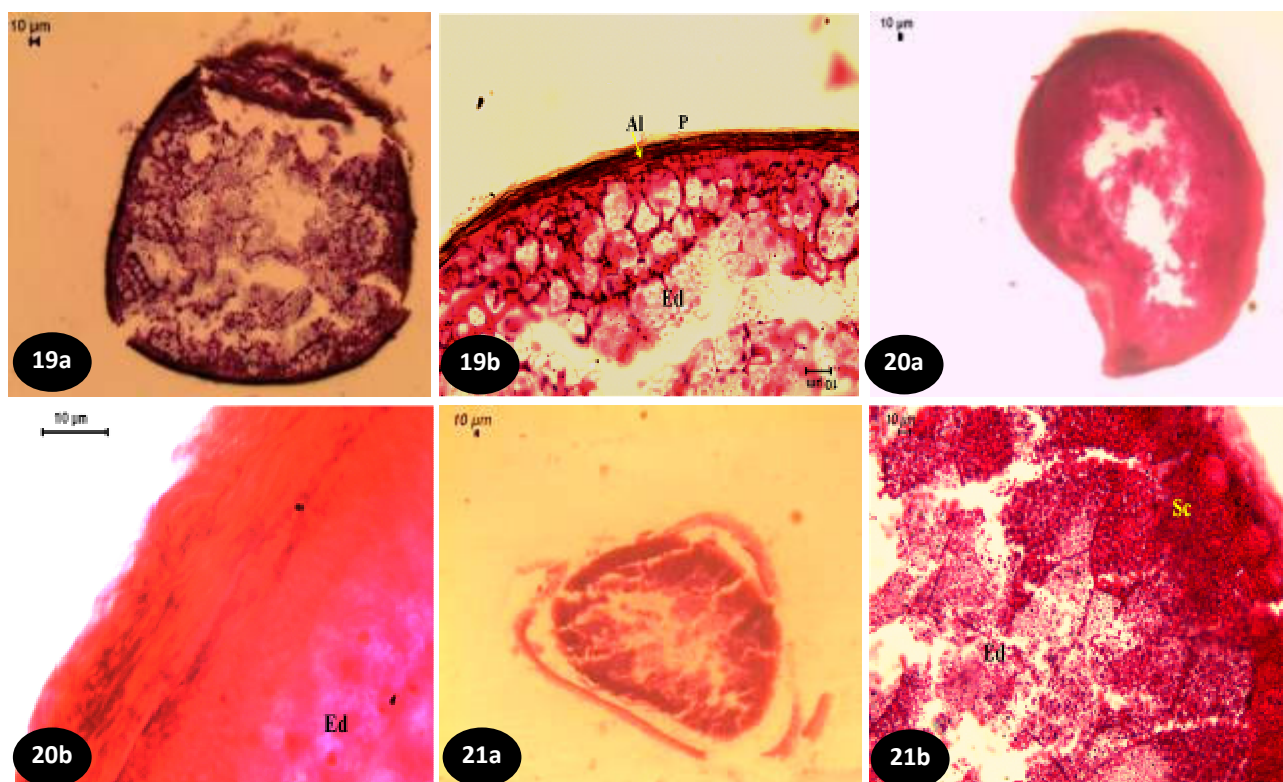
Cross section is oval in outline, 112.5 x 56.66  $\mu\text{m}$  in size. The pericarp layers are not completely compressed

with the average 7.83  $\mu\text{m}$  in thickness. The aleurone cells are rectangular in shape which arranged horizontally. Taking the wide 6.77  $\mu\text{m}$ . The scutellum appeared darker than the endosperm with the average 16.13  $\mu\text{m}$  in thickness. The endosperm containing starch is lighter in staining and distinct by the cell's nucleus and b the white starch granules. Its thickness is 430.41  $\mu\text{m}$ .

**Echinochloa P. Beauv.**

*Echinochloa colona* (L.) Link, Hort. Berol. 2:209 (1833); Figs. (21, 52: a, b).

Cross section is triangular in outline; with obtuse convex borders; 59 x 36  $\mu\text{m}$  in size. The hull cells are relatively large and arranged vertically, they are same as the palisade parenchyma taking the thickness 31.66  $\mu\text{m}$ . The seed coat or pericarp layers are well compressed; they exhibit the thickness 3.25  $\mu\text{m}$ . The aleurone cells are rectangular arranged horizontally and take the average 10.75  $\mu\text{m}$  in thickness. The scutellum tissue exhibit dark cells lie beneath the aleuronic layer. Their wide is 59.74  $\mu\text{m}$  in thickness. The endosperm cells aggregated in polygonal groups. The thickness of the endospermic layer is 332.5  $\mu\text{m}$ .



Figs. 19–21. Cross section LM photos; a– outline shape and b – enlarged part. Bar= 10µm; 19 – *Leptochloa fusca*, 20 – *Cenchrus ciliaris* and 21 – *Echinochloa colona*.

## Poeae

### *Dactylis* L.

*Dactylis glomerata* L., Sp. Pl., ed. 1, 71 (1753); Figs. (22, 53: a, b).

Cross section is circular or triangular with obtuse corners, 112.5 x 56.66 µm in size. The whole section appears to be of the starchy endospermic tissue; covered by the seed coat parts which are condensed and exhibit the thickness; 6.67 µm; while the bulk of endosperm exhibit the width 407.57 µm in thickness. This endospermic region centered with an embryonic region that takes the width 133.14 µm in thickness.

### *Lolium* L.

*Lolium perrene* L., Sp. Pl., ed. 1, 83 (1753); Figs. (23, 54: a, b).

Cross section is oval to rectangular with obtuse corners, 121.33 x 62 µm in size. The seed coat layers are well distinct and clearly divided into two parts; the outer is the pericarp or exo-tegmen and the inner is the testa or the endo-tegmen. Together comprise a valuable width; 25.47 µm in thickness. The aleuronic cells are large, rectangular and arranged vertically and exhibit the thickness 34.67 µm. The scutellum is not clearly distinguished while the endosperm occupies the main mass of the section; it widens in 243.27 µm in thickness.

### *Poa* L.

*Poa annua* L., Sp. Pl., ed. 1, 68 (1753); Figs. (24, 55: a, b).

Cross section is circular to oval in outline, 61.33 x 47.33 µm in size. The seed coat layers are well distinct and clearly divided into two parts; the outer is the pericarp

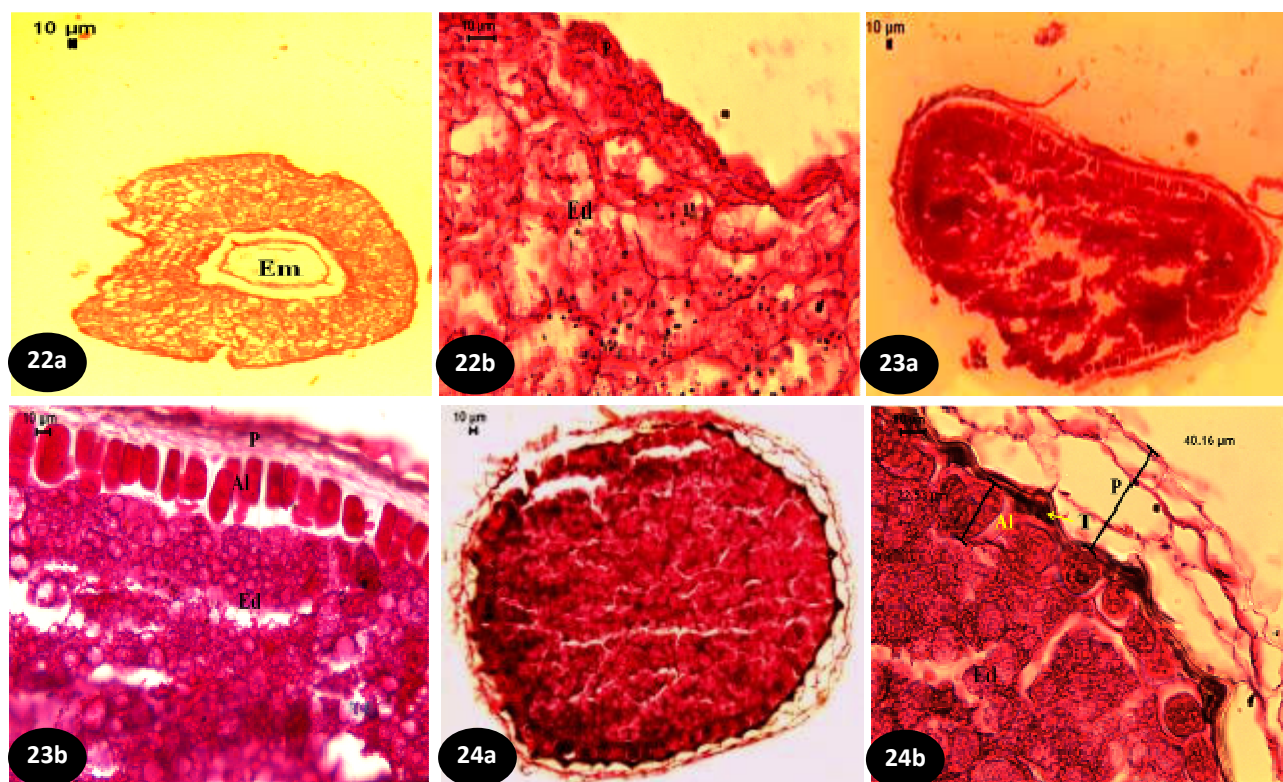
or exo-tegmen which appeared as (2-3) rows of polygonal parenchyma cells in horizontal orientation and the inner is the testa or the endo-tegmen which appeared as thickened epithelial cells with some protrusions outwards. Together comprise a valuable width; 39.37 µm in thickness. The aleuronic cells are relatively quadrate, arranged horizontally and exhibit the thickness 16.52 µm. The scutellum is not clearly distinguished while the endosperm occupies the main mass of the section; it widens in 271.38 µm in thickness.

## Stipeae

### *Oryzopsis* Michx.

*Oryzopsis miliacea* (L.) Asch. & Schweinf., Mém. Inst. Égypt. 2:169 (1887); Figs. (25, 56: a, b).

Cross section is circular in outline; with curved parts outwards; 63.66 x 56 µm in size. The seed coat layers are well distinct and clearly divided into two parts; the outer is the pericarp or exo-tegmen which appeared as 2 rows of parenchymatous lignified cells; in which the outermost row of small rectangular cells in horizontal orientation while the inner row of rectangular in vertical orientation. The inner layer of the seed coat is the testa or the endo-tegmen which appeared as thickened epithelial cells; the two seed coat layers comprise a valuable width; 34.14 µm in thickness. The aleuronic cells are quadrate cells arranged horizontally with the average 9.51 µm in thickness. The scutellum appeared to be embedded within the endosperm surrounding the embryo; hence their width together is 241.51 µm in thickness.



Figs. 22-24. Cross section LM photos; a– outline shape and b – enlarged part. Bar= 10 $\mu$ m; 22 – *Dacylis glomerata*, 23 – *Lolium perenne* and 24 – *Poa annua*.

#### *Stipa* L.

*Stipa capensis* Thumb., Prodr. Fl. Cap. 19 (1794); Figs. (26 b, 57 a, b).

Cross section is rectangular with obtuse corners, 53.33 x 28  $\mu$ m in size. The seed coat layers may be distinct but they are compressed to some extent, together give the width 8.12  $\mu$ m in thickness. The aleuronic cells are thin rectangular cells arranged horizontally and exhibit darker appearance. The thickness of this layer is 5.54  $\mu$ m. The scutellum surrounding the endosperm is well distinguished by its cells' darker appearance and by the cell density. The thickness of the scutellum mass is 32.91  $\mu$ m. the starchy endosperm exhibit high content in the width of 506  $\mu$ m.

*Stipa lagascae* Roem. & Schult., Syst. Veg. 2: 333 (1817), based on *Stipa pubescens* Lag; Figs. (27, 58: a, b).

Cross section is rectangular with obtuse corners in outline, 43.66 x 42  $\mu$ m in size. The seed coat layers can be distinct into the outer pericarp and the inner testa; they are less compressed, together give the width 9.78  $\mu$ m in thickness. The aleuronic cells are rectangular to quadrate cells arranged horizontally and exhibit a thickness of 6.81  $\mu$ m. The scutellum appeared to be embedded within the endosperm surrounding the embryo; hence their width together is 238.60  $\mu$ m in thickness.

*Stipa parviflora* Desf., Fl. Atlant. 1: 98, t. 29 (1798); Figs. (28, 59: a, b).

Cross section is linear with two folded pointed ends in outline, 95.33 x 5.33  $\mu$ m in size. The seed coat layers may be distinct but they are compressed to some extent, together give the width 9.02  $\mu$ m in thickness. The

aleuronic cells are not identified. The scutellum also has not been distinguished while the endosperm is clearly developed and appears with a mass of 21.52  $\mu$ m in thickness.

#### Triticeae

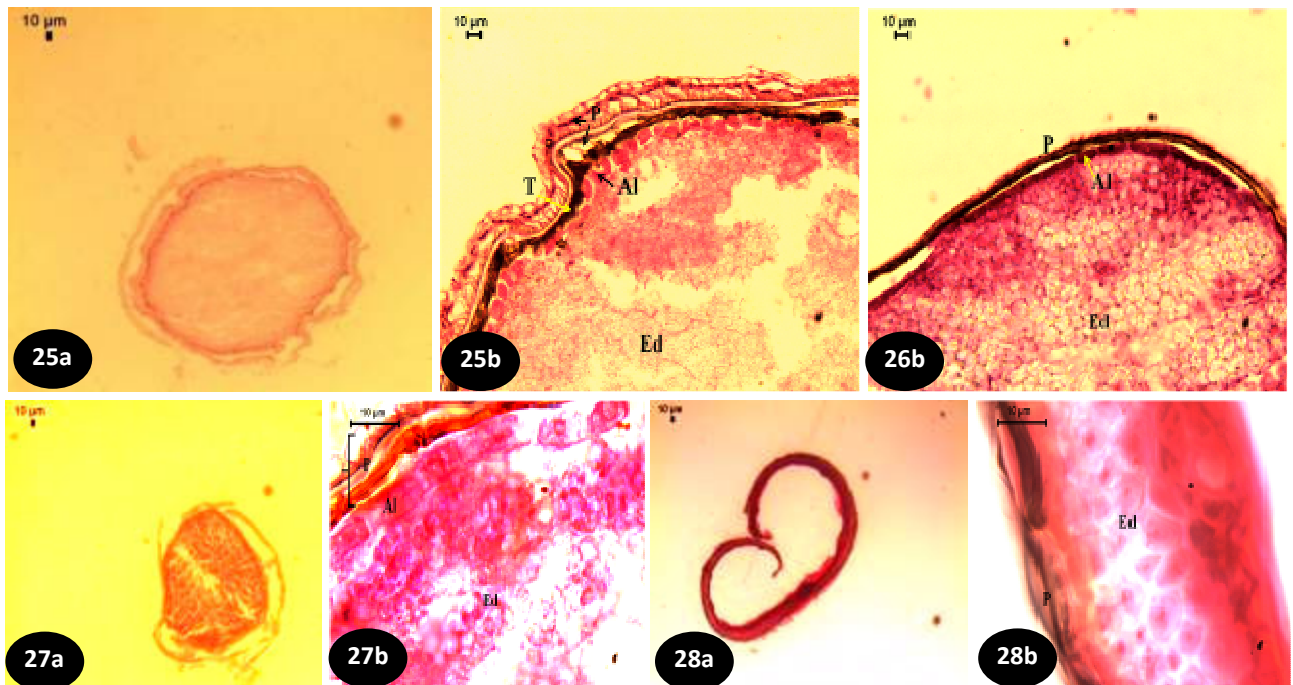
##### *Aegilops* L.

*Aegilops kotschy* Boiss., Diagn.Pl.Orient. 1(7):129 (1846); Figs. (29, 60: a, b).

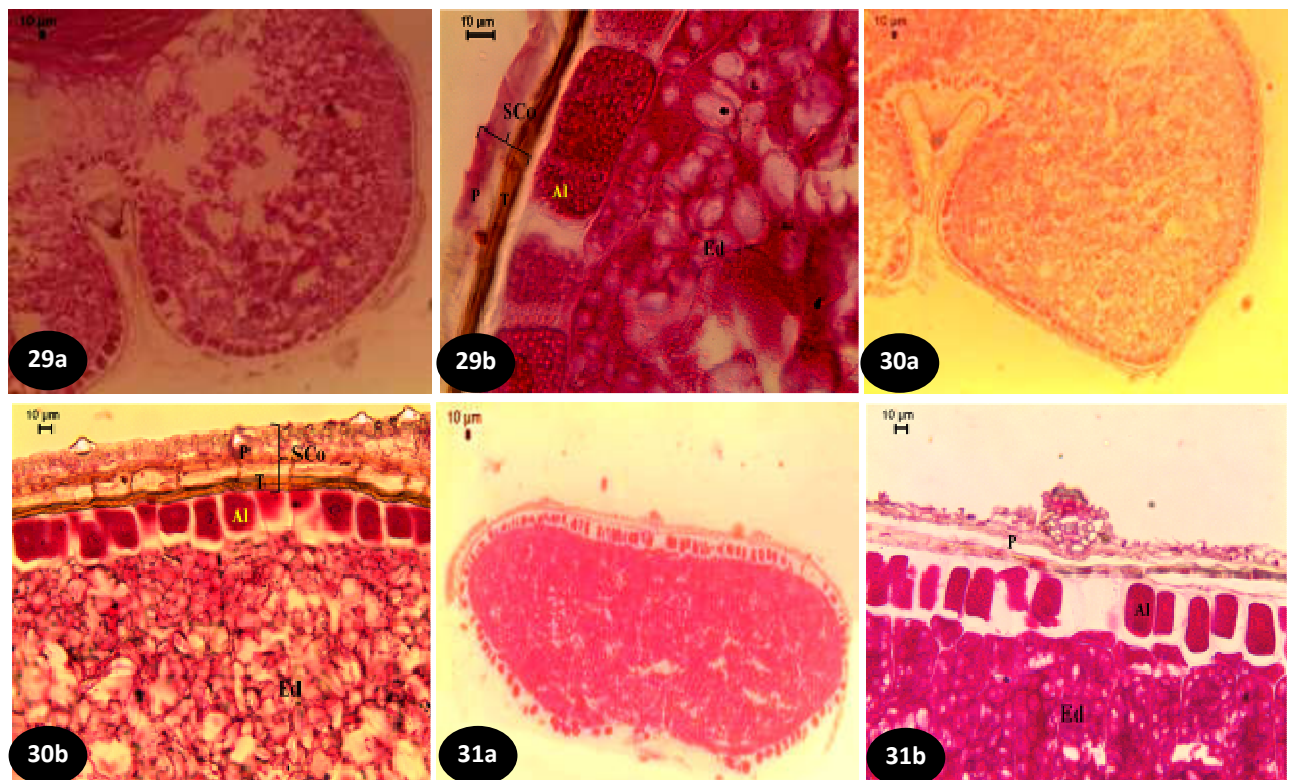
Cross section is cordate in outline, 207.5 x 141.66  $\mu$ m in size. The seed coat layers are clearly distinct and comprise a width of 19.21  $\mu$ m in thickness. The aleurone cells are large rectangular arranged in horizontal row; the living cells with distinct nucleus. The aleuronic layer is 32.05  $\mu$ m in thickness. The scutellum appear in a massive part of the cotyledon cells in a rectangular to cordate shape with a width 296  $\mu$ m. The endosperm occupies the rest area of the section and exhibit varying widths; in the average 493.8  $\mu$ m in thickness.

*Aegilops ventricosa* Tausch, flora 39:108 (1837); Figs. (30, 61: a, b).

Cross section is oval to rectangular, 265 x 132.5  $\mu$ m in size. The seed coat layers are clearly into the outer tegmen of condensed epithelial cells followed by rectangular cells sited horizontally; and the inner tegmen of compressed thick walled cells. The whole coat is 37.36  $\mu$ m in thickness. The aleuronic cells are rectangular to quadrate in shape, arranged vertically and take the thickness 28.38  $\mu$ m. The scutellum appeared to be embedded within the endosperm surrounding the embryo; hence their width together is 631.67  $\mu$ m in thickness.



Figs. 25–28. Cross section LM photos; a– outline shape and b – enlarged part. Bar= 10µm; 25 – *Oryzopsis miliacea*, 26 – *Stipa capensis*, 27 – *Stipa lagascae* and 28 – *Stipa parviflora*.



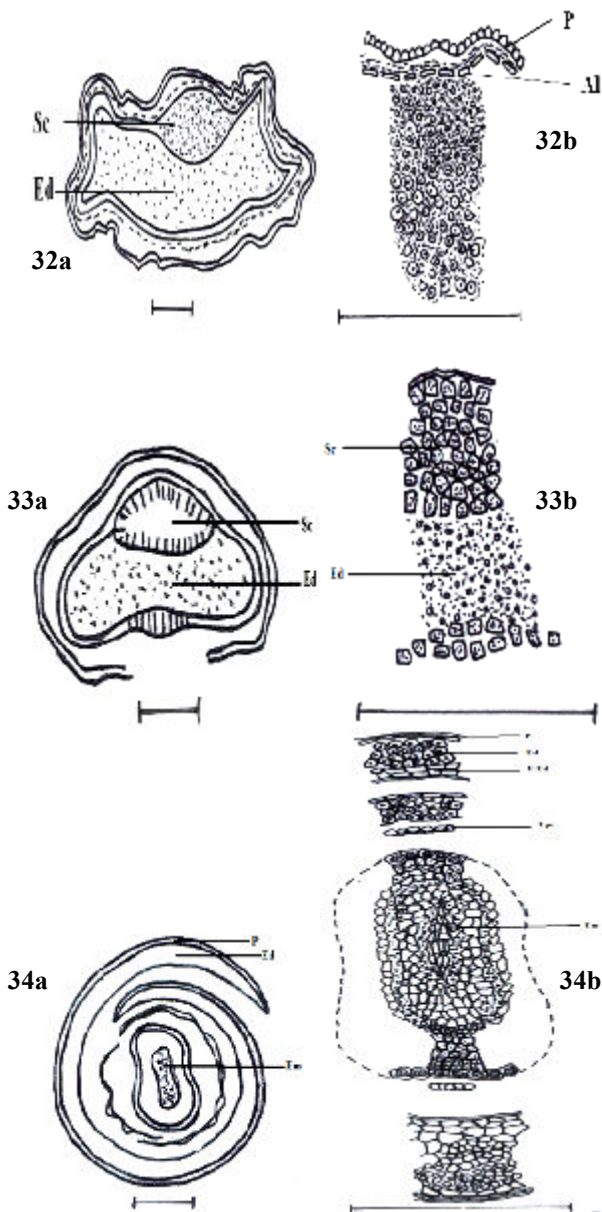
Figs. 29 –31. Cross section LM photos; a– outline shape and b – enlarged part. Bar= 10µm; 29 – *Aegilops kotschyi*, 30 – *Aegilops ventricosa*, 31 – *Hordeum murinum* ssp. *Leporinum* .

**Hordeum L.**

*Hordeum murinum* L., Sp. Pl., ed. 1, 85 (1753). subsp. *leporinum* (Link) Arcang., Comp. Fl. Ital. 805 (1882); Figs. (31, 62: a, b).

Cross section is oval to rectangular with curved corners in outline, 163.33 x 158.33 µm in size. The seed coat is distinguished into two parts; together comprise the thickness 30.90 µm. The aleuronic layer is clearly distinct; large rectangular cells arranged vertically with

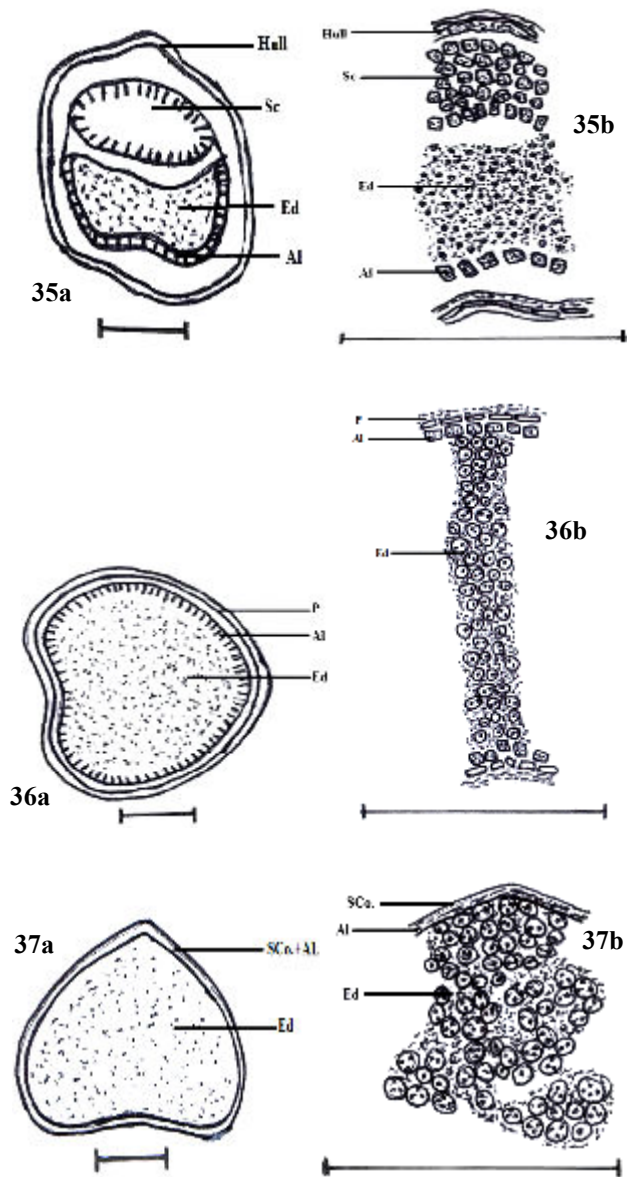
the thickness 44.16 µm. The scutellum appeared to be embedded within the endosperm surrounding the embryo; hence their width together is 303.26 µm in thickness. The variant data collected have been summarized in Tables 3.1 and 3.2. In addition to, all the samples illustrated before, with LM photographs, have been supported by line drawings with a conspicuous scale, showed in Figs. (3.32-3.62), with a diagram (a) and an enlarged part as a sector (b).



Figs. 32-34. Line drawings of fruit sections; a: diagram, b: sector, Bar = 2.5  $\mu$ m. 32: *Sorghum variegatum*, 33: *Aristida adscensionis* and 34: *A. funiculata*.

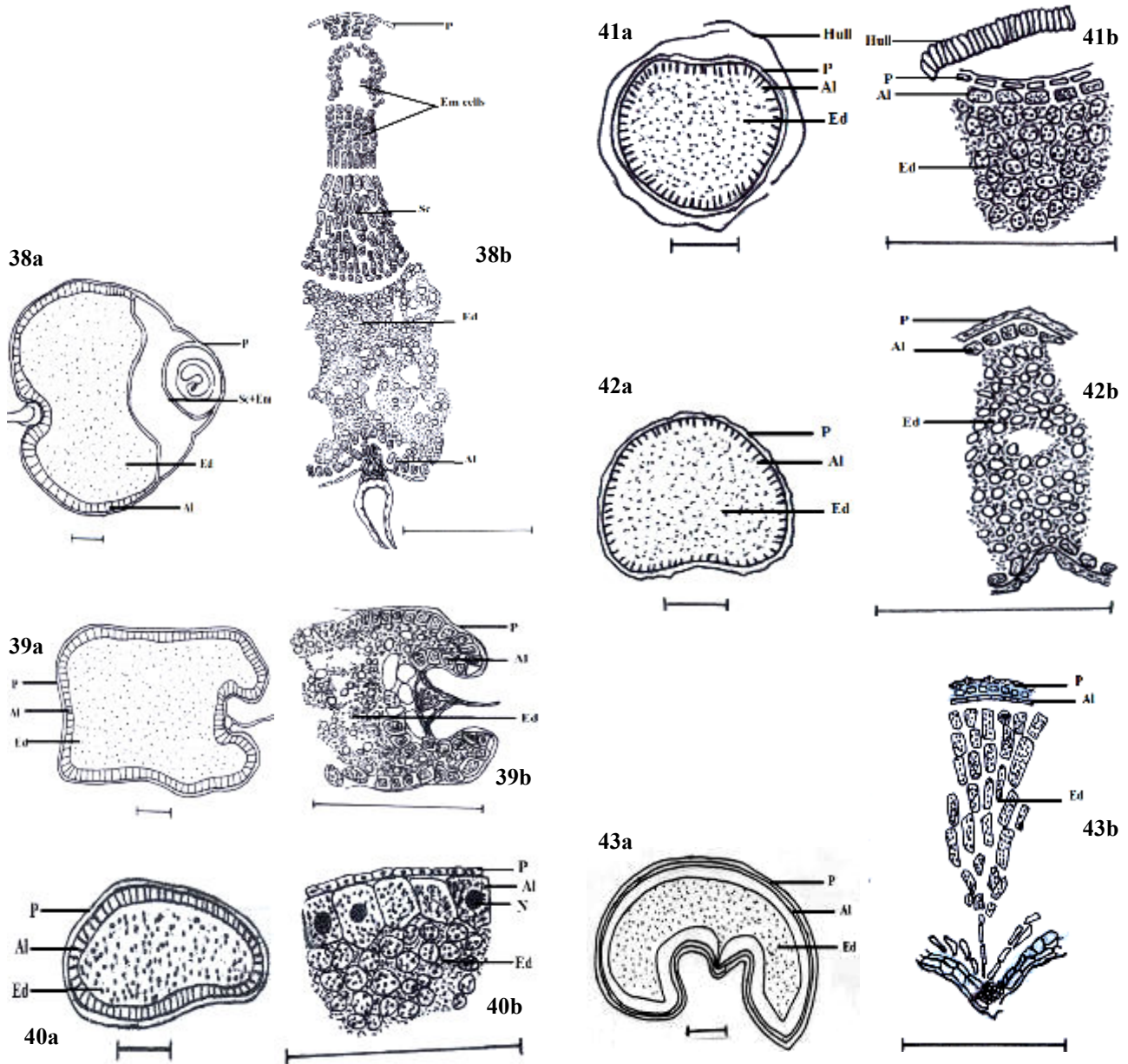
## Discussion

In our study, the taxa examined regarded the main anatomical structure for the caryopsis fruits revealed by Kar *et al.*, (2002). Also they provide a confirmation to the interpretation produced by Olsen *et al.*, (1999) and Olsen (2001) for the cereal differentiated endosperm. The pericarp consists of only a few cell layers: outer epidermis, a few parenchymatous cell layers and an inconspicuous inner epidermis (Hackel, 1896), some taxa exhibit a compressed inner epidermis of epithelial cells. In the Gramineae, where fruits constitute the dispersal units, the seed coat may become an integral part of the pericarp, both together serving as protective layer (Carlquist *et al.*, 1997). In most monocot seeds the testa is fused with the pericarp, Kar *et al.*, (2002) and the fruits also showed the complete fusion between the parts of the



Figs. 35-37. Line drawings of fruit sections; a: diagram, b: sector, Bar = 2.5  $\mu$ m. 35: *Aristida mutabilis*, 36: *Stipagrostis ciliata* and 37: *Schismus arabicus*.

seed coat, pericarp and testa. The pericarp composed of few rows of parenchymatous, simple celled and mostly with none thickened walls followed by the testa of relatively thick walled cells with dark materials, these cells are of condensed epithelial cells. Although the seed coat of Gramineae plants under investigation appeared with a uniform structure, the whole seed coat thickness shows a great variation among taxa at the specific level and even between genera. In Aristideae, Bromeae and Stipeae the thickness of the seed coat showed a significant variation that aid in separating the species included in each tribe. Also it is differentiating between three genera and two species included within Eragrostideae. Therefore, seed coat anatomy is species-specific and can serve as an aid in identification and taxonomy regarding to Carlquist *et al.*, (1997).

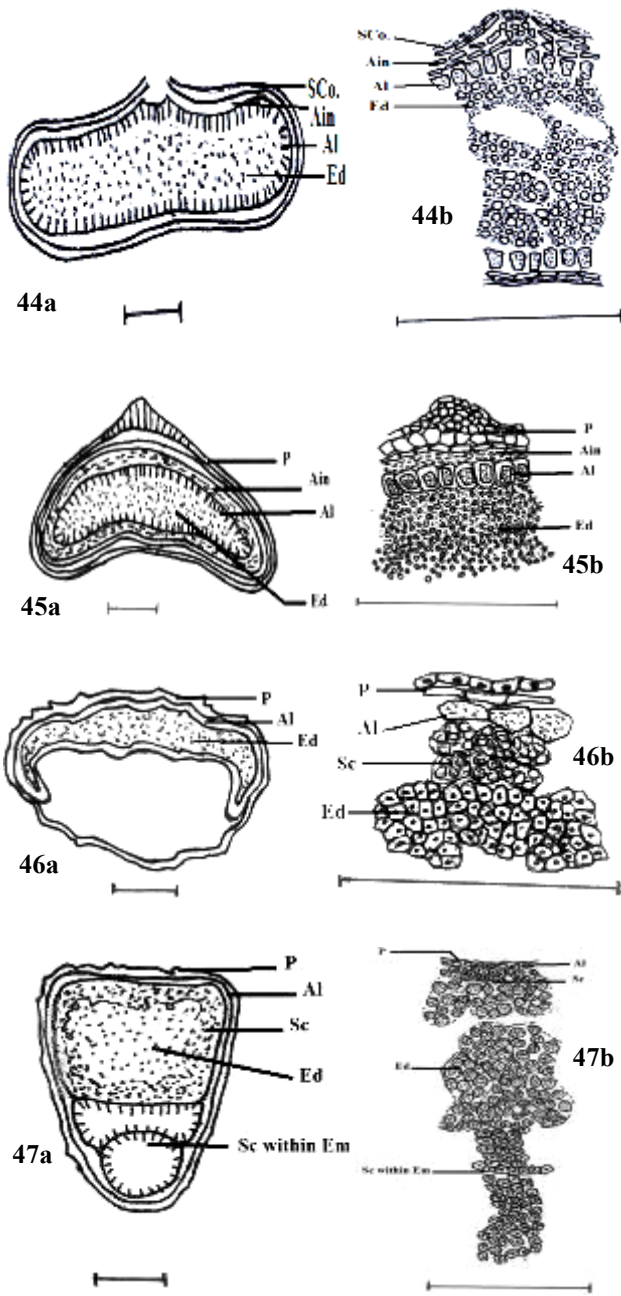


Figs. 38-40. Line drawings of fruit sections; a: diagram, b: sector, Bar = 2.5  $\mu$ m. 38: *Avena barbata*, 39: *A. fatua* and 40: *Phalaris minor*.

Figs. 41-43. Line drawings of fruit sections; a: diagram, b: sector, Bar = 2.5  $\mu$ m. 41: *Polypogon maritimus*, 42: *P. monspeliensis* and 43: *Brachypodium distachyum*.

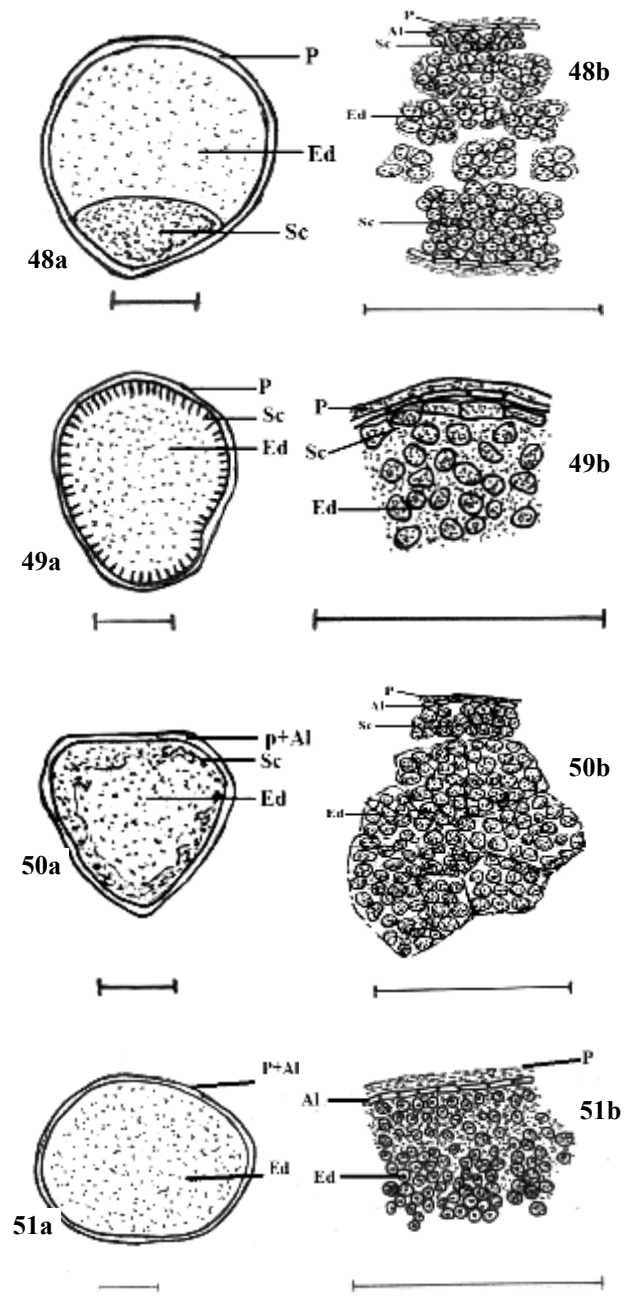
The subsequent layer to the seed coat is the aleurone cells. The living cells with distinct nucleus, sometimes showing darker appearance due to their storage contents of aleurone grains, protein content, and the lipid bodies. The same appearance and description for the aleurone cells illustrated by Irving (1983) and Jane (2004). The aleuronic layer exhibits a great variation in thickness, shape and orientation of cells within the tribes studied at the generic and species levels. The aleuronic cells with their conspicuous construction can be used largely for differentiating taxa among the Gramineae genera and tribes, whereas each tribe with different taxa seems to be of uniform aleurone layer features. In Aveneae, aleurone cells of the same shape and orientation among all taxa studies except for the shape of them that aid in separating *Phalaris minor* and *Polypogon maritimus*. Moreover,

aleurone thickness can help in differentiating between taxa included. The Eragrostideae, aleurone layer is similar within taxa of the tribe, while *Eragrostis minor* only is different whereas it has no aleurone cells observed. In addition to that the aleurone configuration can separate different genera as recorded in Poaceae. In the Bromeae through the two species included; *Bromus rubens* and *B. scoparius*; shows another type of thickened walled undifferentiated cells lie beneath the seed coat, these cells act as the aleurone initials that develop to form the aleurone layer. Like most Poaceae, in these species, the aleurone layer covers the endospermic region except at the transfer cells and that is compatible to Jane (2004). The transfer cells also are characteristic for the genus *Bromus* in this study.



Figs. 44-47. Line drawings of fruit sections; a: diagram, b: sector, Bar = 2.5  $\mu$ m. 44: *Bromus rubens*, 45: *B. scoparius*, 46: *Coelachyrum pervifolium* and 47: *Dactyloctenium aegyptium*.

Majority of monocot seeds are endospermic, e.g. paddy, wheat, maize, barley, etc., and it occupies greater portion of the seed (Kar *et al.*, 2002). In various Gramineae, especially in the examined species, the endosperm presents in the mature seed. It constitutes a main partner for storing the food materials even with the supply from the mother plant. In Gramineae, the endosperm is named starchy; according to the interpretation of Olsen *et al.*, (1999) and Olsen (2001); and functioned for reserving large amounts of starch granules which are consumed by the embryo upon germination and development. These components are characterized by their appearance where as they appear with light color, unstained or white color; in compatibility to Zeleznak & Varriano-Marston (1982), Irving (1983),



Figs. 48-51. Line drawings of fruit sections; a: diagram, b: sector, Bar = 2.5  $\mu$ m. 48: *Eragrostis cilianensis*, 49: *E. minor*, 50: *Leptochloa fusca* and 51: *Cenchrus ciliaris*.

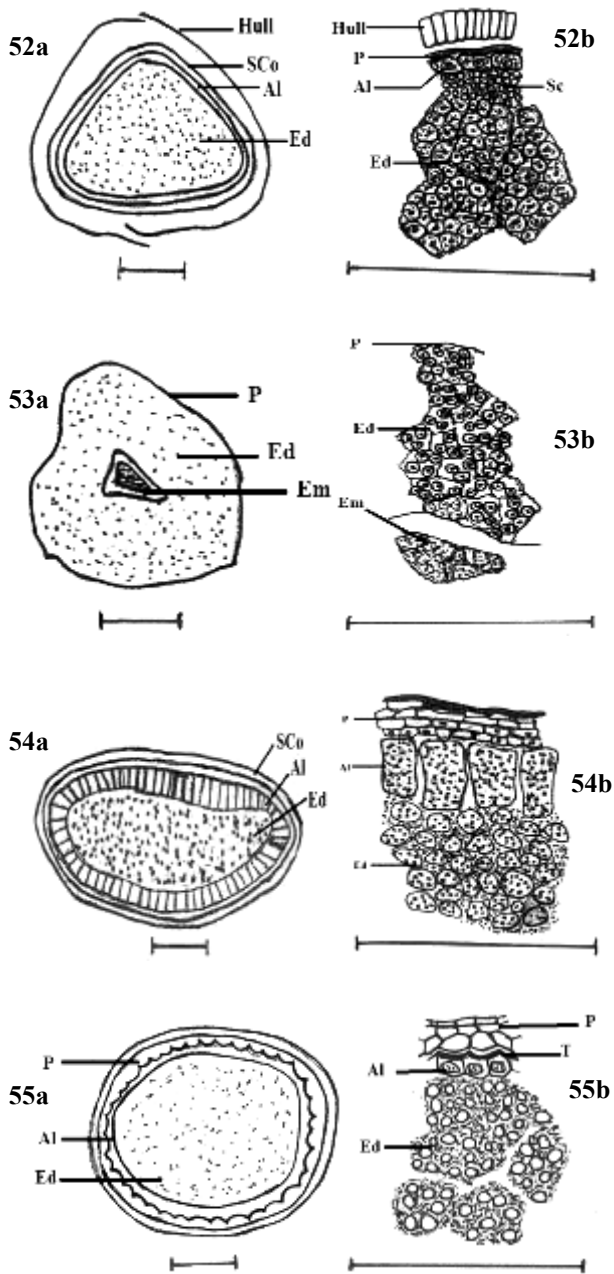
and Jane (2004). Another type of endosperm tissue is identified in the species, *Aristida funiculata* (Aristideae), it is named the fluidly endosperm according to Carlquist *et al.*, (1997) and characterized by its undeveloped cell walls and its fluidly contents. This type of endosperm was noticed in the species *A. funiculata* and not repeated in the other two species included within the Aristideae; *A. adscensionis* and *A. mutabilis* and also in the other taxa in the study. Moreover, undifferentiated, in addition to, the differentiated endosperm together are only scored in the odd genus of Brachypodeae; *Brachypodium distachyum*. Hence the construction of the endospermic tissue can aid in differentiating taxa, in addition to the variation concluded in the endosperm thickness among the various taxa even between genera and between species.



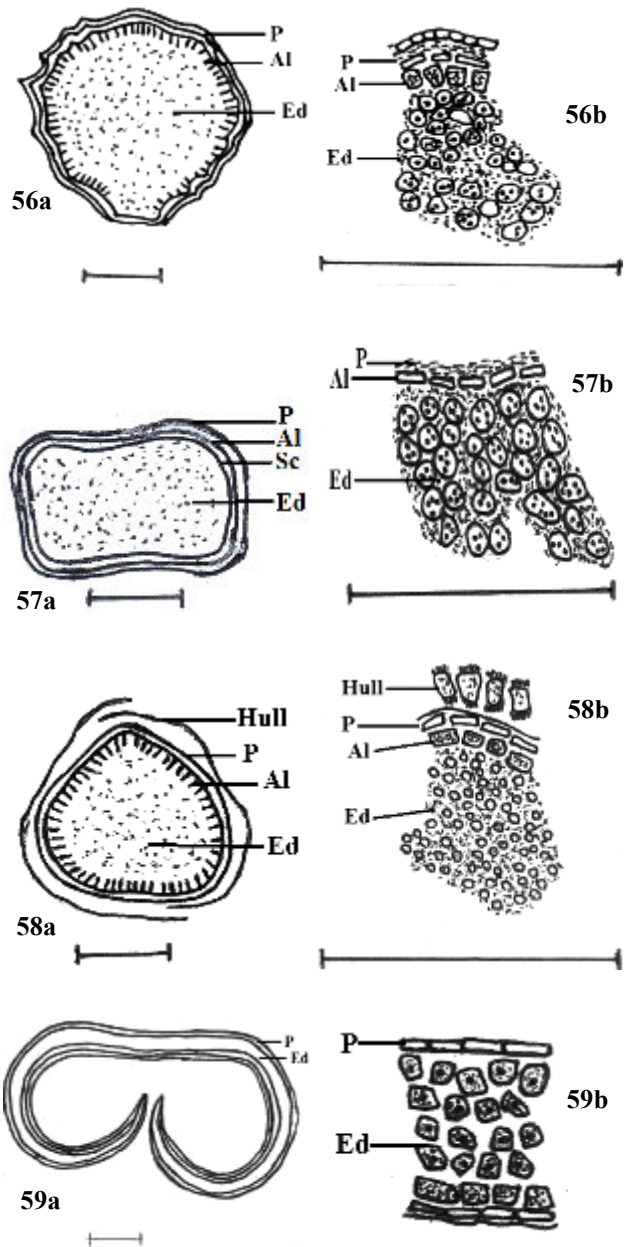
The embryo has one cotyledon in the caryopsis, it is very peculiar in the grass family. The cotyledon is known as scutellum, and lies in contact with the endosperm. It is haustorial in nature whereas it digests and absorbs food for growing embryo upon germination (Kar *et al.*, 2002). The scutellum in this study appeared in different manners, it ranges from not differentiated or identified, arranged as a strip of cells circulating the whole section as a separate layer followed the aleurone, a mass of cells taking different shapes in outline to an embedded within the endosperm. Moreover, it can be a variable even in the same plant group, thus it can be useful for characterizing the anatomical structure of each fruit. As in most grasses, the scutellum found in fruits of certain plants, to comprise a large portion in the embryo as Zeleznak & Varriano-Marston (1982) early identified, in *Sorghum variegatum*

(Andropogoneae), *Aristida adscensionis*, *A. mutabilis* (Aristideae) and *Dactyloctenium aegyptium*, *Eragrostis cilianensis* (Eragrostideae) where it is appeared as a large mass of embryonic cells taking different shapes, meanwhile, it shows a vital difference in the genus of *Eragrostis*, where in *E. minor*, it is a strip of cells between the aleurone and the differentiated endosperm.

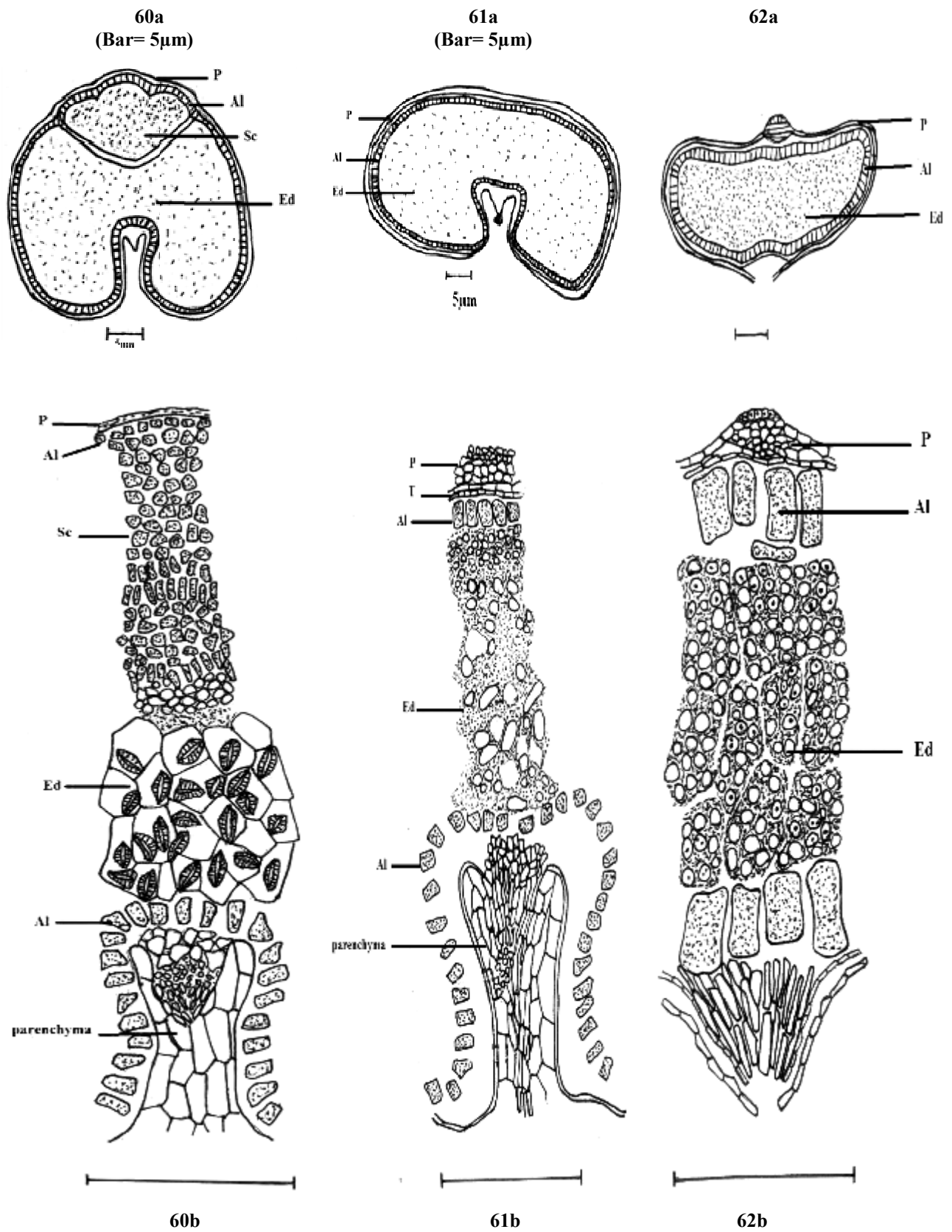
Finally, it can be concluded that the unique anatomical structure of the very marked grain fruit or caryopsis, by its general construction or even by each of its components singly, can serve significantly for identifying a plant group at the three classification terms introduced in this article, a species, a genus or a tribe. A key is presented for aiding the identification of genera and species within tribes studied.



Figs. (52-55). Line drawings of fruit sections; a: diagram, b: sector, Bar = 2.5  $\mu$ m. 52: *Echinochloa colona*, 53: *Dactylis glomerata*, 54: *Lolium perenne* and 55: *Poa annua*.



Figs. (56-59). Line drawings of fruit sections; a: diagram, b: sector, Bar = 2.5  $\mu$ m. 56: *Oryzopsis miliacae*, 57: *Stipa capensis*, 58: *S. lagascae* and 59: *S. parviflora*.



Figs. (60-62). Line drawings of fruit sections; a: diagram, b: sector, Bar = 2.5 μm. 60: *Aegilops kotshyi*, 61: *A. ventricosa* and 62: *Hordeum murinum ssp. leporinum*. Bar= 2.5μm.

## Key for genera and species

1. a. Hull cells absent .....	8
b. Hull cells present .....	2
2. a. Hull cells are parenchymatous .....	4
b. Hull cells are epithelial .....	3
3. a. Scutellum consists of elliptical mass cells .....	<i>Aristida mutabilis</i>
b. Scutellum consists of strip of cells .....	<i>Stipagrostis ciliata</i>
4. a. Aleurone orientation vertical .....	<i>Polypogon monspeliensis</i>
b. Aleurone orientation horizontal .....	5
5. a. Scutellum consists of elliptical mass cells .....	6
b. Scutellum consists of strip of cells .....	7
6. a. Medium of seed coat thickness 9.88(8.18-10.94) $\mu\text{m}$ .....	<i>Sorghum varigatum</i>
b. Medium of seed coat thickness 6.03(4.57-8.38) $\mu\text{m}$ .....	<i>Aristida adscensionis</i>
7. a. Medium of seed coat thickness 10.39(8.33-14.28) $\mu\text{m}$ .....	<i>Coelachyrum bervifolium</i>
b. Medium of seed coat thickness 3.25(2.5-5) $\mu\text{m}$ .....	<i>Echinochloa colona</i>
8. a. Aleurone is not observed .....	9
b. Aleurone is observed .....	12
9. a. Scutellum is not observed .....	10
b. Scutellum is composed of strip of cells .....	<i>Eragrostis minor</i>
10. a. Medium of seed coat thickness 2.95(2.33-4.19) $\mu\text{m}$ .....	<i>Aristida funiculata</i>
b. Seed coat thickness range 6-10 $\mu\text{m}$ .....	11
11. a. Medium of seed coat thickness 6.67(5.63-7.61) $\mu\text{m}$ .....	<i>Dactylis glomerata</i>
b. Medium of seed coat thickness 9.02(8.24-9.53) $\mu\text{m}$ .....	<i>Stipa parviflora</i>
12. a. Orientation of Aleurone is horizontal .....	13
b. Orientation of Aleurone is vertical .....	23
13. a. Scutellum is present .....	14
b. Scutellum is absent .....	20
14. a. Scutellum consists of strip of cells .....	17
b. Scutellum cells shape otherwise .....	15
15. a. Scutellum of triangular mass cells and strip of cells .....	<i>Dactyloctenium aegyptium</i>
b. Scutellum cells shape otherwise .....	16
16. a. Scutellum of oval mass cells and strip of cells .....	<i>Eragrostis cilianensis</i>
b. Scutellum of rectangular to cordate mass cells .....	<i>Aegilops kotshyi</i>
17. a. Scutellum dimension range 28-33 $\mu\text{m}$ .....	18
b. Scutellum dimension range 11-17 $\mu\text{m}$ .....	19
18. a. Scutellum dimension medium 28.58(24.83-35.92) $\mu\text{m}$ .....	<i>Schismus arabicus</i>
b. Scutellum dimension medium 32.91(26.72-40.19) $\mu\text{m}$ .....	<i>Stipa capensis</i>
19. a. Scutellum dimension medium 11.58(10.27-12.41) $\mu\text{m}$ .....	<i>Leptochloa fusca</i>
b. Scutellum dimension medium 16.13(12.92-17.92) $\mu\text{m}$ .....	<i>Cenchrus ciliaris</i>
20. a. Aleurone thickness range 6-7 $\mu\text{m}$ .....	21
b. Aleurone thickness range 9-17 $\mu\text{m}$ .....	22
21. a. Endosperm thickness medium 174.50(146.16-206.0) $\mu\text{m}$ .....	<i>Brachypodium distachym</i>
b. Endosperm thickness medium 238.6(227.14-258.63) $\mu\text{m}$ .....	<i>Stipa lagascae</i>
22. a. Aleurone thickness medium 16.52(13.23-19.66) $\mu\text{m}$ .....	<i>Poa annua</i>
b. Aleurone thickness medium 9.51(8.44-10.94) $\mu\text{m}$ .....	<i>Oryzopsis miliacea</i>
23. a. Scutellum is present .....	24
b. Scutellum is absent .....	27
24. a. Scutellum is quinquangular cells .....	<i>Avena barbata</i>
b. Scutellum is strip of cells .....	25
25. a. Aleurone thickness medium 33.13(31.27-35.43) $\mu\text{m}$ .....	<i>Avena fatua</i>
b. Aleurone thickness range 15-21 $\mu\text{m}$ .....	26
26. a. Scutellum dimension medium 8.87(6.2-11.09) $\mu\text{m}$ .....	<i>Phalaris minor</i>
b. Scutellum dimension medium 21.48(14.56-27.58) $\mu\text{m}$ .....	<i>Polypogon maritimus</i>
27. a. Aleurone thickness range 17-29 $\mu\text{m}$ .....	29
b. Aleurone thickness range 34-45 $\mu\text{m}$ .....	28
28. a. Aleurone thickness medium 34.67(30.61-40.51) $\mu\text{m}$ .....	<i>Lolium perenne</i>
b. Aleurone thickness medium 44.16(42.89-45.21) $\mu\text{m}$ .....	<i>Hordium murinum</i> ssp. <i>Leporinum</i>
29. a. Endosperm thickness medium 631.67(602.41-784.98) $\mu\text{m}$ .....	<i>Aegilops ventricosa</i>
b. Endosperm thickness range 83-157 $\mu\text{m}$ .....	30
30. a. Endosperm thickness medium 83.71(76.01-87.8) $\mu\text{m}$ .....	<i>Bromus scoparius</i>
b. Endosperm thickness medium 156.51(152.86-158.69) $\mu\text{m}$ .....	<i>Bromus rubens</i>

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