PALYNOLOGICAL AND TAXONOMIC STUDIES OF ALLERGY CAUSING AND OTHER GRASSES OF ISLAMABAD

A THESIS

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IN
PLANT TAXONOMY (PLAYNOLOGY)

BY

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بسم الله الرحمن الرحيم

وَ هُوَ الَّذِيْ اَنْزَلَ مِنَ السَّمَآءِ مَآءً فَأَخْرَجْنَا بِهِ نَبَاتَ كُلِّ شَىْءٍ

فَأَخْرَجْنَا مِنْهُ خَضِراً نُّخْرِجُ مِنْهُ حَبًّا مُّتَرَاكِبًا وَ مِنَ النَّخْلِ مِنْ

طَلْعِهَا قِنْوَانٌ دَانِيَةٌ وَجَنّٰتٍ مِّنْ أَعْنَابٍ وَالزَّيْتُوْنَ وَالرُّمَّانَ مُشْتَبِهاً

وَغَيْرَ مُتَشَابِهٍ اُنْظُرُوٓا إِلَى ثَمَرِهِ إِذَآ أَثْمَرَ وَيَنْعِهِ إِنَّ فِى ذَٰلِكُمْ

لَأَيَاتٍ لِّقَوْمٍ يُؤْمِنُوْنَ (سورة الانعام/ 99)

"It is He Who sendeth down rain from the skies: with it We produce vegetation of all kinds: from some We produce green (crops), out of which We produce grain, heaped up (at harvest): out of the date-palm and its sheaths (or spathes) come clusters of dates hanging low and near: And (then there are) gradens of grapes, olives and pomegranates, each similar (in kind) yet different (in variety): When they begin to bear fruit, feast your eyes with the fruits, and the ripeness thereof. Behold! in these things are signs for people who believe."

(Al-Quran 99:6)

Dedication

I dedicate the success of this endeavour to the Kashmiri Freedom Fighters, for their endless forbearance has provided us courage and sense of sacrifice in the way of God and the Islam.

Declaration

The whole of the experimental work described in this thesis was carried out by myself. Laboratory work was done in plant taxonomy laboratory, Quaid-i-Azam University Islamabad and virology and immunology laboratory, National Institute of Health (NIH), Islamabad. The conclusions are my own reached after numerous discussions with my supervisor, Assistant Professor Dr. Mir Ajab Khan and my co-supervisor Dr. Syed Zahoor Husain, an Overseas Pakistani Research Scientist of Reading University, UK. No part of this work has been presented for any other degree.

Muhammad Azam Khan

Signature of the student

I certify that the above statement is correct. I have found that this thesis is complete and satisfactory in all respects, and that any/all revisions required by the final examining committee have been made.

Assistant Professor Dr. Mir Ajab

Signature of the supervisor

This thesis by Mr. Muhammad Azam Khan is accepted in its present form by the Department of Biological Sciences, Quaid-i-Azam University, Islamabad, as satisfying the thesis requirements for the degree of Master of Philosophy in Plant Taxonomy (Palynology).

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Muhammad Azam Khan

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ABSTRACT

Specially during the last decade, pollen allergy diseases are on the increase as reported by the medical practitioners and the media in Islamabad. It was felt that scientific investigation in this direction should be conducted to find out which particular grass pollens in Islamabad are responsible for allergy. This study was carried out in collaboration with National Institute of Health. A palynological and taxonomical study of 54 species belonging to 37 genera of the family Gramineae from Islamabad was conducted. Pollen morphology was studied with light microscope and scanning electron microscope from slides prepared with Erdtman 1943 (modified by personal communication with Dr. Syed Zahoor Husain) method and by mounting dry pollens on the metal stubs with cellotape on it respectively. Light microscopy reveals that the pollens of grasses studied are spheroidal, ovoidal or ellipsoidal, monoporate, ectoporus, some pollens are endoporus smooth (psilate) or granulate, rarely reticulate. Scanning electron microscopy of grass pollens reveals variation in exine surface, involving presence or absence of granules with different variations. The observations show some taxonomic correlations at generic level. It may be said that the differentiating characters of the pollen grains of the grasses have to do with relatively slight and inconstant differences in their shape and size, the shape and size of the aperture and its operculum and the texture of their exine. It is only in relatively few cases where such characters can be used for specific or even generic identification with any degree of certainty. On the basis of exine ornamentation and wall patterns the pollen of grasses have been divided into two new groups and two sub groups. 20 grasses of Islamabad are reported to be allergenic and the pollen samples are presented to National Institute of Health for allergy tests on patients. This is the first such study in Islamabad.

Chapter One
(Introduction)

INTRODUCTION

This research work was carried out in February 1996 under the supervision of Dr. Mir Ajab Khan, Assistant Professor of Botany in Department of Biological Scineces, Quaid-i-Azam University Islamabad and Dr. Syed Zahoor Husain, an overseas Pakistani UNDP consultant in pollen allergy and senior research scientist at Reading University, UK. This research project comprises the palynological and taxonomic studies of allergy causing and other grasses of Islamabad. The research includes the collection of pollens from the members of the family Gramineae, from different sectors of Islamabad, preparation of vouchers plant specimens, identification of plants and pollen collection, preparation of permanent slides for light microscopic studies and collection of polliniferous material for scanning electron microscopic studies.

This research work was based on prevalence of pollen allergies in Islamabad. Recently in Islamabad pollen allergy was diagnosed in large number of patients from different sectors of Islamabad. It was felt that scientific research in this field should be conducted to find out which particular grass pollens in Islamabad are responsible for allergy. This study was undertaken in collaboration with National Institute of Health Islamabad.

1.1 Location of Islamabad

The area situated and adjacent to the north and east of Rawalpindi was named Islamabad, the new Capital of Pakistan by the Federal Government of Pakistan on 24th February 1960. The area of Islamabad forms the north-eastern part of the Pothohar plateau at 33^o-36' and 33^o-49' in latitude and 72^o-50' and 73^o-24' longitude. It is bounded on the noth-east by the Margalla Hills.

1.2 Topography

The city of Islamabad lies at the foot of Margalla hills. The major area is undulating ground rising gradually from an elevation of 494 to 610 meters above sea level. (Stewart,1985)

1.3 Climate and annual rainfall

The climate of Islamabad is monsoonic temperate with an average rainfall of about 1143 mm. The haviest precipitation occurs in the months of July-September which is also the season when grasses are in abundance. The annual mean maximum temperature ranges between 28.9^{oc} to 30^{oc} and mean minimum from 10 to 14.4^{oc}. January is the coldest month with the lowest minimum temperature reaching the freezing point.(Beig etal 1985)

1.4 Physical features

Rawalpindi-Islamabad, along with the Margalla Hills is largely tertiary in age (7-65 million years old) with smaller areas of formations belonging to the cretaceous period - 136 million years. (Department of Earth Sciences Quaid-i-Azam University Islamabad, Dr Tahira Mehmood Department of Biological Sciences Quaid-i-Azam University Islamabad).

The soil in this area is derived from wind and water laid deposits and sedimentary rocks. The soil from wind deposition is dark brown to yellowish brown, has medium to fine texture and well developed profiles. The subsoil is usually of decalcified or calcareous silt loam. The soil profile of the Rawalpindi series consists of very deep, well drained, medium textures soils, decalcified to a depth of 2 feet (Dr. Tahira). They have yellowish brown, pliable non-calcarious massive, very fine sandy loam topsoil about 6 inches thick. This overlies brown to dark brown, friable, non-calcareous, silt loam subsoils with weak, coarse, angular, blocky structure. The substratum is yellowish brown, friable, massive silt loam and strongly calcarious. (Shah, Ibrahim, 1977)

1.5 Grasses and Their Economic Importance

The establishment of grasses and grazing animals among dominant life forms on earth considerably preceded the advent of man. The fossil record of grasses is rather meagre but there are fairly good grounds for assuming that they emerged as a distinct class of the Angiosperm complex during late Cretaceous times, or even earlier when flowering plants were spreading throughout the world (Barnard and O.H. Franbel). By Miocene times, that is some 20 millions years ago, grasses were probably assuming an important place in the earth vegetation. Speciation of the grasses and the development of the grasslands has been occurring throughout the whole period from early tertiary times to the present day.

The grasses are one of the largest families of flowering plants in number of genera and species. From an estimated total of 12,500 genera of flowering plants, 600 or 4.8 percent are grasses, and from an estimated total of 225,000 species, 75,000 or 3.3 percent are grasses (Good, 1953) Clayton and Renvoize (1986) put the total number of grasses in the world at about 10,000 species. They recognized 651 genera and assigned them number indicating their phylogenetic status based upon various evidences.

Geographically, the grasses are ubiquitous and the grass family is truely cosmopolitan. Grasses occur in all continents and there are no significant lacunae in the distribution pattern.

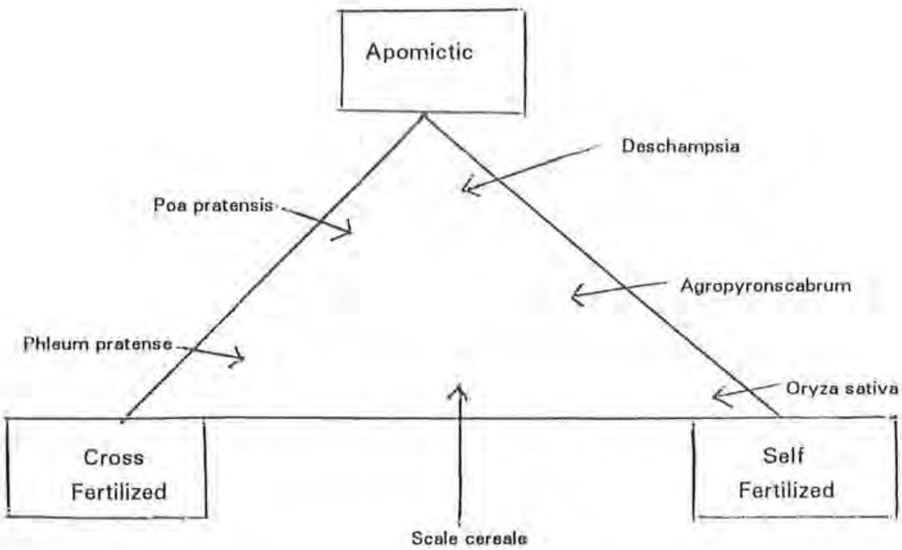
Grasses are found all over the land surface of the globe i.e., marshes and in deserts, on prairies and in woodland, on sand, rocks and fertile soil, from the tropics to the polar regions and from sea level to perpetual snow on the mountains. Their widespread distribution on the earth is probably due to their several lines of parallel and convergent evolution, and to many trends of adaptation having been reversed. Therefore, the grasses as a family are outstanding in their ability to adapt themselves to diverse ecological conditions.

This ability to adapt is surprising because both morphologically and biologically the grasses form a fairly homogenous group. Floral characters are similar throughout the family, a feature which has led the grasses to be regarded as a difficult group from the viewpoint of the taxonomists. With the exception of bamboos, they are all herbaceous with relatively little variation in growth form. The species are virtually all wind-pollinated or cleistogamous, and hence their distribution is not dependent upon the presence of insect pollinators.

Reproduction: Grasses are among the most successful plants occupying adverse environments. Their success is due to a variety of morphological and physiological characters among which are the effective protection of their florets and reduction to a minimum of the time when the florets are open. The developing inflorescence are enclosed by the leaf sheaths untill fully differentiated, while each florets is in turn protected by a lemma and palea, except for the one brief period when they are forced apart by the lodicules to allow pollen dispersal and to exposed the stigmas to cross-pollination. The grasses are pre-eminent to keep this period to a minimum for out breeding populations by controlling the season of flowering and of the daily time of flower opening.

A similar flexibility exists in the breeding system of grasses, which may vary greatly with environmental conditions. Whether the florets are normal or proliferous, cleistogamous or chasmogamous, self or crossed-fertilized, sexual or apomictic, in many species depends on, and are adopted to the climatic conditions prevailing during inflorescence development.

Breeding system: The grasses have exploited a wide range of breeding systems as is evident from the following diagram which is based on data from Fryxell (1957).



Breeding system in grasses (based on data from Fryxell (1957)

Many of the annual grasses are self-fertilized while the majority of the perennials are cross-fertilized and show inbreeding depression and self-incompatibility. The breeding system of grasses can be profoundly modified by environmental conditions. Sometimes this is due to a change in floral behaviour as in wheat and rice (Howard, A., and G.L.C. 1909). The compatibility system in grasses is probably beyond environmental influence, but the occurrence of apomixis male sterility, cleistogamy, monoecium and dioecium are all subject to climatic influence.

The anthers of grasses appear to be among the most susceptible of floral organs to adverse environmental conditions during their differentiation. The male florets of monoecious species may be delayed, inhibited or even replaced by female florets under unfavourable photoperiods and low temperatures. Frost may emasculate wheat and barley (Suneson, 1953) while long days and low temperatures lead to low fertility in normally male-fertile *Pennisetum clandestium* (Youngner, 1961).

Apomixis is common among the grasses and in most it is facultative rather than obligate. In fact, doubt exists as to whether there are any wholly obligate apomicts (Clausen, 1954) and it is becoming apparent that environmental conditions may influence the degree of apomixis in grasses.

Cytogenetics

The chromosome numbers and their behaviour at meiosis have been studied in most important cultivated grass species (Atwood, 1947 , Avdulor, Carnahan, and Hill, 1961). The cytological situation in the Gramineae is complicated because most species are, in fact, polyploids or contain chromosome races forming polyploids series. In addition, many of the apomictic genera such as *Poa* form extensive aneuploid series.

The basic chromosome number in the Gramineae varies and is related to the taxonomic grouping. Carnahan and Hill have listed the chromosome numbers of more than 1550 species and an analysis of these show that over 90 percent fall into one of two major groups. The tropical and subtropical species with small chromosomes representative of the tribes Andropogoneae, Maydeae, Paniceae, Chlorideae, Eragrosteae, and Danthonieae have a basic number n=10 or simple derivatives such as 9 or 12. Those species with a mainly temperate distribution, including the Agrostideae, Aveneae, Phalarideae, Festuceae and Hordeae have large chromosomes and the basic number is usually 7.

Cytogenetic evidence has provided valuable information on phylogenetic relationships in the Gramineae and has been useful in the identification of species in certain genera in which morphological characters alone are insufficient for this purpose (Morrison,1959, 1961 and Rajhathy 1961).

Table 1

Table of Chromosome Number of the Taxa Studied

Taxon	Gametophytic chromosome No. (n)	Sporophytic chromosome No. (2n)	Reference
Alopecurus myosuroides	14	-	Mehra and Sharma 1977
Aristida Adscensionis	33 11	- -	Spies and du Plessis 1987 Bir and Sahni 1983
Aristida funiculata	11	-	Bir and Sahni 1984
Avena ludoviciana	- 21	42 -	Magulaer 1976 Mehra and Sharma 1975
Avena sativa	- 21	42 -	Jones etal, 1989 Mehra 1982
Bothriochloa pertusa	-	40	Caupta and Srivasta 1974
Brachiaria distachya	36 -	- 36	Mehra and Sharma 1975a Muniyamma 1976
Brachiaria eruciformis	18	-	Mehra and Sharma 1975a
Brachypodium distachyon	30	-	Baltisberger & Leuchtmann 1991
Bromus catherticus	-	-	-
Bromus danthoniea	-	28	Chopanov & Yurtsev 1976
Bromus japonicus	- 14	14 -	Chopanov & Yurtsev 1976 Mehra & Sharma 1977a
Bromus pectinatus	-	-	
Cenchrus penisctiformis	18 27	- -	Bir & Singh 1983 Bir & Sanhi 1986
Chrysopogon aucheri	10	-	Faruqi etal 1979
Cymbopogon flexuosus	10	20	Christopher 1978
Cymbopogon schoenanthus	10	-	Faruqi etal 1987
Cynodon dactylon	18 -	- 18	Mehra & Sharma 1975c Chopanov & Yurtsev 1976
Dactyloctenium aegyptium	20 18 23 24	- - - -	Sharma & Sharma 1978 Mehra & Sharma 1975c Kalia 1978 Dujardin 1978
Desmostachya bipinnata	-	20 20	Kalia 1978 Muniyamma etal 1976
Dicanthium annulatium	10 20 -	- - 40,50	Sarkar etal 1975a Kalia 1978 Gupta & Srivastava 1974
Dicanthium foveolatum	-	-	-

Taxon	Gametophytic chromosome No. (n)	Sporophytic chromosome No. (2n)	Reference
Digitaria biformis	9 36 -	- - 36	Mehra & Chaudhry 1975 " Christopher & Abraham 1976
Digitaria nodosa	-	-	-
Digitaria sanguinalis	- - 9 18	18 36 - -	Gupta & Yarshvir 1977 Chopanov & Yurtsev 1976 Mehra & Sharma 1975 Christopher & Abraham 1976
Echinochloa colonum	27 - 28	- 54 -	Mehra & Sharma 1975a Chatterji 1975 Bir & Sindhu
Echinochloa crus-galli	- 27	54 -	Indakova 1974 Christopher & Abraham 1976
Eleusine indica	9 - 9, 18, 27	- 18 -	Mehra & Sharma 1975a Sarkar 1976 Kalia 1978
Eragrostis minor	30 - -	- - 40	Reeder 1977 Sokolovskaga & Probatova 1978
Heteropogon contourtus	39, 40, 50, 60, 69, 70, 80,90	 40, 50,60	Tothill & Hacker 1976 Gupta & Srivavasta 1974
Imperata cylindrica	- 10	20 -	Christopher 1978 kalia 1978
Lolium multiflorum	7 -	- 14	Mehra & Sharma 1975b Skalinska etal. 1978
Oplismenus burmannii	18 36 -	- - 44	Mehra & Sharma 1975a Christopher & Abraham 1976 Mehra & Chaudhry 1975
Parapholis strigosa	-	-	-
Paspalidium flavidum	27 - 22	- 54 -	Chatterji 1975 Shanthamma etal. 1976 Sharma & Sharma 1978
Paspalum dilatatum	- 25 30	50, 60 - -	Dandin & Chennaveeriah 1977 Mehra & Sharma 1975a Mehra & Chaudhry 1975
Paspalum distichium	- 20 30	60 - 40, 60	Dandin & Chennaveeraiah 1977 Fernandes etal. Mehra & Sharma 1975a Katayama & Ikeda
Pennisetum americanum	- -	14 14	Hanna etal. 1976 Brunben 1977

Taxon	Gametophytic chromosome No. (n)	Sporophytic chromosome No. (2n)	Reference
Phalaris minor	14 28 14+0-1B	26 - -	Humphries 1978 Chopanor & Yurtsev 1976 Sharma & Sharma 1978
Phleum himalacum	14+0-B	-	Sharma & Sharma 1978
Phleum pratense	- -	42 28	Skalinska etal. 1978 Magnlaev 1976
Phragmites australis	22-25	47-49, 72, 96 48, 50, 52, 56, 72, 96	Gonzalez-Aguilera etal, 1990 Gorenflot 1986
Poa annua	14 -	- 28	Devesa etal 1990 Koul 1990
Poa infirma	7	-	Devesa etal 1990a
Poa nemoralis	21 7	42 -	Galland 1988 Devesa etal 1991
Polypogon monspeliensis	13, 14+0-1B 7	- -	Faruq 1987 Devesa etal 1991
Sacchanum spontaneum	30 27, 45	60 -	Sinha etal. 1990 Singh etal. 1990
Setaria glauca	18 18	- -	Sinha etal. 1990 Bir & Ehauhan 1990
Setaria pumila	-	36	Devesa etal. 1991
Sorghum halepense	23	-	Gohil & Kaul 1986
Stipa splendens	20 30	- -	Gohil & Kaul 1986 Bir & Chauhan 1990
Urochloa panicoides	24 30	- -	Sinha etal. 1990 Bir & Chauhan 1990
Vetiveria zizanoides	10 10	- -	Bir & Sanhi 1983 Bir etal. 1987

A knowledge of the chromosome numbers and the recognition of the chromosome races within a species complex may influence the choice of particular race or species for crossing or the direction in which the crosses are made (McWilliam, 1962). Investigation of chromosome homology in interspecific hybrids can lead to a better understanding of species relationships and evolutionary history, suggesting possible avenues for further hybridization (Stebbins, and Zohary, 1959). Also cytogenetic studies can contribute fundamental information on the nature of polyploidy and apomixis and the existence of aneuploidy and other chromosomal irregularities.

Polyploidy: Polyploidy has also undoubtedly played an important role in the evaluation of the Gramineae for about 70 percent of the known wild species of grasses are of polyploid origin (Stebbins, G.L. 1947). The major role of polyploidy in evaluation has been in the fixing and spreading of hybrid combinations either at the varietal, sub-species or species level. It has also provided one of the most rapid known methods of producing radically different but nevertheless vigorous and well adopted genotypes. This has been achieved through the production of new combinations of characters rather than the origin of new characters themselves and has thus tended to be a conservative rather than a progressive force in evolution.

Apomixis: Apomixis is a term covering all types of reproduction which replace or substitute the usuall sexual process. Two main types are recognized, vegetative apomixis where reproduction is by means of vegetative proliferation (vivipary), and agamospermy where reproduction is by means of seed (Gustafsson, 1946-47).

Apomixis is common in the Gramineae, agamospermous apomixis is known to occur in 74 species and 12 other species reproduce, at least occasionally, by vivipary (Brown and Emery, 1957, Fryxell, 1957). The greatest number of species with agamospermous type of apmixis occur in genera from tropical and sub-tropical regions. In the subfamily Panicoideae, for example, agamospermy has been recorded in 22 genera and is particularly common in *Bothriochloa, Paspalum, Pennisetum, Urochloa* and *Dicanthium*. In the Festucoideae, grasses of the temperate regions, vivipary tends to be more common. Of the various forms of vegetative apomixis, vivipary or inflorescence proliferation is probably of greatest significance in the Gramineae.

The Uses of Grasses

Of all the plants of the earth the grasses are of the greatest use to the human race. The grasses directly or indirectly provide man and his domestic animals with the principal necessities of life. From the cereals - wheat, barley, oats, and rye of cool regions and rice, maize and millets of warmer lands - enormous crops of grain are harvested, rich in starch, oil, fats, proteins, minerals and vitamins. These grains are the source of flours and meals used in bread making and in the preparation of various food stuffs as well as in the manufacture of numerous products such as adhesives, cosmetics, plastics and oils. The sweet sap of sugar cane and varieties of *Sorghum* yields much of our sugar besides syrups and molasses. Alcoholic beverages, liquors, and industrial alcohol are made from the grains of cereals and from sugar molasses.

Some of the important uses of grasses are as follows:

Food Grasses

The most important food plants for the human race are the cereals, including wheat, maize, rice, barley, rye, oats and many kinds of *Sorghum*. The seeds of the cereals are also extensively used as feed for domestic animals.

Forage Grasses

Forage grasses are used for hay, pasturage, soiling and silage.

Hay grasses: The grasses together with clovers and alfalfa are the basis of permanent meadows. The most important perennial grasses used for hay are Timothy (*Phleum pratense*) Redtip (*Agrostis alba*), orchard grass (*Dactylis glomurata*) smooth brome (*Bromus pectinatus*) and Juhnson grass (*Sorghum halepense*).

Pasture grasses: The more common grasses used for permanent pasture are: (*Poa nenoralis*), Bermuda grass (*Cynodon dactylon*), smooth brome (*Bromus catherticus*), Italian ryegrass (*Lolium multiflorum*) and Dallis grass (*Paspalum dilatatum*).

Soiling grasses: Grasses used for soiling are for the most part the cereals, millet and other annual grasses used for temporary meadows.

Silage grasses: Any grass may be cut and stored in soils, but corn and the sorghum are the ones most used.

Range Grasses

A large number of grasses make up much of the wild pasture known as the range. Important range grasses are: red canary grass (*Phalaris arundinacea, Aristida funiculata, sitpa splendens)* Brome grass (*Bromus japonicus*).

Soil, Sand, and Mud-binding Grasses

Most grasses by providing a cover over the surface and a fine network of roots in the soil prevent erosion by wind and water, especially on hills and mountains slopes, river sides and on muddy and sandy sea shores.

There are several grasses which may be used for the control of drifting sand of coastal dunes. The rhizomes of these grasses spread rapidly through loose sand, branching and rooting profusely and giving rise to erect leafy shoots capable of growing up through gradually increasing layers of sands.

On tidal mud-flats, flooded at high water, the common salt marsh-grass (*Puccinellia maritima*) spread over the bare mud by means of its creeping rooting stolons gradually forming the short dense turf of a salt marsh.

Grasses in the Industrial Arts

The most important species of the industrial arts group is sugarcane. The fiber producing grasses are utilized in paper making. The pith of the corn stalk and the oil of the corn grain find many uses in the arts.

Certain aromatic grasses furnish essential oils used in perfumery. The best known are lemon grass (*Cymbopogon citratus*), citronella grass (*Cymbopogon nardus*) and vetiver (*Vetiveria zizanioides*).

The bamboos, the largest of grasses, are of vast importance in the industrial arts. The culms or stems are very strong and are used for building houses and bridges. When the stems are splits, flattened out, and the partitions at the joints removed they make very durable boards, a foot or more wide for floors and walls. Rafts and floats are made of the hollow stems closed at the joints by natural airtight partitions. With the partitions removed bamboo stems furnish water pipes. Much of the furniture and many of the utensils and implements used are made wholly or in part of bamboo. Brooms are made from the seed heads of broomcorn, a variety of *Sorghum*. Leg horn hats are made of a kind of wheat straw cut young and bleached. Straw of rice and oats is used for matting and for hats.

Grasses for Lawns

The lawn is a most important part of a well-planned landscape, park or garden. Kentucky blue grass, used for pasture, is the best known lawn grass. Bermuda grass is often used as a lawn grass in shady places.

Ornamental grasses

It is true that grass flowers cannot compete in colour, scent and splendour with the lily or the rose, nevertheless, they posses distinctive types of foliage and flower-head which provide a very pleasing setting or more showy plants. For practical purposes ornamental grasses may be divided into two groups depending on whether they are grown for their attractive flower heads or for their graceful and unusual foliage. Among typical ornamentals or the plume grasses, giant reed (*Arundo donax*) and pampas grass (*Cortadlria selloana*) are the most popular for parks and large areas. Dwart bamboo (*Bambusa mutiplex*) is used for hedges.

1.6 The Classification of Grasses

The angiosperms are widely distributed with so many variations that sometimes it seems almost impossible to arrange them in systematic order. Since the prehistoric times the people were interested in the solution of the problem, and for the first time a few plants were classified according to their medicinal and food value and thus the taxonomy of flowering plants originated.

There can be three different possible types of systems of classification, the **artificial**, the **natural** and the **phylogenetic** classification.

Artificial system:- In artificial system of classification only a few characters of the plants are being considered, for example, the grouping of plants into herbs, shrubs and trees or the sexual system of **Linnaeus** based on the number of stamens and styles. There are so many drawbacks in this system, the most important one is that the plants closely resembling each other are very often placed in widely separated groups, while those quiet different from each other are being placed in the same group. The artificial systems are not in current use. The best known artificial system is of **Linnaeus** published in 1735.

Natural System:- In the natural system all the important characters of the plant are being considered, and the plants are classified according to their related affinities. This system reflects the situation as it is thought to exist under natural conditions, for example, Bentham and Hooker's system (1862-83).

Phylogenetic system:- In phylogenetic system, the plants are classified according to their evolutionary and genetic affinities. But it seems a bit difficult to classify the plants (especially grasses) perfectly on the basis of evolutionary tendencies due to imperfection of fossil records, and therefore, at present the plants are classified partly according to natural and partly according to phylogenetic basis. The system of classification proposed by **Engler** in 1886, by **Hutchinson** in 1926 and by **Tippo** in 1942 are phylogenetic.

Scheucher (1708) was one of the first who published a scientific paper about grasses. It went under the title Agrostographial Helvetica Prodromus. **Linnaeus** (1753) systematised the grass classification in his first edition of "Species plantarum" and listed 40 grass genera. **Linnaeus** sexual system of classification was based on the number and arrangement of stamens and pistils. Linnaeus listed 28 genera of grasses under *Triandria digynia*, but the other twelve genera were classified in quite different groups, for example, *Cinna* in *Monandria digynia*, *Nardus* in *Triandria monogynia*, *Zea* and *Coin* in *Monoecia triandria*, *Anthoxanthum* in *Diandria digynia*, *Oryza* in *Hexandria digynia* and *Andropogon*, *Ischaemum*, *Cenchrus*, *Holcus* and *Aegilops* in *Polygamia monoecia*.

In the beginning of the nineteenth century, taxonomists started to classify plants according to a wide range of morphological characters (natural system of classification). **Brown** (1810) understood the true nature of grass morphology. He recoganized the spikelets as a reduced inflorescence branch. He classified the grasses into Paniceae and Poaceae and describe the spikelet characteristics of these groups. He noted that Paniceae were distributed mostly in the tropics and sub-tropics while the Poaceae were mainly adopted to temperate regions.

De Beaurois (1812) named and described a large number of grass genera and recognized the grass family as the best known of the higher plants. **Kunth** (1833) distinguished 13 tribes but recognized no sub-families. **Fries** (1846) recognized Clisanthees and Euryanthees as his two main groups of grasses. **Benthum** (1881) divided **Brown's** Paniceae into 7 tribes and further divided some of the tribes into sub-tribes. **Har** (1880) recognized three main groups of grasses - Frumentaceae, Sacchariferae and Fragmitiformes.

A phylogenetic system of classification of the grasses was presented first by **Avdulov** (1931) and elaborated in various versions by **Pilger** (1954), **Tateoka** (1957), **Prat** (1960), **Stebbins** and **Crampton** (1961), **Parodi** (1961), **Jacques-Felix** (1962), **Pot Tal** (1964), **Goned** (1968), **Clayton** (1978), and **Hilu** and **Wright** (1982). Most of these workers claimed their classifications to be the phylogenetic systems but actually this is largely not so. **Hubbard** (1966) recognized 59 tribes which he placed in 19 `groups` which were not named or given a precise taxonomic rank.

Table 2a

Major Classifications of Grasses since Avdulor

Avdulor (1931)	**Pilger (1954)**	**Tateoka (1957)**	**Prat (1960)**	**Stebbins & Crampton (1961) Parodi (1961)**
Poatae	Panicoidea			
	Andropogonoideae	Panicoideae	Festucoidees	Panicoideae
Phragmitiformes	Eragrostoideae	Eragrostoideae	Panicoidees	Eragrostoideae
Festuciformes	Festucoideae	Pooideae	Chloridoidees	Festucoideae
	Bambusoideae	Arundinoideae	Oryzoidees	Arundinoideae
Sacchariferae	Plyroideae	Pharoideae	Olyroidees	Bambusoideae
	Oryzoideae		Phragmitiformmes	Oryzoideae
	Micrairiodeae			
	Anomochlocideae			

Table 2b

Jacques-Felix (1962)	**Potztal (1964)**	**Gould (1968)**	**Clayton (1978)**	**Hilux Wright (1982)**
Pnaicoide	Pooideae	Festucoideae	Bambusoideae	Festucoideae
Chloridoide	Micrairioideae	panicoideae	Centothecoideae	Nardoideae
Festucoide	Eragrostoideae	Eragrostoideae	Arundinoideae	Oryzoideae
Arundinoide	Oryzoideae	Bambusoideae	Chloridoideae	Arundinoideae
Bambusoide	Oly roideae	Oryzoideae	Panicoideae	Centotheocideae
Oryzyoide	Panicoideae	Arundinoideae	Pooideae	Panicoideae
Stipoide	Andropogonoideae			Eragrostoideae
Streptogynoide	Bambusoideae			Bambusoideae
Ehrhartoide	Anomochloideae			
Olyroide				
Zizanioide				

Several notable systems have been produced by contemporary botanists, including **A. Takhtajan** (1910-1992) of Leningrad, **A. Cronquist** (1919-1990) of New York, and **R. Thorne** (1920-) of California **Cronquist's** system is the best developed, and it has been selected for use in the family circumscriptions and family sequence in several recent floristic projects in the world.

Synopsis of sub-families and tribes of the family Gramineae
(following A. Cronquist, 1982)

Table 3

Class	Liliopsida
Sub-class	Commelinidae
Order	Cyperales
Family	Poaceae
Subfamily	**Tribes**
I. Festucoideae	Festuceae
	Aveneae
	Triticeae
	Meliceae
	Stipeae
	Brachylytreae
	Diarrheneae
	Nardeae
	Monermeae
II. Panicoideae	Paniceae
	Andropogoneae
III. Eragrostoideae	Eragrosteae
	Chlorideae
	Zoysieae
	Acluropodeae
	Unioleae
	Pappophoreae
	Orcuttieae
	Aristideae
IV. Bambusoideae	Bambuseae
	Phareae
V. Oryzoideae	Oryzeae
VI. Arundinoideae	Arundineae
	Danthonieae
	Centotheceae

Systematic arrangement of the family Gramineae
(After Bentham & Hooker, Engler & Prantle and Hutchinson)

Table 4

Bentham & Hooker	Engler & Prantle	Hutchinson
Phanerogams Monocotyledones Glumaceae Gramineae	Phanerogam Monocotyledoneae Glumiflorae Gramineae	Angiospermeae Dicotyledones Glumiflorae Graminales Gramineae

1.7 Phylogeny of Grasses

Efforts have often been made to trace the descent of present day grasses but the fossil record for grasses is so limited that it is almost negligible as compared to their large number of genera and species in the world today. Grasses probably came into being in the Mesozoic, after flowering plants were well diversified. The first reported grass like fossils are from the upper cretaceous, and the first definitely known grass fossils are from late tertiary rocks of Europe (**Gould**, 1968). Carbonized grass fruit from tertiary deposits of the florissant beds of Colorado were assigned to stipa by **Cockerell** (1908).

Hutchinson (1934) suggested that the grasses along with the sedges have been derived from Liliaceous ancertral stock in a Juncaceae complex. **Lawrence** (1969), however, did not regard the Gramineae and Cyperaceae as closely related. He noted that grasses have terminal flowers whose ovaries probably evolved from ancertral types with parietal placentation, whereas sedges have axillary flowers whose ovaries evolved from the types with free central placentation. The Cyperaceae are more like the Juncaceae than the Gramineae. **Ziegenspeck** (1938) believed that the parental line from Liliales divided immediately into two branches, one giving rise to Commelinaceae and Gramineae and the other to Juncaceae and Cyperaceae. From the first line Commelinaceae branched off, leaving reduction and specialization produced the Gramineae in its present form. **Stebbins**

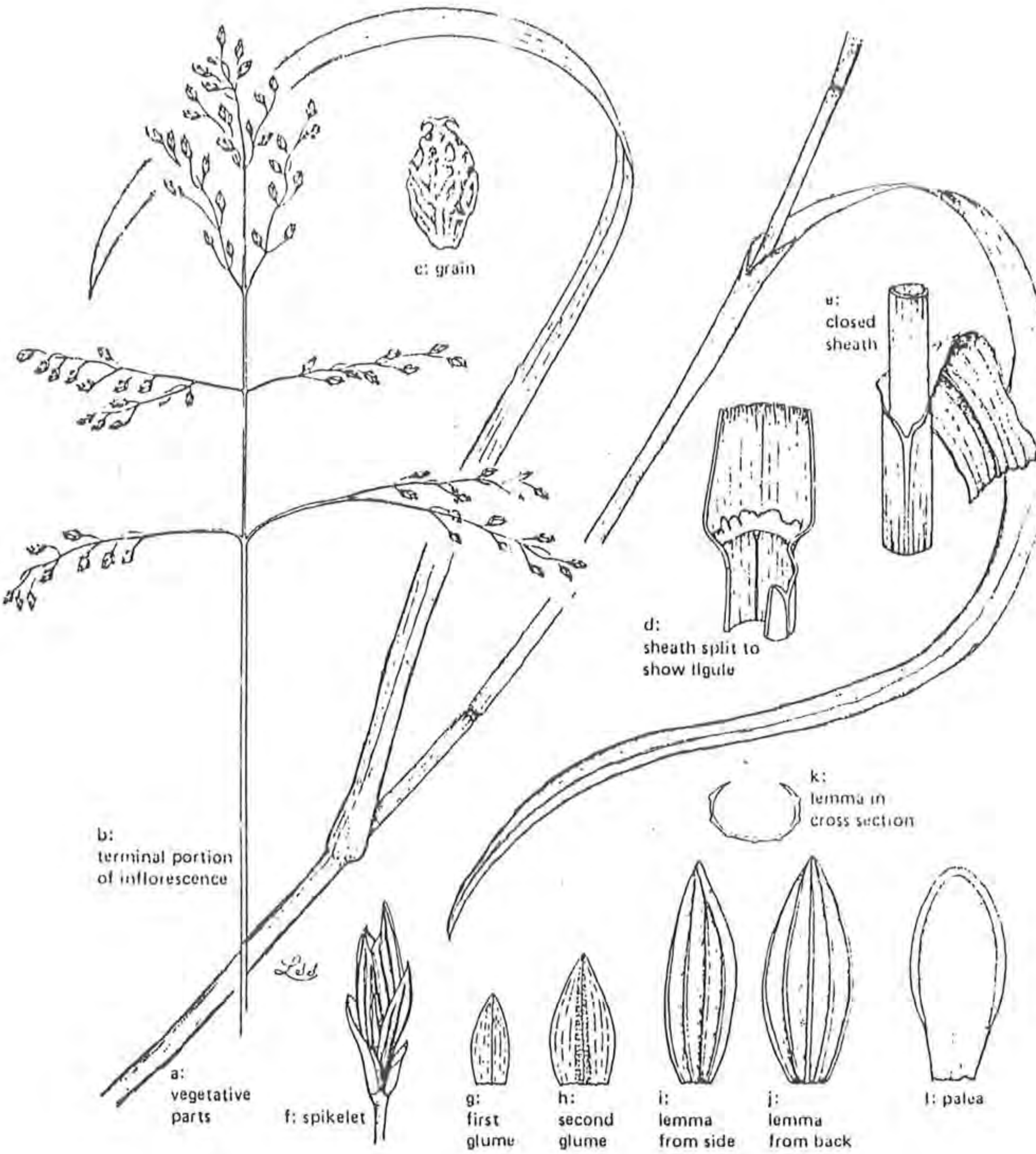


Diagram of a typical grass plant showing vegetative and morphological structure in detail.

(1956) suggested the relationship of grasses to be with the families Flogellariaceae and Restionaceae.

Sharma (1979) suggested that in response to the forces of evolution and natural selection grasses have added some parts and eliminated others to produce an extra ordinary mosaic of characters. He suggested that progenitors of the present-day grasses were probably herbaceous forest grasses which now seem extinct but lived in the cretaceous, judging from the few fossil data available for grasses. The characters of those grasses are now found in Bambuseae, Phareae and some members of Oryzeae. **Avdulor** (1931) suggested that the phylogenetic tendencies within the Gramineae have been from high basic number and small size chromosomes to low basic number and large chromosomes. The series phragmitiformes (including tribes Arundineae and Bambureae) with high basic number is primitive and genera with low basic numbers (many of his festuci-formes) are more advanced. **Bews** (1929) **Prat** (1936) and **Stebbins** (1956) regarded the Bambuseae as the most primitive tribe within the family Gramineae. The Bambuseae have three lodicules, six stamens, perfect many flowered spikelets; woody, perennial stems; articulate leaves, awnless glumes and lemma, and high number of chromosomes of small size.

Beetle (1955) regarded phareae as the most primitive of all the tribes. The phareae have well developed lodicules, six stamens, perfect spikelets, a herbaceous perennial habit, petiolate leaves and a tropical distribution. **Tateoka** (1957) placed Phareae and Oryzeae in his primitive group. The members of the Oryzeae have a one flowered spikelet and some members like *Hygroryza, Oryza* and *Leersia* possess six stamens. The Oryzeae also posses high chromosome numbers of small size.

1.8 Description of the family Poaceae

A large cosmopolitan family with about 898 genera and 10,000 species throughout the world (**Tveler**, 1989) and represented by 158 genera and 492 species in Pakistan (**Cope**, 1982). The family Poaceae can easily be distinguished from other families by its unique and unusual vegetative and floral structure.

Habit:- Mostly the plants are annual, biennial or perennial herbs or shrubs.

The grass plant for the purposes of description can conveniently be divided into two parts: the vegetative shoot and the reproductive shoot.

The Vegetative Shoot

Root:- Roots are fibrous in nature and in certain circumstances are profusely developed.

Rhizomes:- Rhizomes are underground stems and consist of short internodes covered with reduced leathery sheaths without blades and end in terminal coriaceous pointed buds which enable them to pierce the soil often to considerable distances.

Culms:- The stem of a grass, known as the culm, is made up of solid disc-like nodes separated by internodes. Most culms are smooth and glaborus between the nodes.

Internodes:- The internodes of most grasses are hollow but there are notable exceptions.

Nodes:- The nodes are transverse septa which serve to strengthen the stem. They are often marked by a darker colour and a slight constriction or swelling in diameter of the culm. The base of the leaf sheath is attached at the nodes.

Leaves:- The foliage of the grass plant consists of the sheath, the ligule and the leaf blade, the three combined to form one organ, the leaf.

(a) **Leaf-sheath.** The sheaths originate at the nodes of the culm. The culm-sheaths are mostly terete in shape and clasp the stem firmly.

(b) **The ligule.** An outgrowth, the ligule, occurs at the inner distal margin of the leaf-sheath and is found to originate from the epidermis alone. The ligules of the grasses exhibit great variation in shape and texture, but for individual species they are constant in texture and show very little variation in size and shape. In texture, they may be hyaline and delicate, translucent milky-white or coriaceous. In some the ligule may be completely absent.

(c) **Auricle:** An ear-shaped part or appendage, such as that occurring at the base of some grass leaves e.g., rice (Oryza sativa)

(d) **Leaf blade.** At the top of the leaf sheath is the leaf blade, the cheif organ of nutrition of the plant. The blades are typically flat, narrow and sessile. In dry regions they are usually involute or convolute; in tropical shade they are often comparatively short and wide.

The Reproductive Shoot

The inflorescence. The inflorescence of the grass plant is produced on shoots which may be terminal or axillary, but most often terminal. Most inflorescence, although they originate in the axil of the uppermost leaf, are at anthesis well exerted.

As in every other organ of this family the variety of inflorescence is bewildering, ranging as it does from closely packed spikelets to the most effuse of panicles, from few spiculate to inflorescences which contains hundreds of spikelets.

Inflorescences may be conveniently divided into spikes, racemes, spike-like racemes and panicles, true and false but there is always a central axis or rhachis.

The Axis or Rhachis. This is the structure to which the spikelets are attached, either sessile or by means of branches or pedicels. It may be fragile and consist of joints, or tough and continuous, and is often obviously noded.

The Spikelet. The spikelet is the unit of inflorescence. Essentially it consists of a pair of empty bracts at the base, alternately and distichously arranged on a tough or fragile jointed axis, the rhachilla. Above them, again distichous and alternate on the rhachilla, is a floret or series of florets each consisting of two bracts enclosing a flower. The outer bract is called the lemma, the inner the palea. The spikelet itself may have from none to more than forty florets.

The Rhachilla. Rhachilla is the axis of the spikelet upon which the glumes and florets are distichously aranged. It is sometime tough, that is, the mature florets fall away from it leaving it intact, but generally speaking it breaks up above or below the glumes and between the florets; the florets fall away with the adjacent joint of the rhachilla.

The Glumes. These are the two empty bracts seated at the base of the spikelets one above the other, named upper and lower glumes respectively. When the glumes are main protective cover for the florets they are usually of the same length and are of a much tougher texture than the lemma, but in other cases where the protective role is taken over by the lemma, the latter is tough and coriaceous, and the glumes herbaceous or hyaline.

The glumes are mostly not awned but in some cases the glumes are powerfully awned.

The Lemma. These are the flower bearing bracts. The lemma are hyaline in texture. Usually the lemma bears a long own as an extension of the midrib at the apex or back. The nerves of the lemma are sometimes of value. The outer surface of the lemma is often glabrous but the surface may be hairy and/or the nerve ciliate.

The Palea. The palea is the scale borne on the floral axis directly facing the lemma, and between them is to be found the flower. The palea is mostly 2-keeled and often concave between the keels.

The Flower. The flower consists of gynoecium, androecium and lodicules.

The Gynoecium. The gynoecium consists of the pistil and its contents. The component parts of the pistil are ovary, ovules, style and stigma. One carpel, unilocular ovary, single ovule, style short, usually two, stigma usually two arise from the carpellary wall, feathery.

The Androecium. The stamens constitute the androecium. Usually three stamens sometime six, e.g., in *Oryza, Bambusa* etc., and sometimes reduced to two or one, the stamens are with three, long slender filaments and versatile anthers. Anther two celled, dehise longitudinally.

The Lodicules. These are small to fairly large (in comparison with the lemma) scales, oblong, or lanceolate in shape, toothed or lobed in various ways, glabrous or hairy, two or three in number or completely absent. They are hyaline, often richly vascular and with fleshy bases.

The lodicules become very turgid at anthesis and it is believed that when in this state they serve to force apart lemma and palea so that the anthers may be thrust out and also subsequantly the style.

Fruit. The fruit of the grasses is usually a caryopsis, in which the single seed is grown fast to the pericarp, forming a seed like grain.

Chapter Two
(Introduction to Palynology)

INTRODUCTION TO PALYNOLOGY

Palynology is the science of pollen grains and spores. It is relatively new weft in the complicated web of natural sciences (Scientia amabilis). It is particularly connected with paleobotany (pollen analysis of quaternary and pre-quaternary deposits) and taxonomy.

The word "palynology" was coined by **Hyde** and **Williams** (1945) as a substitute for "the science of pollen grains and spores". It comes from the Greek verb palynein, meaning "to spread, the distribute" in recognition of the fact that many pollen grains and spores are easily carried by the wind. "Sporology" has been mentioned as a possible alternative and the cytological difference between "microspores" and "pollen grains" is not so great that these two groups cannot be dealt with under a common heading.

Palynology is at present penetrating into many other domains of botany and allied sciences, from which it is not separated by distinct lines of demarcation. The nucleus of palynology, is namely the pollen grains and spores themselves, and the morphology, fine structure etc. of their wall (sporoderm), particularly of its outer most layer, the exine. This layer is usually extraordinarily resistant and exhibits array of characteristic details that it can be used for the identification of plants. The resistance of grains and spores is so great that they can be preserved as fossil in peat and lake sediments etc. and thus provide a record of climatic and vegetational history stretching from our present days right back to Cambrian or, maybe, even pre-Cambrian times. Moreover, pollen grains and spores are found everywhere. It has been said that they have probably a wider distribution, both with regard to time and space, than any other organism or parts of organisms.

2.1 Subdivision of Palynology

Tentatively, palynology can be subdivided as follows:

1. **Basic Palynology (Pollen and spore morphology)**
2. **Applied Palynology**
    - i. **Palynotaxonomy**. Pollen and or spore morphology and plant taxonomy.
    - ii. **Geopalynology or palaeopalynology.** The study of fossil pollen grains and spores.
    - iii. **Aeroplaynology.** The study of pollen or spore distribution through the air.

iv. **Melittopalynology.** The study of pollen grains etc. in honey.

v. **Pharmacopalynology.** The study of pollen grains in drugs.

vi. **Iatropalynology.** The study of pollen grains etc. in connection with allergies.

vii. **Copropalynology.** The study of pollen grains in excrement.

2.2 Pollen Grain

Plants characteristically undergo a cyclic alternation of generation in which a spore producing generation, called the sporophyte (spore plant), is followed by a gamete-producing generation, called the gametophyte (gamete plant), and so on. In lower plants, such as ferns, both generations are distinctly evident and recognizable as plants. In evolutionary higher plants, however, the gamete producing generation has been progressively reduced in size and in duration of its existence, where in the seed plants, the male gametophyte has been diminished to the tinny pollen grain.

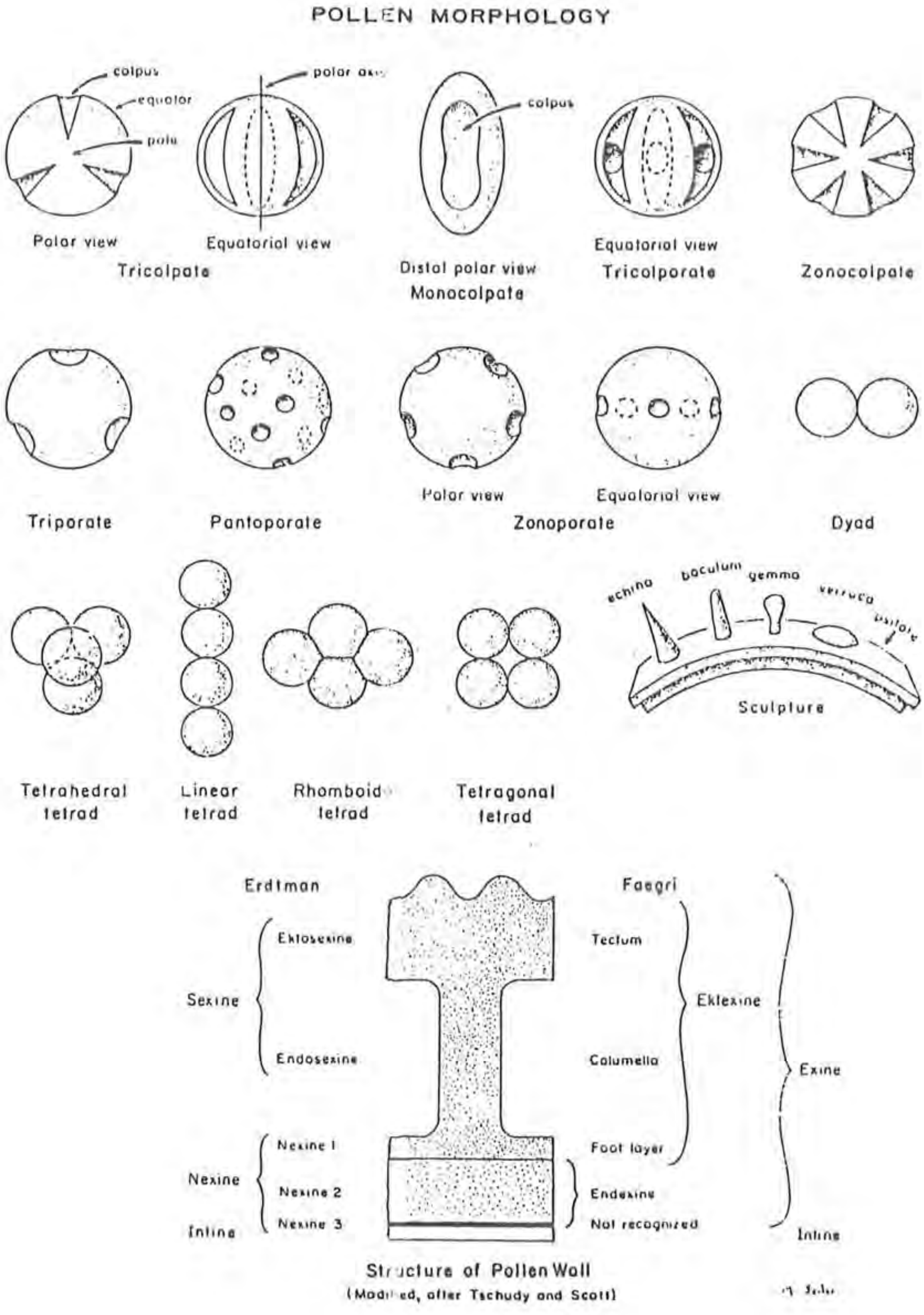
Pollen grains (male gametophytes) are produced on highly modified leaves called microsporophylls. In cone-bearing plants, such as pine trees, the microsporophylls is a scale of a male cone. In flowering plants the microsporophylls is the stamen of a flower. A stamen consists of a pollen producing anther, and a stalk (filament). As the anther matures, four groups of specialized cells called microspore mother cells (or pollen mother cells or microsporocytes). Each of the four groups of the microspore mother cells is surrounded by nutritive tissue and supporting cells and is collectively referred to as an anther sac, a pollen sac, or a microsporangium. Each microspore mother cell divides to form four micro spores, that is why the flower bearing plant is called the sporophyte. While still in the anther sac and shortly before being released, each microspore begins to germinate; that is, its nucleus divides into two nuclei, the generative nucleus and the tube nucleus. These are not separated from each other by cell walls but are still generally regarded as constituting two cells, - one the generative cell, being inside the other, the tube cell. The two nucleate structure is the pollen grain, or the male gametophyte. The pollen grain's generative nucleus will later divide into male sex cells, or gametes that is why the pollen grain is called the gametophyte. The two male sex cells are known as sperm nuclei and correspond to the sperm of animals.

Pollen may be produced in relatively small amounts, as few as several dozen per anther sac, or in large numbers, as in the wind-pollinated coniferous trees, where a singal cone may produce million of grains. Pollen grains are commonly yellow in colour and measure between 24 to 50 microns in size, but could also be orange, green or other colours and may measure from about 2 microns to several hundred micorns. Pollen grain contain proteins and sugars and serve as an attractant to insects and other animals, which aid in pollination. Because pollen grains are distinctive in shape and structure, particularly in the form of their outer walls, they are identifiable to their plants of origin. Pollen research contributes to medical knowledge (allergies), to agriculture, and in the study of fossilized specimens, to the evolution of plants and the search for oil.

2.3 Pollen Wall

The pollen grain is surrounded by an elaborate, ornate cell wall. The pattern of the pollen wall can be intricate and beautiful; at the sametime it is useful both to the plant and to plant taxonomists. The wall is composed of an extremely hard material called sporopollenin. This material is so hard that pollen grains many thousands of years old, still retain their pollen wall texture and pattern. Plant taxonomists study pollen wall patterns and evolutionary relationships.

When the pollen grains are mature, the anther wall splits open and the pollen are shed. Once on the stigma, if the pollen and the stigma are genetically compatible, it will germinate to form an elongate pollen tube. The ornate pattern of the pollen grain wall serves as the means for receptive stigmas to recognize compatible pollen. The troughs and ridges of the pollen wall apparently contain proteins in specific patterns and concentrations. These patterns correlate with those of the stigma. Metabolic events are triggered within the pollen grain to stimulate the pollen tube to grow into the pistil's tissue. Lack of recognition indicate incompatibility and the pollen grain will not germinate (Elliot Weier, etal, 1982). Recognition system also exist at different levels, for example, some compatibility/incompatibility reactions are triggered after pollen tube germination. In such



Diagramatic represent tion of various types of pollen grains, surface sculpturing a d structure of pollen wall.

a case an incompatibility reaction would actually inhibit further pollen tube growth into the style. Other reaction systems regulate pollen tube entry into the embryo sac and gamete release.

The elaborate cell walls of pollen grains present many intriguing problems. Their intricate details are sometimes species-specific and their chemical constitution is so resistant to decay, that pollen may still be present in fossil and subfossil plant deposits when all other traces of biological material have been lost.

The deposition of the wall begins during meiosis and passes through a number of steps, some of which occur after developing pollen grains lie free in the pollen sac in the anther. There is an evidence of some change in the ribosomes in developing pollen and of ribosome association with the plasma lemma. There is also an evidence that anther cells surrounding pollen sacs may be influential in wall pattern formation. Sculpturing of pollen wall is so precise and consistent in its major feastures that it forms the basis for a well developed field of pollen taxonomy.

2.4 Pollen-Wall Proteins

It has been known, for a long time, that pollen grains release enzymes into the germination medium (Green 1894, Stanley and Linsken 1964, 1965, Lewis etal. 1967, Markinen and Brew Baker 1967). Tsinger and Petrovskaya-Baranova (1961) were the first to report the presence of proteins in the walls of pollen grains. It is largely through the work of J. Heslop-Harrison and his associates that the details of pollen-wall proteins and their significance have become apparent. Both layers of the pollen wall, the intine and exine, contain a considerable amount of protein (Knox and Heslop-Harrison 1969). The intine protein are present in the form of radially-arranged tubules or tangentially-oriented leaflets. They are generally concentrated near the germpore. The exine proteins are present in the cavaties between the baculae (in tectate grains) or in the surface depressions (in non-tectate grains). A part of these proteins are mostly hydrolytic enzymes such as esterases, acid phasphatase, amylase and ribonuclease (Knox and Heslop-Harrison, 1970). The proteins responsible for pollen allergy are also present in the pollen wall (Knox etal. 1970, Knox and Heslop-Harrison 1971).

Esterases occur predominantly in the exine and acid phosphatases in the intine. Esterases and acid phosphatases can, therefore, be used as marker enzymes for exine and intine proteins respectively (Vithange and Knox 1976).

2.5 Pollen stratigraphy

Pollen stratigraphy involves the identification and study of fossil pollen in soils and rocks formations. Because the outer wall of pollen grains are quite resistant to chemical decomposition, the grains can serve as valuable microfossils. Fossil pollens were originally identified in 1836. Lennart Von Post (1916) made the first application of pollen Stratigraphy in studies of peat bogs in Sweden.

Fossil pollen is most often associated with sedimentary rocks and in particular with lake, swamp or bog deposits. It can also be found in deltaic, near shore-marine and even deep-ocean deposits. The most suitable deposits for pollen preservation are fine grained sediments that have been subjected to little distortion, compaction or oxidation. Pollen is not as common in limestone or other deposits because of their pH. Pollen is extracted from sediments by the use of strong acid or by flotation of the grains in a heavy liquid, such as zinc chloride.

The chronologic and areal distribution of pollen in geologic deposits can be used to reconstruct past climates and environments and is also used as a method of stratigrophic correlation. Pollen Stratigraphy is better adapted to identifying ecotones - the boundaries between different plant communities and to indicate changes within a plant community. Pollen data can be used to determine former environments on a larger scale than can most other fossils, which tend to reflect only the immediate surroundings of the former organism. Other uses of pollen stratigraphy include the location of ancient shorelines and the identification of human-induced changes in an area, such as those cause by the introduction of agriculture.

2.6 Terminology - definition of Palynological terms used in this work (after Erdtman 1969; Faegri & Iverson, 1975)

Aperture:- Morphologically it is an opening or a thinning of exine (except in operculate opertures where the intine is thickened); physiologically it could be a germinative zone.

Aperture Membrane:- Thin exine of the aperture.

Aperturate:- Pollen grain provided with one or more apertures.

Annulus:- Border to a porus which is produced by either a thickening or thinning of the exine.

Colpus:- Meridional simple aperture having length/breath ratio greater than 2.0.

Colpate:- Pollen grain provided with one or more colpi.

Colporus:- Meridional composite aperture having an elongated ectoaperture (colpus) and an endoaperture.

Colporate:- Pollen grains with compound apertures one or more porate colpi.

Columellae: General term for small, rod-like elements radially directed and forming the inner layer of the sexine. They are attached at their bases to the nexine and at their heads to the tectum.

Costa A thickning of the nexine near an aperature.

Ectexine:- Outer layer of exine staining red with fuchsin B.

Ectoaperture:- The thinning or opening in the ectexine/sexine.

Endexine:- Inner layer of exine that apears faintly pink after staining with fuchsin B.

Endoaperture:- Thinning or opening in the endexine/nexine.

Equatorial Axis:- The greatest axis, perpendicular to the polar axis, except when the pollen is constricted at the equator.

Exine:- External wall of pollen containing sporopollenin.

Eurypalynous:- Families characterized by a great array of pollen types (different apertures, sculpture etc.).

Granulate:- Pollen grains with very small grain like structure on its surface.

Intine:- Part of the pollen wall between the exine and the cytoplasm.

Lamellae: Tagential layers of exine material which are usually seen in the nexine.

Layer:- Subunits of the pollen wall.

Lumen: A gap or space between the walls of reticulate, striate or rugulate sculpture.

Murus: A ridge or wall separating two lumina of reticulate, striate or rugulate sculpture.

Nexine:- Inner exine representing either sole (foot layer) or end exine or both.

Operculum:- Thickened exine covering the aperture.

Polar Axis:- Line between the proximal and distal poles.

Porus or pore:- Simple aperture with length/breadth ratio less than 2.0.

Porate:- Pollen grain provided with one or more pori.

Psilate:- Pollen grain with no external visible features i.e., smooth.

Reticulum: A network or mesh-like pattern on the exine.

Reticulate: Pollen grain with a reticulum.

Rugulate: Pollen grain with sculpturing elements elongated sideways, length greater than twice the breadth.

Scaborate:- Pollen grains with very small isodiametric sculpturing elements called scabrae.

Sculpturing:- External features of the pollen wall.

Sexine:- Outer usually sculptured layer of exine.

Stenopalynous:- Families characterized by slight variations in pollen types.

Striate: Pollen grain with a pattern consisting of approximately parallel muri and lemina.

Tectum:- The outer stratum of the sexine found over a columellar or granular stratum.

Verrucae: Wart-like processes, usually broader than high and never constricted at the base.

Verrucate: Pollen grains possessing verrucae on the surface.

2.7 POLLEN ALLERGY

Allergy:- Allergy is an abnormal reaction of the body to substances normally harmless, such as pollen, dust, certain foods, drugs and insect stings. The term allergy is of Greek origin and means "abnormal response".

The symptoms of allergy vary with the causative agent, which is called an allergen antigen, with which the part of the body is affected. The symptoms, or allergic reactions, may include sneezing, watery eyes, and nasal congestion, as in hayfever and allergic rhinitis; a rash, stomach upset and itchy swellings on the skin as in some food and drug allergies spasms within the lungs that interfere with breathing as in asthma and in rare cases, anaphylactic shock which may lead to asphyxiation and death. Anaphylactic shock occasionally fallows injections of penicillin or other drugs and may sometimes follow the sting of a bee or wasp.

Common allergens, in addition to those mentioned above, include animal fur, feathers, cosmetics, textile dyes, smoke, bacteria, Louse dust, mites and other plants. Molds, chemical pollutants in the atmosphere, animal excretions, blood serum received by transfusion, may aslo cause sickness. Even heat, cold and light may also cause allergy in susceptible people. Allergens may act fallowing inhalation, injection, ingestion or contact with the skin.

The Allergic Reaction

An allergic reaction occurs when the immune system, which is the body's normal defense against dangerous foreign substances, such as a virus, people with this type of unusual immune system are said to be hypersensitive. The body immune system reacts to an allergen in many different ways to cause the discomforting symptoms such as allergy. In many allergies, the process begins when the allergen stimulates the immune system producing certain antibody molecules called immune globulin E (igE). These antibody molecules then combine with the allergen molecules and bind to certain cells called mast cells and basophils, causing the release of histamine and other active compounds. The histamine in turn affects the blood vessels and mucous membranes, leading to swelling, congestion. These physiological changes lead to a runny nose if the allergen is air borne and inhaled. Other cells and other constituents of the blood serum can cause other types of allergies, such as poisonary dermatitis and serum sickness.

Types of Allergy

Allergies characteristically are not symptomatic with the first exposure to the allergen, and the symptoms occur only upon re-exposure to the same agent. A person is said to have been sensitized by the first contact. That is, the immune system some how "learns" to respond to the agent with an allergic reaction, but it reacts only at later contacts. Sensitization of this type occurs in a variety of infectious diseases, such as Brucellosio, Glanders, Syphilis, and Coccidio-idomy, Cosies, in which allergy develops to the infecting bacteria, fungi or viruses.

In many cases genetic disorders are responsible for the tendency to be allergic to a variety of substances. Persons with such inherited tendencies are called atopic. Numerous studies have shown that atopic who sufers with allergy are more likely to sufer with other allergies when compared with the general population. Many atopics so afflicted have generally a family history of allergic diseases.

Diagnosis

Allergic disease is diagnosed from the patient's medical history, symptoms and so called skin tests, which help to identify the allergen. Small doses of the many of the most common allergens are injected subcutaniously to substances which the patient is allergic, resulting in redness and swelling at the injection site. Skin tests are often "false positive", however, they may indicate a sensitivity when in fact none exists.

Treatment

If the allergens can be identified, treatment of allergy may be merely the avoidance of the offending agents. If they can not be avoided, as with house dust, pollen, insect stings and perhaps animal fur, treatment is by descensitization. In descensitization small amounts of the substance that causes the allergy are injected in different concentration under the skin during repeated visits to a physician. After many such injections, the body may "learn" not to react to the offending substance.

Pollen Allergy

With a few notable exceptions, all pollen found in the ambient air is potentially allergenic. About 60 families of higher plants are implicated in pollinosis (Lewis etal; 1983) out of which only about half of these cause significant allergy. Pollen grains of these plants are mostly aperturate (with pores or furrows), a few, such as those of populars, are nonaperturate. The number of pores may be one per grain, as is typical of grasses; two per grain, as in members of the mulberry and stinging nettle families; three per grain, as in birches; four to six, as in alders, walnuts.

What is important in immediate hypersensitivity is that proteins and other compounds - perhaps recognition molecules typical of species - stored in the exine and the intine are released through these pores and apertures when the pollen is in contact with mucosal surfaces. This release an allergens gives rise in sensitized atopic persons to allergic rhinitis, allergic sinusitis, and bronchial asthma.

Pollen Dispersal and Allergy

Mature anthers release pollen that transmit the male genetic material in sexual reproduction. Pollen may be wind-dispersed (anemophilous) and depending on its buoyancy, sculpturing, shape and thickness, as well as environmental conditions, can be carried some distance from the immediate vicinity of the patient. Anemophilous species pollen are the cause of the vast majority of pollen allergens. The flowers of these species possess a set of adaptive characteristics that includes reduction in size and number of perianths parts; little or no necter, few or no aromatic compounds; small, dry and smooth pollen (20 to 40 μm in diameter) with slow terminal velocities (2 to 6 cm/second); a complex feathery stigma with a relatively large surface area, and a large number of pollen grains per ovule (Adams etal., 1981).

In temperate areas, allergenic plants are traditionally grouped as trees, grasses and weeds; this is a useful grouping because it follows a generalized flowering sequence from spring to autumn. Trees and shrubs flower primarily from late winter to late spring, grasses from late spring to mid summer, and weeds from mid summer to autumn. Some grasses begin flowering in spring after a mild winter and continue flowering during a wet summer until the autumn. Still other grasses do not begin flowering until late summer. Therefore in certain localities a secondary release of pollen with subsequent grass pollinosis is not unusual.

2.7 IATROPALYNOLOGY OF THE FAMILY POACEAE

The branch of palynology which deals with the study of pollen grains in connection with allergies is called Iatropalynology. Grass pollen is one of the most serious problems, mainly because it is so abundant in the atmosphere. In a Swedish study of a whole range of allergies, over 30% were caused by pollens. Many grasses are known to cause allergy. The important of these are: *Dactylis glumerata, Lolium perenne, Phleum pratensis, Poa pratensis, Festuca pratensis, Phragmites communise, Sorghum halepense, Cynodon dactylon, and Zea mays.*

The grasses shed light pollen, sometimes in enormous quantities, which is the cause of much hay fever. Next to the ragweeds and their allies, they are probably responsible for more hay fever than are the plants of any other group. Most of the species that produce the largest quantities of pollen flower in late spring and early summer, and post monsoon rains in Pakistan. There are some grasses that have a more extended flowering period, for example, Bermuda grass, which flowers throughout the year causing much pollen allergy. Patients sensitive to grass pollen begin to show symptoms when the pollen content of the air rises above 50 grains m^{-3}.

Pollen grains from the atmosphere come into contact with the cornea of the eye and with the surfaces of the trachea and bronchi, where the allergic reaction takes place. They are unlikely to penetrate into the lungs themselves because of their relatively large size and the degree of the air turbulence in the upper respiratory tract. Once they have landed on the lining membranes they are removed in the surface mucous coat by the beating of cilia, probably being brought back the pharynx within an hour of entry, but by then the irritating biochemical reactions have taken place.

The allergens which elicit a response are proteins and glycoproteins which leak from their storage sites within the complex structure of the pollen grain wall. Their likely role in nature is in the process of recognition that takes place between the pollen grain and the stigma surface.

Species composition and density of pollen in the atmosphere vary with flowering season and also with weather conditions, as shown on the studies of grass pollen in Denmark by van den Assem (1971). Allergic problems are thus greatest when weather conditions are warm and dry and when the offending species, such as grasses, are in full bloom.

It was found that many sufferers have found relief by living in areas of low vegetation cover, such as the arid desert regions. But the human desires to be surrounded by plant life has resulted in an increasing extension of gardens, parks and lawns and the consequence is that air borne pollen and the incidence of hay fever is now on the increase.

2.8 PREVIOUS TREATMENT OF THE FAMILY POACEAE

Pollen grains of the family Gramineae have been studied by different workers in the last 30 years, the following are the main contributors.

Demerc 1924, **Armbruster** and **Oenike** 1929, **Cranwell**, 1942, **Drahowzal** 1936, **Durham** 1951, **Erdtman** 1923, 1939, 1943, 1945, **Ferrari** 1927, **Firbas** 1937, **Geisler** 1945, **Griebel** 1930, **Janes** and **Newell** 1948, **Knell** 1914, **Knowlton** 1922, **Kuprianowa** 1945, 1948, **Meinke** 1929, **Nakamura** 1943, **Nygren** 1946, 1949, **Parnell** 1921 **Qaiser** etal 1994, **Schnarf** 1931, **Selling** 1947, **Vieitez** and **Blanco** 1947,. **Wodehouse** 1928, 1935, 1942, 1945, **Yamasaki** 1933, **Young** 1908, **Zander** 1935

One of the conspicuous structural features of pollen is the ornamentation of the exine. The importance of the architecture of the pollen wall, in biosystematics, has been realized since long. Extensive investigations have been carried out on this aspect particularly by **Wodehouse** and Erdtman, who laid the foundations of `Palynology` (Faegri and Iverson 1964, Wodehouse 1965, Erdtman 1966, 1969). Interest in this area continues (Nair 1970, Brooks etal. 1971, Ferguson and Muller 1976, Crompton 1981).

The range of variation in grass pollen surface revealed by **Rowley** (1960), **Anderson** and **Bertelsen** (1972) and **Grant** (1972) was confirmed and somewhat extended by **Watson** and **Bell** (1975).

An attempt was made by **Kohler** & **Lange** to differentiate wild grass pollen from cereal pollen by light microscopy (Grana 18: 133-140, 1979). They examined under Light Microscope and Scanning Electron Microscope 12 species from 8 genera which are of special interest for pollen analysis and for the history of settlement. Among the numerous earlier attempts to differentiate wild grass pollen from cereal pollen by light microscopy (**Firbas** 1937, **Grohne** 1957, **Geng** 1961, **Faegri** & **Iverson** 1975 and others) the elaboration of several types of exine sculpture by **Beng** (1961) deserves special emphasis.

Anderson & **Bertelsen** (1972) confirmed the exine's microstructure studied by **Rowley** (1960). While these authers delt with species of eight genera of the Poaideae (Festucoideae) related to cereals, **Watson** & **Bell** (1975) extended their investigations to the whole family, starting from allergy research problems. Their study of 18 species representing five subfamilies gives a first survey of the exine sculpture of the Poaceae and reveals a certain degree of taxonomic order. **Albers** (1975) studied all 8 genera of a subtribe and reported on the important influence of cytological factors on size and fine structure. **Damblon** (1975) added to the fine sculpture of some grass pollen by demonstrating the advantage of the sputtering method.

A palynological study of 64 species belonging to 40 genera of the family Gramineae from Karachi was conducted by **Tahmeena Siddiqui** and **M. Qaiser** (1985). Pollen morphological study of aquatic grasses growing in different pools and lakes of the Indian Botanic Gardens was conducted by **M.S. Mondal** (1989).

2.9 PALYNOLOGY IN RELATION TO TAXONOMY

Pollen grains have not been very frequently used in taxonomy for the simple reason that they are rather very small structure. However, since the publication of R.P. **Wodehouse's** book on pollen grains (1935) interest in the study of pollen grains has increase considerably. In fact the major reason of the pollen study was not important in taxonomy but their significance as casual organisms and some of the diseases like hay influenza.

Recently pollen grains have also become very important as a source of data in paleontology. Pollen grains are one of the structure which have been preserved in fossils. Large groups have been identified with the help of pollen grains. Pollen grains are also playing an important role in the honey industry.

Swedish botanist **G. Erdtman** has been mainly responsible for establishing the palynology as a full-fledged science. He started his publications in 1943. His first book "Pollen Morphology and Plant Taxonomy" appeared in 1952 and since then he has been publishing its editions, largely as a result of Erdtman, palynology is now a major discipline of the plant sciences. There is an institute of palynology at Sweden, Holland, United States and Norway. A text book of pollen analysis by Faegri is one of the important books relevant to this subject.

Major characters of the pollen grains used in taxonomy

There are three main characters which are often used in taxonomy.

1. The number and position of depressions and position of furrows (colpi).
2. Number, position and complexity of the pores or apertures.
3. The form of ornamentation or sculpturing of the outer wall of the pollen grain exine.

There are obviously number of modifications in these characters. They are usually used in identifying plants species, genera or families.

NUMBER, POSITION AND COMPLEXITY OF THE APERTURE

The number, position and complexity of the aperture has also been considerably modified. There is either a reduction in number of pores or an increase in the number of pores. Likewise, the sculpturing or ornamentation has also been variously modified.

Generally the insect pollinated flowers have pollen grains with elaborate sculpturing while the wind pollinating flowers tend to have smooth pollen grains. In other words anemophily appears to be a derived condition or advance condition, for example, Gramineae. In gamopetalous families it is the dominant way of pollination.

Pollen grains may be considerable importance either at the generic level or sometimes at the specific levels. Usually the families have different types of pollen grains but there are some families in which the pollen grains are not very variable. Such families are known as **stenopalynous** families. Some of the stenopalynous families are: Cruciféreae, Asclapidaceae, Labiatae and Gramineae. Most of the families have variable pollen characters and known as **eurypalynous**, for example, Compositeae, Euphorbiaceae, Rosaceae etc. In stenopalynous families pollen grains cannot be of much use on the other hand eurypalynous pollen grains character is helpful generally at the tribe level.

Sometime pollen grains are the characteristics of the genera like the Salicaceae - salix and populus. Populus has spherical and round pollen grains with distinct aperture. Salix on the other hand has long narrow and three furrowed pollen grains.

Recently with the invention of the scanning electron microscope (SEM) peripheral parts have been studied. The exine can be examined in depth with scanning electron microscope. The wall has been divided into various parts even the outer exine have two parts - the ectexine and endexine. It is generally agreed that the two should be studied separately. Number of studies have shown that the extexine is variable and usually endexine does not show much variation.

The nuclear condition of the pollen grains have also of considerable significance. The pollen grains may be either two or three nucleated. The mono cotyledon families are usually binucleate likewise the polypetalous families are trinucleate. There are some exceptions for example, the families of centrospermeae have trinucleate condition. However, this character have been found to be of little taxonomic value.

Palynology have been used in taxonomy in a number of ways:

1. It has been very helpful in identifying the genera or taxa of uncertain affinities.

2. Palynology has also been very helpful in indicating probable lines of evolutionary trends. It has, for instance confirm the view that the line of demarcation between the monocotyledons and dicotyledons is arbitrary. There are number of families of dicotyledons like Magnoliaceae and Nymphaceae which possess monocatyledenoid characters. On the other hand some families of the monocotyledons like Alismataceae, Butamaceae (Wodehouse and others e.g. Salisbury 1926, have treated the affinity to Ranunculaceae) possess dicotyledonoid characters specially the leaves venation.

Chapter Three
(Materialsand Methods)

Materialsand Methods

3.1 Source of material

Freshly polliniferous material of 37 genera were collected from different sectors of Islamabad in different flowering seasons (spring and Monsoon). Fresh, mature, closed flower buds were selected.

3.2 Light Microscopic Studies

There are many methods used for pollen analysis. The important one is the classical acetolysis technique devised by Erdtman (1969). The steps involved in acetolysis are as follows:

1. Material placed in 5.0 ml concentrated glacial acetic acid for at least one hour.
2. Sample lightly macerated with blunt glass stirring rod, then poured through a fine mesh screen/cloth into a funnel placed in centrifuge tube.
3. Sample tube filled to 10.0 ml and centrifuge for 10 minutes, then supernatant discarded after careful removal using glass pipette.
4. 10.0 ml of a 9:1 mixture of 99% anhydrous acetic acid and concentrated sulphuric acid (the acetolysis mixture) added to sample tube, then place inboiling water for 2-5 minutes or untill the sample darken to dark brown considerably.
5. Sample centrifuged and supernatant removed with glass pipette; 15 ml distilled water added several time to halt acetolysis, stirring slightly with glass rod.
6. Sample centrifuged and supernatant removed.
7. Sample and remaining liquid removed with glass pipette and carefully spotted on to a paper towel which to absorb most liquid.
8. Glycerine jelly with phenol and safaranine as a stain was used as mounting medium, a small piece on a dissecting needle was used to pick up sample from paper towel.
9. Glass slide with small sample heated on a hot plate, coverslip was placed over sample, nail polish or paraffin shavings placed around the edges of coverslip, cooled to make permanent slide.

The drawback of this method is that it is lengthy complex and time consuming. It is modified by PUNT (1962) and HOU (1969) as a micro method suitable for the preparation of pollen slides from single anther or even single pollen grain. The method that was used for preparation of slides for light microscopic studies is as under:

1. The flower/anther was heated in a few drops of distilled water in a watch glass on the hot plate, when fully soften the flower was teased open with fine forcep and with the help of a mounting needle under the dissecting microscope and the anthers were dissected out. The remaining unwanted floral parts were removed to the margin of the watch glass leaving the anthers in the middle. The pollen grains were teased out by crushing of the anthers with a glass stirring rod. Finally the anthers were drawn to the edge of the watch glass, leaving just the pollen in the middle. Return the watch glass to the hot plate and evaporated to complete dryness.
2. With a bulb pipette a few drops of acetolysis mixture were added to dry the pollens in the watch glass on the heating block. Warm untill the pollen darkens and the solution went to a dark brown colour.
3. The watch glass was allowed to cool for a few minutes methylated spirit was added drop by drop to the centre of the remaining acetolysis mixture. This displaced the acetolysis mixture to a ring around the rim of the watch glass, leaving the pollens in the centre. More methylated spirit was added to the pollens, never allowing it to dry at this stage.
4. A small portion of glycerine jelly with a safranin stain added with a fine scalpel and this was rolled over the pollens in the watch glass untill all or most of the grains have adhered to it. The glycerine jelly now with pollens was transferred to a clean glass slide and placed it on the hot plate and when completely melted, the coverslip was carefully lowered on the glycerine jelly.
5. The slide was labelled and sealed with white transparent nail varnish as sealant.
6. As acetolysed pollens tended to be markedly deformed to avoid this, pollen grains slides for light microscopy were prepared directly in distilled water. This method was adopted

after personal discussion with my co-supervisor Dr. S.Z. Husain. The method is as follows:

1. The spikelets were removed from their floral receptacle and freed as far as possible from all extraneous materials. The mass of flowers was then soaked in distilled water in a watch glass and gently stirred with a glass rod to loosen the pollens from the anthers. After much practice the floral parts and other unwanted materials were removed to one side of the watch glass. Pipette out the clear distilled water containing large number of pollens in the middle of the watch glass.
2. A drop of pollen containing water was placed on clean glass slide.
3. Cut a small block of glycerine jelly with safaranin stain (glycerine jelly with safaranin stain can be prepared by mixing 1 gram of 0.1% thymol in 225 grams of 22.5% glycerol and 120 grams of 12% gelatine in 655 grams of 65.5% water, then mix all these with 50 mg safaranin and make the volume upto litre) added with a fine scalpel and rolled this in drop of water containing pollens on the slide.
4. The glass slide was placed on hot plate and as soon as it has completely melted, any air bubble were removed with a clean mounting needle. Then carefully the coverslip was placed onto the glycerine jelly.
5. The slide was labelled and sealed with transparent nail varnish as sealant.

3.3 Scanning Electron Microscopic Studies

For scanning electron microscopy pollens were not acetolysed because grass pollen tend to collapse after acetolysis due to the presence of their thin and delicate exine and only distilled water and untreated dry pollens were used.

Material for scanning electron microscopy was air dried on to the stubs previously coated with double sided self-adhesive tape. After drying, the specimens were coated with approximately 200 A^o of gold using Jeol Ion Sputter Coater. All specimens after coating were examined with a Jeol JSM-35CF scanning electron microscope.

When specimens prepared by this method were examined it was observed that the focused pollens reptured like pressed balloon. I discussed it with Dr. S.Z. Husain who suggested that stubs should be prepared by using totally dry pollens. The following method for preparation of stubs for scanning electron microscopy was followed.

1. Staminate flowers were teased open with a fine forcep and a mounting needle under a dissecting microscope the anthers were dissected out.
2. Anthers were placed on a clean glass slide and crushed with a glass stirring rod and the anther deberis were removed with a mounting needle and the slide was examined under the light microscope for presence of pollens and circle was marked around the pollens.
3. The stub was coated with a double sided self-adhesive tape. The coated stub was pressed on the pollens bearing area of the slide so that maximum pollens should stick on the cellotape. The slide was examined under the light microscope to confirm the pollens were transferred on the stub. After successful transference of pollen grains on the stub, the stub was coated with gold using Jeol Ion Sputter Coater. All specimens after coating were examined with a Jeol JSM-35CF scanning electron microscope. Quite satisfactory results were obtained by this method. Other methods such as critical freeze drying, mounting pollens on the stub in stickly acetone cellotape solution but non of these methods yieldedsatisfactory results.

3.4 Problems Encountered

The major problem encountered when studying pollen grains with scanning electron microscope was that the grass pollens were easily over acetolysed, distored and ruptured when mounted directly in distilled water.

Many grasses, particularly those having cleistogamic mode of reproduction, produce small number of pollen grains within closed florets. These grasses such as *Bromus, Panicum, Elusine, Digitaria* etc. produce flowers with mature pollens at specific time. Therefore, these grasses must be collected for polleniferous material during their perfect flowering time.

It was observed that most of the grasses which produce large number of pollen grains are allergy causing grasses. The pollen grains of these grasses must be collected at the time of their flowering period on large scale so that at the time of preparation of pollen specimens for scanning electron microscopy maximum pollen would be available for transference on to the stubs.

I have also adversely encountered the problem of teasing out the pollens from dry specimens. As in grasses the flower is much reduced and it is difficult to dissect flower easily without dissecting microscope. Therefore, there is a need to collect the pollen grains in pure form while the plants are shedding their pollens.

Another problem that I had to face was the charging of scanning electron microscope. It might be due to the metal particles remained on the stub surface during shining of the stubs for mounting. This problem can be resolved by rinsing the stubs thoroughly in acetone.

The major problem with all methods was manipulating pollen grains during treatment and retrieval, handling (dry and isolated). Anthers and pollen sacs should be collected from plants actively shedding pollens and stored in special capsules for future use.

3.5 Morphology of the grasses

Morphological data are based on studies in the habitats of the plants and the herbarium specimens.

Fresh plants were collected from different sectors of Islamabad and mounted on herbarium sheets for study. Herbarium material from the Quaid-i-Azam University Herbarium was also used in this research. The vouchers specimens have been submitted to the Herbarium Quaid-i-Azam University Islamabad.

Five specimens per species were used for morphological characters; 3-4 values were taken for each character of a representative plant.

The following characters were considered:

1. Plant height
2. Culm pubescence
3. Number of nodes
4. Leaf length and width
5. Leaf blade pubescence
6. Leaf sheath pubesence
7. Ligule length
8. Length and width of panicle
9. Length and width of spikelets
10. Number of spikelets
11. Pédicel length
12. Number of florets
13. Lower glume shape
14. Lower glume length and width
15. Upper glume shape
16. Upper glume length and width
17. Number of lower glume veins
18. Number of upper glume veins
19. Shape of lemma
20. Lemma length and width
21. Awn length
22. Number of lemma veins
23. Palea length and width
24. Anther length
25. Caryopsis length

The follwoing 37 genera and 54 species have been used in present research.

Alopecurus myosuroides

Aristida adscensionis

Aristida funiculata

Avena ludoviciana

Avena sativa

Brachypodium distachyon

Bothriochloa pertusa

Brachiaria distachya

Brachiaria eruciformis

Bromus catherticus

Bromus danthoniae

Bromus japonicus

Bromus pectinatus

Cenchrus penisctiformis

Chrysopogon aucheri

Cymbopogon flexsuosus

Cymbopogon schoenanthus

Cynodon dactylon

Dactyloctenum aegyptium

Desmostachya bipinnata

Dicantheium annulatum

Dicanthium foveolatum

Digitaria biformis

Digitaria nodosa

Digitaria sanguinalis

Echinochloa crus-galli

Echinochloa colonum

Eleusine indica

Eragrostis minor

Heteropogon contourtus

Imperata cylindrica

Lolium multiflorum

Oplismenus burmannii

Parapholis strigosa

Paspalidium flavidum

Paspalum dilatatum

Paspalum distichium

Pennisetum americanum

Pennisetum lanatum

Phalaris minor

Phleum himalaccum

Phleum pratense

Phragmites australis

Poa annua

Poa infirma

Poa nemoralis

Polypogon monspeliensis

Saccharum spontaneum

Setaria glauca

Setaria pumila

Sorghum halepense

Stipa splendens

Urochloa panicoides

Vetivèria zizanioides

Chapter Four
(Results)

Results

4.1 Morphology of Grasses

Results of morphological studies of 54 species belonging to 37 genera of the family Poaceae are presented in table 5&6 and key to the genera. Photographs of the taxa studied are shown in plates (1-27). The results of morphological features which help in identification of the genera and species of the family are given below:

***Alopecurus myosuroides* (plate 1)**

Huds. Fl. Angl. 23. 1762.

Synonyms:- *Alopecurus agrestis* L. Sp. Pl. ed. 2: 89. 1762

Type:- England, Hudson.

An annual glabrous grass upto 25.0cm tall with tufted slender culms. *Leaf blade* 4.0-7.0 cm long and 2.5-4.0 mm wide, glabrous, leaf sheath glabrous. *Ligule* 1.5-2.0 mm long, membranus. *Panicle* erect cylindrical, upto 6.0 cm long, 3.0-5.0 mm wide, tapering towards the end. Spikelets elliptic or ovate, 5.0 mm long, 1 flowered. *Glumes* united by their margins for 1/3 to 1/2 their length, oblong or broadly ovate, 3-nerved, minutely hairy. *Lemma* as long as the glumes, broadly ovate, 5-nerved, awned, the awn projecting by 4.0-6.0 mm above the glumes. *Palea* absent. *Anther* 2.0-2.5 mm long.

Flowering and fruiting period: March- April.

Aristida adscensionis (plate 1)

L. Sp. Pl. 82. 1753; FBI 7: 224.1896 var. *adscensionis*.

Synonyms:- *Aristida caerulescens* Desf., *A. curvata* (Nees) Trin & Rupr; *A. depressa* Retz., *A. festucoides,* Poir., *A. guineensis* Trin & Rupr., *A. submucronata* Schumach, *Chaetaria adscensionis* (L.) P. Beauv. *C. curvata* Nees, *C. festucoides* (Poir) P. Beaur.

Type:- Ascension Island, osbeck (LINN).

An annual grass with erect or ascending culms often branching from the base, smooth and glabrous, upto 25.0-30.0 cm tall. *Leaf blade* flat, upto 22.0 cm long and 1.0-1.5 mm wide, pubescent, leaf sheath smooth. *Ligule* a row of very short hairs. *Panicle* purplish, nodding, 8.0-20.0 cm long, 1.0-1.5 mm wide. *Glumes* lanceolate, unequal, the lower about 4.0-4.5 mm long, acute, the upper 7.0 mm long, relatively narrow. *Lemma* cylindrical, 5.0-7.0 mm long and 0.5-1.0 mm wide, bearded or ciliate along the margin, 3-nerved, central awn 15.0 mm long. *Anther* 1.5 mm long. *Caryopsis* 6.0 mm long.

Flowering and fruiting period: July-August.

Aristida funiculata (plate 2)

Trin. & Ruper., Sp. Gram. Stip. 159, 1842. Cope in Nasir and Ali, Fl. Pak. 143: 45-46 (1982).

Synonyms:- *Aristida macrathera* Rich, *A. mallica* Edgew, *A. royleana* Trin. & Rupr. Arthratherum Kotschyi Hochst. ex Steudel.

Type:- Senegal, Leprieur (P).

Tufted annual grass, 10.0-30.0 cm tall. *Leaf blade* linear, flate or folded, 8.0 cm long, 1.0-2.0 mm wide, pubescent. *Ligule*, a row of short hairs. *Panicle* narrow whitish, nodding, 5.0-15.0 cm long, 1.0-1.5 cm wide. *Spikelets* lanceolate, 6.0 mm long, 1.0-1.5 mm wide. *Glumes* long, membranous, unequal, the lower 4.0-5.0 mm long and 1.0-1.5 mm wide, the upper 7.0 mm long and 1.0 mm wide, both finely attenuate. *Lemma* cylindrical about 7.0 mm long and 1.0-2.0 mm wide 3 nerved. Awns upto 15.0 mm long. *Anther* 2.0 mm long. *Caryopsis* 6.0 mm long.

Flowering and fruiting period: Late April-May

Avena ludoviciana (plate 2)

Durieu, Act. Soc. Linu. Bordeaux 2:41. 1855.

Synonyms:- *Avena persica* Steud. Syn. Pl. Glum 1:230/1854.

Type:- At (B)

An annual grass upto 65.0 cm tall with tufted slender culms. *Leaf blade* upto 30.0 cm long, 10.0 mm wide, rough. *Ligule* upto 6.0 mm long. *Panicle* upto 17.0 cm long and 5.0 mm wide, spreading. *Spikelets* 20.0 mm long and 5.0 mm wide, 2-flowered. *Glumes* lanceolate, finely acute, upto 20.0 mm long and 6.0 mm wide 9-nerved. *Lemma* oblong densely hairy, upto 15.0 mm long 5.0 mm wide 6-nerved. Palea upto 12.0 mm long and 3.0 mm wide. Awn length 3.5 cm. *Anther* upto 3.0 mm long. *Caryopsis* 3.0 mm long.

Flowering and fruiting period: March-April.

Avena sativa (plate 3)

L., Sp. P. 1:79 (1753); Guest & Al-Rawi Fl. Iraq 9:338-340 (1968).

Type:- "Hortus Cliftortianus", Linnaeus (BM), Lectotype.

Annual, clum solitary or tufted, upto 80.0 cm tall. *Leaf blade* upto 5.0 mm long. *Panicle* spreading or narrow, 30.0 cm long and upto 10.0 cm wide, loose. *Spikelets* pendulous, upto 18.0 mm long and 4.0 mm wide, 2-flowered, rhachilla articulated beneath each floret. *Glumes* lanceolate finely acute, upto 18.0 mm long and 6.0 mm wide 8-nerved. *Lemma* oblong, upto 8.0 mm long and 4.0 mm wide, densely bearded around the callus; usually 2-4 dentate at apex, 4-nerved. Awn weak, upto 27.0 mm long. *Anther* 2.5 mm long. *Caryopsis* 1.0-2.0 mm long.

Flowering and fruiting period: March-April.

Bothriochloa pertusa (plate 3)

(L.) A. Camus L.C. 164

Synonyms:- *Holcus pertusus* L., *Andropogon pertusus* (L.) Willd., FBI 7:173.

Stoloniferous sward forming perennial, culms erect, or geniculately ascending upto 18.0 cm high. *Leaf blade* 4.5-5.0 cm long and 2.0-3.0 mm wide, smooth. *Ligule* just a hairy strip. *Inflorescence* subdigitate, bearing 3-8 shortly pedunculate racemes, raceme 3.0 cm long. *Spikelets* sessile, narrowly elliptic, 3.0-6.0 mm long and 2.0 mm wide. *Glumes* 2.5-4.0 mm long and 1.0 mm wide, lower glume pitted above the middle with a deep circular pit at or about the middle blunt, slightly shorter than the pointed upper glume, 5-nerved. *Lemma* lanceolate, 2.5 mm long and one mm wide, 6-nerved. Awn 16.0 mm long. *Anther* 1.5 mm long.

Flowering and fruiting period: August-September.

Brachiaria distachya (plat 4)

(L.) Stapf in Prain, L.C. 565.

Synongms:- *Panicum distachyon* L. Mant. Alt. 183. 1771., FBI 7:37.

Creeping annual, culms 10.0-30.0 cm long, ascending from a prostate base. *Leaf blades* broadly linear to narrowly lanceolate, 2.0-9.0 cm long, 3.0-6.0 mm wide, pubescent. *Ligule* is a row of small hairs. *Inflorescence* of 2-3 racemes on an axis 0-5-2.0

cm long, raceme 4.5 cm long. *Glumes* ovate, 2.2-3.0 mm long and 2.0 mm wide, 5-verved. *Lemma* ovate, 1.5-2.0 mm long and 1.0 mm wide, 5-nerved, awnless. *Anther* 1.0-1.2 mm long. *Caryopsis* 2.0 mm long.

Flowering and fruiting period: July-August.

Brachiaria eruciformis (plate 4)

(J.E. Sm) Griseb. in Ledeb. Fl. Ross. 4:469. 1853.

Synonyms:- *Panicum eruciforme* J..E. Sm.; *Panicum isachne* Roth ex R.&S.; *Panicum isachne* Roth., FBI 1:28. 1896.

Type:- Ethiopia, Dehli Dikeno, Schimper in Buchinger 1173 (P).

An annual grass. Culms ascending, 20.0-50.0 cm tall. *Leaf blades* linear to narrowly lanceolate, 2.0-7.0 cm long and 2.0-5.0 mm wide, pubescent. *Ligule* a row of small hairs. *Infloresence* of 3-14 widely spaced racemes, 0.5-2.0 cm long. *Spikelets* elliptic, 1.8-2.0 mm long and 1.2 mm wide. *Glume* lanceolate, 0.3 mm long and 0.2 mm wide, lower glume a minute scale. Upper lemma readily deciduous, smooth, skinny, obtuse. *Anther* 1.0 mm long. *Caryopsis* 1.5-2.0 mm long.

Flowering and fruiting period: July-August.

Brachypodium distachyon (plate 5)

(L.) P. Beauv.

Synonyms:- Trachynia distachya (L.) Link.

A compactly tufted annual, culms 10.0-38.0 cm high, but usually much less geniculately ascending, rarely erect, glabrous. *Leaf blades* upto 10.0 cm long and 2.0-3.0 mm wide. flate, pubescent. *Ligule* 1.0-1.5 mm long membranous. *Infloresence* with 1-3 spikelets crowded at the tip of the peduncle. *Spikelets* cylindrical, lanceolate, 9.0 mm long and 3.0 mm wide, 10-flowered. *Glumes* unequal, lower glume lanceolate, 6.0 mm long and 1.2 mm wide 5-nerved, upper lanceolate, 7.0 mm long and 1.2 mm wide 7-nerved. *Lemma* lanceolate, 9.0 mm long and 3.0 mm wide, 3-nerved, tipped by an awn upto 15.0 mm long. *Anthers* 1.0-2.0 mm long. *Caryopsis* 6.0 mm long.

Flowering and fruiting period: April-May

Bromus catherticus (plate 5)

Vahl, Symb. Bot. 2:22 (1791); Cope in Nasir & Ali, Fl. Pak. 143: 582-583 (1982).

Synonyms:- *Festuca unioloides* Willd., Hort. Berol. 1:3 (1803); *Cerotochloa unioloides* (Willd.) P. Beaur. Ess. Agrost. 75t. 15/17 (1812); *Bromus uniloides* Kunth in H.B.K., Nov. Gen. Sp.Pl. 1:151 (1815).

Type:- Peru, Dombey (P).

Annual grass, culms 20.0-70.0 cm high, glabrous. *Leaf blades* upto 20.0-30.0 cm long, 3-6.0 mm wide flate, sheath glabrous or pubescent. *Ligule* 6.0 mm long, membranous. *Panicle* oblong, upto 30.0 cm long. *Spikelets* large, upto 30.0 mm long and 6.0 mm wide, very strongly compressed, 6-12 flowered. *Glumes* sub equal, narrowly lanceolate, lower glume 8.0-15.0 mm long, upper 11.0-16.0 mm long. *Lemmas* closely over lapping, laterally compressed and strongly keeled, 5-9 nerved, minutely bidentate, awn weak, short, 1.5-3.0 mm long. *Anther* 0.2-0.5 mm long. *Caryopsis* 1.2-5.0 mm long.

Flowering and fruiting period : Late March-April

Bromus japonicus (plate 6)

Thunb. ex Murr., Syst. Veg. 119. (1784); Rozher and shishbin in Kom; Fl. USSR 2:578; Bor in Towns, Guest & Al-Rawi, Fl.Iraq 9:146 (1968); Bor in Rech.F., Fl. Iran. 70:112 (1970); Stewart, Ann, cat. vase, Pl. W. Pak & Kash. 140. (1972); Tzveler, Poaceae USSR 229. (1976); Smith in Tutin etal; Fl. Eur. 5:188. (1980); Cope, Fl. Pak. Fasc. 143:564. (1982).

Synonyms:- *Bromus patulus* Mart. & Kochl., Dentsch. Fl., ed. 3,1 (2):685. (1823); Hook f. Fl. Brit. Ind. 7:361 (1896); *B. patulus* Mert & koch *var. velutinus* Boiss., Fl. Or. 5:655. (1884); *Bromus anatolicus* Rozher & Shishkin in Kom., Fl. USSR 2:578. (1934); *B. Japonicus* Thunb. *var. velutinus* Bor in Towns, Guest & Al-Rawi, Fl. Iraq 9:147. (1968); Bor in Rech. f, Fl. Iran 70:114. (1970) Stewart, Ann. Cat. Vase. Pl. W. Pak & Kash. 140 (1972).

Type:- Described from Japan, Thunberg (Ups).

Annual grass, 2.0-35.0 cm high, culms erect or geniculately ascending. *Leaf blades* upto 15.0 cm long and 2.0-3.0 mm wide, leaf sheaths hairy or smooth. *Ligule* 1.5-2.5 mm long membranus. *Panicle* 6.0-10.0 cm long, very lax and spreading, the pedicels very long, filiform and flexuous. *Spikelets* 12.0-24.0 mm long and 2.0-4.0 mm wide, ovate to oblong-lancealate, 7-14 flowered, compact. *Glumes* glabrous or hairy, the lower lanceolate, 6.0 mm long and 4.0 mm wide, 3-nerved, the upper ovate, 5.0-8.0 mm long and 1.0-2.0 mm wide, 7-nerved. *Lemmas* oblanceolate, 7.0-8.0 mm long and 4.0 mm wide, minutely 2-toothed at the tip; awn sub-apical, flattened specially at the base, 13.0 mm long on the upper lemmas. *Palea* 5.0 mm long and 3.0 mm wide. *Anther* one mm long. *Caryopsis* 6.0 mm long.

Flowering and fruiting period: April-first week of May.

Bromus pectinatus (plate 6)

Thunb., Prodr. Fl. Cap. 1:22 (1794); Clayton, Fl. Trop. East Aft. Granimeae 68 (1970); Cope, Fl. Pak. 5466 (1982)); Chaudry, Grasses S. Arabia, 1989.

Synonyms:- *Bromus patulus* Mert & Koch *var. pectinatus* (Thunb.) Stapf. I.C.; *B.Japonicus* Thunb. *var.pectinatus* (Thunb) Aschers & Graeb; Syn Mitteleur. Fl. 2 (1). 620. (1901).

Type:- South Africa, cape of Good Hope, Thunberg 2522 (UPS).

Annual grass upto 35.0 cm tall. *Culms* erect or geniculately ascending, 5 nodes, glabrous. *Leaf blades* 8.5 mm long and 2.0 mm wide, sheath hairy. *Ligule* 1.5 mm wide, lanceolate, 6-flowered, somewhat laterally compressed. *Glumes* narrowly lanceolate, lower glume 5-6 mm long and 1-1.5 mm wide, 3-nerved, upper glume 7.0-11.0 mm long and 1.0-2.0 mm wide, oblanceolate, 5-nerved. *Lemma* narrowly oblanceolate, 6.0-10.0 mm long and 1.5-2.0 mm wide, 5-nerved, the awn 7.0-12.0 mm long, arising from below the 2-toothed membranous apex of the lemma. *Palea* 0.5 mm large and 0-2.0 mm wide. *Anther* 0.5-1.0 mm long. *Caryopsis* 3.0 mm long.

Flowering and fruiting period: March-April.

Bromus danthoniae (plate 7)

Trin. in C.A. Mey., Vertz Pf. Cauc. 24 (1831); Bor in Towns; Guest & Al-Rawi, Fl. Iraq 9:136-141 (1986); Cope in Nasir & Ali, Fl. Pak. 143:580-582 (1982).

Synonyms:- *Bromus macrostachys* Desf. *Var. triaristatus* Hack. in flora 62:155. 1879; FBI 7:362

Type:- Caucasus, C.A. Meyer (LE).

An annual grass, 10.0-41.0 cm high, solitary, erect or geniculately ascending, fascicled culms, 3-4 nodded, smooth and glabrous. *Leaf blades* 5.0-12.0 cm long and 1.4-3.0 mm wide, narrowly linear, blades and sheaths pubescent. *Ligule* 0.9-1.0 mm long a row of very small hairs. *Panicle* 2.7-8.0 cm long and 1.9-2.0 cm wide, pedicles 20.0 mm long, ascending. *Spikelets* 17.5-32.5 mm long, elliptic or oblong elliptic, 5.-15 flowered, compact. *Glumes* lanceolate, lower glume 4.5-7.5 mm long and 1.2-1.8 mm wide 3-5 nerved, hyaline margins; upper glume 5.5-8.5 mm long and 3.0-3.5 mm wide, narrowly ovate or broad lanceolate, 7-9 nerved; hyaline margined. *Lemmas* narrowly lanceolate, 12.0-15.0 mm long and 3.0 mm wide, 9-nerved, with broad hyaline margins widened above the middle into an obtuse angle, the lower lemma 1-awned, the upper lemmas 3-awned; the central awn longer than the lateral two, the central awn 1.5-3.0 mm long. *Palea* 7.0-10.0 mm long and 1.0-1.2 mm wide. *Anthers* 0.2-0.5 mm long. *Caryopsis* 1.2-5.0 mm long.

Flowering and fruiting period: Late March-April.

Cenchrus penisctiformis (plate 7)

Hochst. & Stend., Syn. Pl. Glum 1:109.1854.

Synonyms: *Pennisetum cenchroides var. echinoides* Hk.f., FBI 7:88.

Type: Saudi Arabia, Jeddah, Schimper 973 (K) & S.1., Schimper 974 (P).

Annual grass, upto 30.0 cm tall, culms erect, solid, glabrons. *Leaf blade* 9.0 cm long and 2.0 mm wide, pubescent, leaf sheath glabrous. *Ligule* a dense row of short hairs. *Spike* varying from long and dense to short and lax bristles, white, green or dark-purple, 8.0 cm long and 1.0 wide. *Spikletes* lanceolate, 5.0 mm long and 3.0 mm wide, 1-2 flowered. *Glumes* sub equal, lower glume lanceolate, 3.0 mm long and 1.5 mm wide, upper glume lanceolate, 4.0 mm long and 2.0 mm wide, 3-7-nerved. *Lemmas* lanceolate, 4.0 mm long and 2.0 mm wide, awn very short, 7-nerved. Palea 3.0 mm long and 1.5 mm wide. *Anther* 2.2 mm long. *Caryopsis* 1.0-2.0 mm long.

Flowering and fruiting period: April-First week of May.

Chrysopogon aucheri (plate 8)

(Boiss) Stapf in Kew Bull. 1907, 21.1907.

Synonyms: *Andropogon aucheri* Boiss; FBI 7:195.

Type: Saudi Arabia, Jeddah to Makkah? Schimper.

An annual grass, culms slender, 20.0-58.0 cm high, glabrous, 5-6 nodes. Leaves short crowded at the base. Leaf blade hairy, 6.5 cm long and 2-2.5 mm wide, leaf sheaths glabrous. *Ligule* a ciliate rim. *Panicle* oblong, 8.0-11.0 cm long and 1.0-2.0 cm wide, branched at tip. *Spikelets* sessile, 5.0-8.0 mm long and 1.0-2.0 mm wide, linear-subulate, callus densely bearded. G*lumes* subequal, membranous the upper produce a plumose awn 24.0 mm long, oblong, 6.0 mm long and 1 mm wide, lower glume broadly oblong, 5.0-8.0 mm long and 1.0-1.5 mm wide, 3-7 nerved. *Lemmas* lanceolate, 6.0 mm long and 1.0 mm wide. *Anther* 3.0 mm long, yellow. *Caryoprsis* 2.0 mm long.

Flowering and fruiting period: Late March-April-May.

Cymbopogon flexsuosus (Palte 8)

Sprengel Pl. Pugill, 2:14 (1815)

Synonyms: *Andropogon flexuosus* (Flora of Lybia).

An annual grass, culms erect, upto 80.0 cm high, glabrous, 3-7 nodes. *Leaf blade* glabrous, 37.0 cm long and 5.0 mm wide, leaf sheath glabrous. *Ligule* 3.0 mm long, ovate with brown hairs. *Panicle* spathteate, narrow, dense, 6.0 cm long and 5.0-10.0 mm wide. *Spikelets* oblong-elliptic, 4.5 mm long and 2.0 mm wide, pedicel 2.2 mm long, 1-3 flowered. *Glumes* lanceolate, 4.0-4.2 mm long and 1.0-5.0 mm wide, 3.0-5.0 nerved. *Lemmas* lanceolate with an awn 16.0 mm long, 3-nerved. *Palea* 3.5 mm long and 1.5 mm wide. *Anther* 2.0 mm long yellow. *Caryopsis* 1.0-2.0 mm long.

Flowering and fruiting period: August-September.

Cymbopogon schoenanthus (plate 9)

(L.) Sprengel, pl. Pugill, 2:14 (1815); Clayton & Renvoize in polhill, Fl. Trop. East Afr. Gramineae: 765 (1982).

Synonyms: *Andropogon sennarensis* Hochst. in Flora 27:243 (1844); *A. proximus* A. Rich., Tent. Fl. Abyss. 2:464 (1851); *Cymbopogon sennarensis* (Hochst.) Chior., Gram. essenze: 16 (1909); C. proximus (A. Rich.) Stapf in Prain, Fl. Trop. Afr. 9:271 (1919).

Type: S.I. Plukent (BM)

A perennical tufted grass usually about 35.0 cm high but upto 1.0 meter tall. *Leaf blades* linear, 15.0 cm long and 2.5 mm wide, the leaf sheath glabrous, persistent on the culms. *Ligule* 1.5-2.0 mm long. Spikes densely woolly with hairs, the lower most pedicel swollen, 3.5 cm long and 1.0-2.0 mm wide. *Spikelets* sessile, 5.0 mm long and 1.0-1.2 mm wide, 1-2 flowered, *Glumes* lanceolate hairy, 3.5 mm long and 2.0 mm wide, lower glume flate in the upper halt and with a deep v-shaped groove in the lower, the keels winged above; 3-9 nerved. *Lemmas* lanceolate to ovate, 2.5 mm long and one mm wide, nerves not clear. *Anther* 1.8 mm long. *Caryopsis* 1.0-2.0 mm long.

Flowering and fruiting period: Late July-September.

Cynodon dactylon (plate 9)

(L.) Pers., syn. pl. 1:85.1805; FBI 7:288.

Synonyms: *Panicum dactylon* L.; Digitaria dactylon (L.) Scop. *Capriola dactylon* (L.) Ktze., Rev. Gen. Pl. 2:764 (1891).

Type: S. Europe (Herb. Linn. 80/35).

A rhizomatus, stoloniferous, perennial grass; culms slender, upto 25.0 cm tall. *Leaf blades* linear, 4.5 cm long and 2.0-4.0 mm wide, glabrous, leaf sheath glabrous. *Ligule* a very short ciliate rim. *Spike* digitate, 4.5 cm long and 1-1.5.0 mm wide. *Spikelets* 2.0-2.8 mm long and 1.5 mm wide, 1-flowered. *Glumes* unequal, lower glume slightly shorter than the upper, lanceolate, lower glume 1.5-2.3 mm long and 0.8-1.0 mm wide, upper glume 1-5-2.5 mm long and 0.8 mm wide, 1-nerved. *Lemmas* boat shaped, 2.0 mm long and 1.2 mm wide, 3-nerved, keeled. *Palea* as long as the lemma. *Anther* 1.5 mm long.

Flowering and fruiting period: March-September.

Dactyloctenium aegyptium (plate 10)

(L.) P. Beaur., Ess. Agrost. Expl. 15.1812. Clayton & Renvoize in Polhill, Fl. Trop. East Afr. Gramineae: 254 (1974); Cope in Nasir & Ali, Fl. Pak. 143:107 (1982).

Synonyms: *Cynosurus aegyptius* L. Sp. Pl. 72.1753. *Elunsine aegyptiaca* (L.) Desf., Fl. Atlant. 1:85.1798; FBI 7:295. *Chloris mucronata* Michx., Fl. Bor, Amer. 1:59 (1803); *Dactyloctenium mucronatum* (Michx) Willd., Enum. Hort. Berol 1029 (1809).

Type: Described from egypt (in Bauhin, Pinax 7(1623) and India.

Annual grass up to 45.0 cm tall, rarely more. Culms glabrous, 3-4 nodded. *Leaf blades* flat, 13.0 cm long and 5.0 mm wide, papillose-hispid. *Ligule* a 0.5 mm long row of small hairs. *Inflorescence* of 3-5 digitate spikes, each 2.3 cm long and 5.0 mm wide. *Spikelets* 3.0 mm long and 1.2 mm wide, 3-flowered, laterally compressed. *Glumes* subequal, lanceolate, 1.5-2.0 mm long and 0.8 mm wide, both prominently keeled, the upper with a divergent rather stontown as long as or more usually shorter than the glume 3-nerved. *Lemmas* ovate, 2.5 mm long and 1.8 mm wide, keeled, cuspidate. *Palea* keeled winged or wingles, 2.0 mm long and one mm wide. *Anther 0.2-.05* mm long. *Caryopsis* about one mm long.

Flowering and fruiting period: May-early July.

Desmostachya bipinnata (plate 10)

(L.) Stapf in Thiselt. Dyer, Fl. Cap. 7:632 (1900); Borin Towns., Guest and Al-Rawi, Fl. Iraq 9:429 (1968); Bor in Rech. f., Fl. Iran. 70:436 (1970); Cope in Nasir & Ali, Fl. Pak. 143: 109 (1982).

Synonyms: *Briza bipinnata* L. Syst. Nat. ed. 10, 2:875. 1759. *Eragrostis cynosuroides* (Retz). P. Beauv. Ess. Agrost. 162. 1812, FBI 7:324; *Stapfiola bipinnata* (L.) O. Ktze.

Type: Egypt, Hasselquist.

A robust, coarse perennial grass, culms stout glabrous up to 40.0 cm high. Leaf blades upto 20.0 cm long and 5.0 mm wide, glabrous, flat or floded, acute. *Ligule* a row of very short hairs. *Inflorescence* a strict panicle of densely clustered or spaced spikes of spikelets, 9.0 cm long and 1.0 cm wide, each spike 1.0-4.0 cm long. *Spikelets* compressed, 2.2 mm long and one mm wide, 4-flowered, awnless. *Glumes* ovate, equal, 1 mm long and 0.5 mm wide, 1-nerved, membranous. *Lemmas* keeled, ovate, 1.8-2.0 mm long and 1.2 m wide, 3-nerved. Palea 2-keeled, 0.8-1.0 mm long and 0.5 mm wide. *Anther* one mm long.

Flowering and fruiting period: April-August.

Dicanthium annulatum (plate 11)

(Forssk) Stapf in Prain, Fl. Trop. Afr. 9:178 (1917) Bor in Towns., Guest & Al./ Rawi, Fl. Iraq 9:523 (1968); Bor in Rech. f., Fl. Iran. 70:540 (1970); Cope in Nasir and Ali, Fl. Pak. 143:280-282 (1982); Clayton and Renvoize in polhill, Fl. Trop. East Afr. Gramineae: 725 (1982).

Synonyms: *Andropogon annulatus* Forssk., Fl. Aegypt.-Arab.173. 1775.

Type: Egypt, Forsskal (C).

A perennial grass, culms 30.0-48.0 cm high, nodes hairy. Leaf blades flat or rolled, 10.5 cm long and 2.0-3.0 mm wide, pubecent, leaf sheath smooth. *Ligule* 1.0-2.5 mm long, membranous. *Inflorescence* of 2.0-7.0, shortly peduncled, digitate or subdigitate spikes, 3.0-4.0 cm long and 1.5 mm wide. *Spikelets* more or less imbricate with or without lower few pairs on a spike homogenous, sessile, 3.8 mm long and 1.2 mm wide. *Glumes* broadly lanceolate, 3.0-4.0 mm long and 1.0-1.5 mm wide, pubescent or long-hairy below the middle, 3-nerved, the awn 18.0 mm long. *Lemma* lanceolate 2.0-3.0 mm long and 1 mm wide. *Palea* 2.5 mm long and 1.0 mm wide. *Anther* 1.5 mm long.

Flowering and fruiting period: Late March-October.

Dicanthium foveolatum (plate 11)

(Del.) Roberty in Boissiera 9:170 (1960); Cope in Nasir and Ali, Fl. Pak. 143:279 (1982); Clayton and Renvoize in polhill, Fl. Trop. East Afr. Gramineae: 723 (1982).

Synonyms: *Andropogon foveolatum* Del., Fl. Egypt. 16, f. 8/2 (1812); *A. Stirctus* Roxb., Fl. Ind. ed.2, 1:250 (1832); *Eremopogon foveolatus* (Del.) Stapf in Prain Fl. Trop. Afr. 9:183 (1917); *E.strictus* (Roxb.) *A.camus* in Ann. Soc. Linn. Lyon, n.s. 68:208 (1921).

Type: Egypt, Delile (K).

A tufted perennial grass, upto cm to 70.0 cm tall. Culms slender, wiry. *Leaf blades* narrow linear, 20.0 cm long and 3.0 mm wide pubescent, leaf sheath smooth. *Ligule* 1.0-2.0 mm long. *Inflorescence* of solitary narrow spike (raceme) subtended by a narrow spathide. *Spikes* 1.5-4.5 cm long 1.0-1.5 mm wide; the lower few spikelets-pairs homogenous or not. *Spikelets* sessile, elliptic, 2.5-4.0 mm long and 1.0 mm wide. *Glumes* subequal, lanceolate, with a circular depression in the upper third, acute, 3.5 mm long and 1.0-1.5 mm wide, awn 18.0 mm long, 5-nerved. *Lemmas* lanceolate, 2.5 mm long and 1.0 mm wide. 5-nerved. *Palea* 1.5 mm long and 0.8 mm wide. *Anther* 1.2 mm long.

Flowering and fruiting period: May-October.

Digitaria biformis (plate 12)

Willd. Pl. Hort. Berol. 92. 1809

Synonyms: *Panicum biforme* (Willd.) Kunth, 1829; *P. Sanguinale* L. var biforme (Willd.) Hack. en.Dur. and Schinz.

Type: China, Canton, Wennerberg (LD).

An annual grass, culms up to 40.0 cm high, decumbent at the base and geniculately ascending. *Leaf blades* broadly linear, 12.0 cm long and 3.0-5.0 mm wide, pubescent, leaf sheath pubescent. *Ligule* 3.2 mm long, membranous. *Infleresence* digitate or sub-digitate, composed of 2.0-12.0 racemes; racemes stiff, 12.5 cm long and 2.0-5.0 mm wide. *Spikelets* binate and overlapping by about 2/3 their length on a winged rhachis, with triquetrous midrib, narrowly elliptic, 3.0 mm long and 1.0 mm wide, sharply acute, 1-flowered. *Glumes* equal, lower glume distinct, ovate or triangular 1.5-2.0 mm long and 1.0 mm wide 3-nerved, upper glumes 1.5 mm long and 1.0 mm wide, 3-nerved. *Lemmas* ovate, 2.5 mm long and 1.0 mm wide, 7-nerved, the nerves evently spaced, appressed, silby pubescent. *Palea* membranous very small. *Anther* 0.2 mm long.

Flowering and fruiting period: Late June-July.

Digitaria nodosa (plate 12)

Parl., Pl. Nov. Min. Not. 39 (1842); Cope in Nasir and Ali; Fl. Pak. 143.227 (1982).

Synonyms: *Panicum parlatorei* Stend.; *P.pabulare* Aitch. and Hemsl. 1882. Paspalum sanguinale (L.) Lamk. var. pabulare (Aitch.) Hkt., FBI 7:15. *Digitaria parlatorei* (Stendel) Chior. in Ann. Ist. Bot. Roma 13:41 (1914).

Type: Canary Islands?

A tussocky perennial grass without rhizames but with bulbous bases of the culms giving rise to new shoots. Culms up to 30 cm tall, glabrous, 5 nodes. *Leaf blades* linear to narrow lanceolate, 12 cm long and 3-5 mm wide, pubescent, leaf sheath pubescent. *Ligule* a 0.2 mm long row of very small hairs. Inflorence of 4-12 spikes, digitate, sub-digitate or racemose on an axis up to 10 cm long, the spike 12 long and 2.5 mm wide. *Spikelets,* 1.5-2 mm long and 1 mm wide, *Glumes* minute oval scales, the lower glume 0.5-1 mm long and 0.8 mm wide, 3-nerved, upper glume, 3-nerved, ovate, 7-nerved, as long as the spikelets, usually sparsely to densely hairy with long white hairs. *Anther* 0.2 mm long.

Flowering and fruiting period: Late June-October.

Digitaria sanguinalis (plate 13)

(L.) Scop. Fl. Carn., ed. 2,1:52 (1771); Bor in Towns., Guest & Al. Rawi, Fl. Iraq 9:478 (1968); Bor in Rech. f., Fl. Iran, 70:491 (1970); Cope in Nasir & Ali, Fl. Pak. 143:231 (1982); Clayton & Renvoize in polhill, Fl. Trop. East Afr. Gramineae: 650 (1982).

Synonmys: *Panicum sanguinale* L. Sp.Pl. 57. 1753. *Paspalum sanguinale* (L.) Lamk; FBI 7:13.

Type: Cultivated at Leiden (L.).

An annual decumbent grass with culms 15.0-50.0 cm tall. *Leaf blades* linear to linear-lanceolate 6.5 cm long and 4.0 mm wide, pubescent, leaf sheath smooth. *Ligule* 1.5 mm long. *Infloresence* of 2-7 spikes, the spikes digitate, or sub-digitate in 2 or more whorls or racemose on a central axis, each 7.0 mm long and 1.5 mm wide. *Spikelets* 3.0 mm long and 1.0 mm wide, acute, 1-Flowered. *Glumes* ovate lower glume minute 0.2 mm long, 3-nerved, upper glume 5-nerved, 1.5 mm long and 1.0 mm wide. *Lemmas* ovate lanceolate, 2.5-3.0 mm long and 1.1 mm wide, 5-nerved, scaberulous on the nerves with minute siliceous spines, appressed pubescent. *Palea* 2.5 mm long and 1.0 mm wide. *Anther* 1.0 mm long. *Caryopsis* 2.0 mm long.

Flowering and fruiting period: July-August.

Echinochloa colonum (Plate 13)

(Linn) Link, HOrt, Berol. 2:209. 1833; Blatter & McCann, Bombay Grasses 148.1935; Bor, Fl. Assam 5:246.1940; Sultan & Stewart. Grasses W.Pak. 1:44.1958; Bor, Grasses Burma Ceyl. Ind. Pak. 308.1960; Bor in Towns; Guest & Al-Rawi; Fl.Iraq 9:479.1968; Bor in Rech. f., Fl. Iran. 70:479.1970; Clayton in Tutin etal; Fl. Eur. 5:262.1980.

Synonyms: *Panicum colonum* Linn; Syst. Nat; ed. 10,2:870.1759; Boiss; Fl. Or; 5:435.1884; Buthie; Fodder Grasses 4.1888.Hook.f., Fl. Brit. Ind. 7:32.1896; *P.brizoides* Linn; Mant. 2:184.1771; *Oplismenus colonum* (Linn) H.B.K., Nov. Gen.Sp. 1:108.1816; *Echinochloa crus-galli* (Linn) P.Beauv. Subsp *colona* (Linn) Honda in Bot. Mag; Tokyo 37:122.1923.

An annual grass, clums 10.0-50.0 cm high, erect or ascending. *Leaf blades* 4.0-28.0 cm logn, 2.0-8.0 mm wide. *Ligule* absent; sheath glabrous. *Inflorescence* typically linear 1.0-15.0 cm long; the racemes neatly 4-rowed, seldem over 3.0 cm long, simple, commonly half their length apart. *Spikelets* 2.0 mm long and 1.5 mm wide. *Glumes* ovate, equal, 1.5 mm long and 1.0 mm wide, 3-nerved. *Lemma* ovate, 2.0 mm long and 1.5 mm wide, 5-nerved. *Palea* membranous. *Anther* 1.0 mm long. *Caryopsis* 2.0 mm long.

Flowering and fruiting period: July-August

Echinochloa crus-galli (plate 14)

(L.) P. Beauv., Ess. Agrost. 53, 161 (1812); Bor in Towns.; Guest & Al. Rawi, Fl. Iraq 9:480 (1968); Bor in Rech. f., Fl. Iran. 70:480 (1970); Cope in Nasir & Ali, Fl. Pak. 143:193 (1982); Clayton and Renvoize in polhill, Fl. Trop. East Afr. Gramineae: 577 (1982).

Synonyms: *Panicum crus-galli* L., Sp. Pl. 56 (1753). *Echinochloa subverticillata* Pilg. in Not. Bot. Gart. Mus. Berlin-Dahlem 15:451 (1941); *E.glabrescens* Kossenko in Bot. Mat. Gerb. Bot. Inst. Kamarer 11:40 (1949).

Type: Described from Europe.

An annual grass, culms 20.0-40.0 cm high, erect or ascending, glabrous. *Leaf blades* flat, 11.0-20.0 cm long and 0.9 mm wide. *Ligule* absent. *Inflorescence* 6.5 cm long and 10.0 mm wide, narrow or ovate. *Spikelets* irregularly arranged in 2-several rows on the rhachis, the spikelets 2.0 mm long and 1.5 mm wide, with bulbous based short and long bristils. *Glumes* ovate, the lower glume 1.5 mm long and 1.0 mm wide, 3-nerved the upper glume 1.5-2.0 mm long and 1.0-1.5 mm wide 5-nerved. *Lemmas* ovate, 2.0 mm long and 1.5 mm wide, the lower lemma projected into an awn up to 15.0 mm long, 5-

nerved. *Palea* 2.0 mm long and 1.5 mm wide. *Anther* 1.0 mm long. *Caryopsis* 2.0 mm long.

Flowering and fruiting period: July-August.

Eleusine indica (plate 14)

(L.) Gaertn., Fruet. Sem. Pl. 1:8 (1788); Bor in Rech. f., Fl. Iran. 70:437 (1970); Cope in Naisr & Ali, Fl. Pak. 143:103 (1982).

Synonyms: *Cynosurus indicus* L. Sp. Pl. 1:72 (1753); *Eleusine africana* Kennedy-O, Byrne in Kew Ball. 12:65 (1957).

Type: South Africa, Cape province, Warrenton-on-vaal, Wilmann H.K.I .(K).

A tufted annual grass up to 50.0 cm tall culms glabrous, 2-4 nodded. *Leaf blades* flat or folded, 17.0 cm long and 5.0 mm wide, glabrous, leaf sheath 7.0 cm long, glabrous. *Ligule* with a ciliate fringe. *Inflorescence* of usually 2-several digitate spikes, often with one of these set below the main cluster of spikes at the tip; spike, 5.0-10.0 cm long and 1.0-2.0 mm wide. *Spikelets* 3.5 mm long and 1.0-2.0 mm wide, 3-flowered. *Glumes* unequal, lanceolate acute, the lower glume 2.0 mm long and 0.8 mm wide, 3-nerved the upper glume, 2.0-2.5 mm long and 1.5 mm wide, 3-nerved. *Lemmas* with a subsidiary nerve close to the keel on either side in the upper part, 2.3-3.0 mm long and 1.0-1.5 mm wide. *Palea* membranous 2/3 of the length of the lemma. *Anther* 0.2 mm long. *Caryopsis* 0.5 mm long.

Flowering and fruiting period: Late June-August.

Eragrostis minor (plate 15)

Host, Gram. Austr. 4:15 (1809); Clayton in polhill, Fl. Trop. East Afr. Gramineae: 234 (1974); Cope in Nasir & Ali, Fl. Pak. 143:95 (1982).

Synonyms: *Eragrostis pooides* P. Beauv., Sp. Pl. 1:68 (1753). *E. multiflora* (Forssk.) Aschers. var. *pappiana* chiox in Ann. Ist. Bot. Roma 8.65 (1905); *E. pappiana* (Chior.) Chiro. in Ann. Ist. Bot. Rama. 8:371 (1908).

Type: Italy, Baeck (LINN).

A tufted annual grass up to 35.0 cm tall, culms glabrous, 3 nodded. *Leaf blades* flat, 14.5 cm long and 2.0 mm wide, pubescent, leaf sheath glabrous, 3.8 cm long. *Ligule* a row of short hairs. *Panicle* open or rather dense, ovate, 4.0-14.0 cm long and 5.0 mm wide, with or without glands on the branches and pedicels, pedicels 2.0-2.0 mm long. *Spikelets* 5.0 mm long and 1.5-2.0 mm wide, 10-flowered, breaking up from the base upward. *Glums* ovate, 1-3 nerved, subequal, 1.0-2.0 mm long and 0.5-1.5 mm wide, often glandular on keel. *Lemmas* ovate, 1.2-1.5 mm long and 1.0 mm wide, often glandular on the keel, obtuse 3-nerved. *Palea* persistent. *Anther* 0.2 mm long.

Flowering and fruiting period: June-August.

Heteropogon contourtus (plate 15)

(L.) P. Beauv. ex Roemer & Schultes, Syst. Veg. 2:836 (1817); Borin Towns., Guest & Al-Rawi, Fl. Iraq 9:528 (1968); Bor in Rech. f., Fl. Iran. 70:548 (1970); Cope in Nasir & Ali, Fl. Pak. 143:312 (1982).

Synonyms: *Andropogon contourtus* L., Sp. Pl. 1:1045 (1753).

Type: India, illustration in Plukenet, phyt., f. 19115 (1692).

A densely tufted, branched perennial grass, culms 30.0-80.0 cm high, glabrous, 2-4 nodded. *Leaf blades* pubescent, a cuminate, leaf sheath glabrous. *Ligules* a row of very small hairs. Racemes 4.0 cm long and 3.0 mm wide, the awns twisted together into a bundle at the top of the *raceme*; lower homogamons spikelets - pairs 6-7 *spikelets* sessile, 9.0 mm long and 3.0 mm wide including bearded sharb callus, spikelets in the upper part of the raceme female. *Glumes* equal, lanceolate, 8.0 mm long and 2.0-5.0 mm wide, 9-nerved, awn 8.0 cm long; *Lemmas* lanceolate, 8.0 mm long and 3.0 mm wide. *Palea* 4.0 mm long and 1.5 mm wide. *Anther* 2.5 mm long.

Flowering and fruiting period: April-September.

Imperata cylindrica (plate 16)

(L.) Raeuschel, Non. Bot., ed. 3:10 (1797); Bor in Towns; Guest & Al-Rawi, Fl. Iraq 9:532 (1968); Bor in Rech. f., Fl. Iran. 70:513 (1970); Cope in Nasir & Ali, Fl. Pak. 143:252 (1982); Clayton in Polhill. Fl. Trop. East Afr. Gramineae: 700 (1982).

Synonyms: *Lagurus cylindricus* L. Syst. Nat., ed. 10, 2:878 (1759); *Saccharum cylindricum* (L.) Lam., Encycl. Meth. Bot. 1:594 (1785); *S. koenigii* Retz.,Obs. Bot. 5:16(17989); *S.thunbrgii* Retz; I.C. 17 (1789). *Imperata arundinacea* Cyr., Pl. Rar. Neap.

2:27, t. 11 (1792); I. Koenigii (Retz.) P. Beau. var. *major* nees, Fl. Afr. Austr. 90 (1841).

Type: Europe (LINN).

A coarse, rhizomatous perennial grass, culms 10.0-30.0 cm high, glabrous, 2.0-3.0 nodded. *Leaf blades* flat, 5.8 cm long and 3.0 mm wide, pubescent, leaf sheath glabrous, 8.7 cm long. *Ligule* 0.1 mm long hairs row. *Panicle* silky, white hairy, dense, cylindrical, 10.0 cm long and 1.0 cm wide. *Spikelets* 4.0 mm long and 1.0 mm wide, 2-flowered. *Glumes* lanceolate subequal, the lower glume 3.0-4.0 mm long and 1.0-5.0 mm wide, the upper glume 4.0 mm long and 1.0-5.0 mm wide, 5-nerved. *Lemmas* lanceolate, 3.0-5.0 mm long and 2.0 mm wide, awnless. *Palea* 2.5 mm long and 2.0 mm wide. *Anther* 2.2 mm long.

Flowering and fruiting period: March-May.

Lolium multiflorum (plate 16)

Lam., Fl. Fr. 3:621 (1778); Bor in Towns., Guest & Al-Rawi, Fl. Iraq: 93 (1968); Bor in Rech. f., Fl. Iran. 70:92 (1970); Cope in Nasir & Ali, Fl. Pak. 143:377 (1982).

Synonyms: *Lolium italicum* A.Br. in Flora 17:243. (1834).

Type: France (P.).

An annual grass, culms solitary or tufted 10.0-15.0 cm high, glabrous, 2-4 nodded. *Leaf blades* auriculate, pubescent, 14.0 cm long and 2.0-4.0 mm wide, leaf sheath, glabrous, 7.0 cm long. *Ligule* 1.5 mm long membranous. *Spike* slender to rather stant, erect or nodding, compressed, 7.0-14.0 cm long and 2.0-4.0 mm wide. *Spikelets* awned, 12.0 mm long and 3.5 mm wide, 6-flowered. *Glumes* shorter than the spikelets, narrowly oblong, 4.0-7.0 nerved, lower glume present only in the terminal spikelet, upper glume 12.0 mm long and 2.0 mm wide. *Lemma* overlapping, lanceolate 6 mm long and 2.5 mm wide, awned, the awn 7 mm long as long as the lemma. *Anther* 3.2 mm long.

Flowering and fruiting period: March-April.

Oplismenus burmannii (plate 17)

(Retz.) P. Beauv. Ess. Agrost. 54, 168, 169. 1812; FBI 7:68.

Synonyms: *Panicum burmannii* Retz. Obs. Bot. 3:10.1783.

An annual grass with prostrate or trialing culms, 2.0-72.0 cm long. *Leaf blade* lanceolate to narrowly ovate, 7.0-8.0 cm long, 18 mm wide, pubescent, leaf sheath glabrous, 2.5 cm long. *Ligule* 1.2 mm logn, membranous. *Inflorescence* 9.0 cm long, 5.0 mm wide, racemes 0.5-2.5 cm long, their rhachis hirsute, the spikelets contiguous. *Spikelets* lanceolate, 2.5 mm long and 1.5 mm wide, often with a transverse ban of hairs across the middle of the lower lemma, rarely glabrous. *Glumes* lanceolate with an awn, unequal, lower *glume* 2.0 mm long and 1-1.5 mm wide, upper glume 1.2-1.5 mm long and 1 mm wide, 3-5 nerved. *Lemmas* lanceolate to ovate, 2.5 mm long and 1.0 mm wide, 3-nerved. *Paleas* as long as the lemmas. *Anther* 1.2 mm long.

Flowering and fruiting period: June-August.

Parapholis strigosa (plate 17)

(Dum.) C.E. Hubbard in Blumea, Suppl. 3:14 (1946)

An annual grass, culms upto 35.0 cm high, glabrous, 4-nodded, loosely tufted or salitary, erect and spreading. *Leaf blades* glabrous, 15.0 cm long and 4.0 mm wide, leaf sheath rounded on the back, glabrous, 6.5 cm long. *Ligules* 0.2 mm long membranous. *Spikes* usually straight and erect, cylindrical, stiff, 14.0 cm long and 1.5 mm wide, axis smooth, jointed, the joints deeply hollow out on one side, breaking horizentally at maturity beneath each *spikelet*. *Spikelets* embedded in hollows in the spike axis, solitary and alternating on oposite sides of axis, 4 mm long and 1.0 mm wide, closely pressed to the axis, 1-flowered. *Glumes* equal, or nearly so, as long as the spikeltes, narrow, pointed, rigid, 3-nerved. *Lemmas* oblong, blunt, as long or nearly as long as the glumes, membranous, finely 3-nerved. *Paleas* about as long as the lemmas. *Anther* 1.2 mm long. Grain tightly enclosed between the glumes and the joint of the spike-axis.

Flowering and fruiting period: July-August.

Paspalidium flavidum (palte 18)

(Retz.) A.Camus in Lecomte, Fl. Gen. del, Indo-chine 7:419.1922.

Synonyms: *Panicum flavidum* Retz. Obs. Bot. 4:15. 1786; FBI 7:28.

A tufted perennial grass, culms 10.0-15.0 cm high, erect or ascending from a prostrate base, glabrous 3-nodded. *Leaf blades* linear or folded, blent at the tip, 7.3 cm long and 7.0 mm wide, leaf sheath glabrous, 6.3 cm long. *Ligule* a row of very small hairs. *Inflorescence*, 8.0-15.0 cm long and 3.0 mm wide, raceme 1-2.5.0 cm long, distinct by 2-4 times their own length, their rhachis very narrowly winged from a triquetrous midrib, 0.5-0.8 mm wide, glabrous or minutely ciliate. *Spikelets* ovate, 2.0-3.0 mm long and 1.5 mm wide. *Glumes* ovate, unequal, the lower glume 1.5 mm long and 1.2 mm wide, 3-nerved truncate the upper glume 2.2-2.2 mm long and 1.8-2 cm wide, 5-nerved. *Lemmas* ovate, the lower floret with a palea, its lemma as long as the spikelet, the nerves not raised granulose. *Anther* 0.2 mm long.

Flowering and fruiting period: Late June-August.

Paspalum dilatatum (palte 18)

Poir. in Lam. Encyl. Meth. Bot. 5:35 (1804); Bor in Towns., Guest and Al. Rawi, Fl. Iraq 9:492 (1968); Bor in Rech. f., Fl. Iran. 70:493 (1970); Cope in Nasir and Ali, Fl. Pak. 143:211 (1982); Clayton and Renvoize in Polhill, Fl. Trop. East Afr. Gramineae: 608 (1982).

Synonyms: *Paspalum ovatum* Nees ex trin; Gram Pan. 113 (1826).

Type: Argentina, Buenos Aires, Commerson (P).

A tufted perennial grass, culms robust, 20.0-40.0 cm tall, glabrous, 3-nerved. *Leaf blades* glabrous, 12.6 cm long and 5.0-7.0 mm wide, leaf sheath glabrous, 10.8 cm long. *Ligules* 1.0 mm long membranus. *Inflorescence* of usually 3-5 racemosely arranged spikes on 2.0-20.0 cm long axis; the spikelets paired in 2 or 4 rows on the rhachis. *Spikes* catterpiller like, 6.0-1.0 cm long and 1.5-2.0 mm wide. *Spikets* ovate, 3.0-3.5 mm long and 2.0 mm wide, 1-flowered. *Glumes* equal, ovate, 3.0-3.5 mm long and 2.0 mm wide, upper glume sparsely pilose on the surface, ciliate on the margins, 3-nerved. *Lemmas* ovate, lower lemma like the upper glume but not ciliate; upper lemma minutely papillose, 3-nerved. *Anther* 0.5 mm long. *Caryopsis* 2.0-1.0 mm long.

Flowering and fruiting period: Late April-June.

Paspalum distichium (plate 19)

L., Syst. Nat. ed. 10,2:855 (1759); Hitche. and Chase, Man. Grasses U.S. 603-604 (1950). 164.

Synonyms: *Digitiria pospalodes* Michx., Fl. Bor. Am. 1:46 (1803); *Paspalum paspaloides* (Michx) Scrib. in Mem. Torrey Bot. Club. 5:29 (1894); Bor in Towns., Guest and Al-Rawi, Fl. Iraq 9:494 (1908); Cope in Nasir and Ali, Fl. Pak. 143:211-212 (1982) as *P. Paspaloides.*

Type: Jamaica

A stoloniferous perennial grass; culms 10.0-20.0 cm tall, glabrous, 3-nodded. *Leaf blades* glabrous. 8 cm long and 3.5 mm wide, leaf sheath glabrous, 5.0 cm long. *Ligule* 1.0 mm long, membranous. *Inflorescnce* of usually two spikes, each 5.0-9.0 cm long and 1.0-1.5 mm wide, *spikelets* in two rows on winged rhachis. *Spikelets* abruptly acute, appressed minutely, 2.0-3.0 mm long and 1.2 wide, 1-flowered. *Glumes* ovate, equal, upper glume, thick leathery, pubescent, 3-nerved, 2.0-3.0 mm long and 1.0-2.0 mm wide. *Lemmas* ovate, as long as the spikelet, the lower lemma thick, leathery, 3-nerved. *Anther* 0.2 mm long.

Flowering and fruiting period: Late June-September.

Pennisetum americanum (plate 19)

(L.) Schumann in Engl. Ptlanzenw. Ost. Afr. B51, C.tab. 4.

Synonyms: *P. typhoides* (Burm. f.) Stapf; *Panicum americanum* L.

Type: Ceylon, Hermann (BM).

A tall cultivated grass, culms upto 80.0 cm tall, glabrous, 5-nodded. *Leaf blades* flat, large, upto 40 cm long and 1.0 cm wide, pubescent, cordate at the base, leaf sheath 9.0 cm long, pubescent. *Ligules*, 1.0-5.0 mm long, hairy *Panicle* stift, very dense, cylindrical, upto 30.0 cm long, 10.0-20.0 mm wide, bearing spikelets in clusters of 2,s. *Spikeles* turgid, 3.5-4.5 mm long. *Lemmas* and palea pubescent on the margines. *Anther* 3.5 mm long. Grain spherical, ususally white, protruding from spikelet at maturity.

Flowering and fruiting period: June-August.

Pennisetum lanatum (plat 20)

Klotzsch in Bot. Erg. Waldrem. Reise 65, f. 99. 1862.

A tuffted perennial grass with tough extensive rhizomes; culms, 30.0-80.0 cm high, erect, glabrous, 5-nodded. *Leaf blades* 9.0 cm long and 2.0-2.5 mm wide pubescent, leaf sheath pubescent, 8.0 cm long. *Ligule* a row of long hairs. *Panicle* linear, 3.0-5.0 cm long and 0.5-1.0 cm wide, rhachis with shallow angular ribs, pubescent, involucre enclosing 2-4 spikelets, each shortly pedicelled, bristles densely to sparsely ciliate, bramched, often several times above the base. *Spikelets* lanceolate, 3.0-5.0 mm long and 2.0-2.5 mm wide, 2-flowered. *Glumes* lanceolate, unequal, the lower glume 3.0-5.0 mm long and 1.0-1.5 mm wide, upper glume 4.0 mm long and 1.5-2.0 mm wide, 5-nerved. *Lemmas* 3.0-5.0 mm long and 1.0-2.0 mm wide, the lower lemma acuminate, upper lemma acute, firmer in texture and slightly shorter than the lower. *Palea*, 3.0-5.0 mm long and 1.0-2.0 mm wide. *Anther* 3.0-5.0 mm long.

Flowering and fruiting period: April-May-June.

Phalaris minor (plate 20)

Retz., Obs. Bot. 3:8 (1783); Bor in Towns., Guest and Al-Rawi, Fl. Iraq 9:364 (1968); Bor in Rech.f., Fl. Iran. 70:346 (1970); Cope in Nasir and Ali, Fl. Pak. 143:494 (1982).

Type: Locality: Orient.

A tufted annual grass, culms 20.0-47.5 cm high, ovate, hairy, 5-nodded. *Leaf blades* 11.0-17.5 cm long and 1.0-1.8 mm wide, dorselly glabrous, leaf sheath, glabrous, 14.7 mm long. *Ligule* 3.0 mm long, membranous, prominent. *Panicle* densely spicate, ovate to cylinderical, 2.0-4.5 cm long and 1.0-1.4 cm wide. *Spikelets* 4.0 mm long and 2.5 mm wide 1-flowered. *Glumes* subequeal, broadly winged, the wing usually dentate or entire, sterile florets represented by two minute scales; fertile florets 2.5-4.0 mm long, the lower glume 4.5 mm long and 2.0 mm wide, the upper glume 1.0-2.0 mm long and 0.5-1.0 mm wide, 2-nerved. *Lemma* ovate, 3.0 mm long, 2-nerved. *Palea* 1.0 mm long and 0.5 mm wide. *Anther* 0.8-1.0 mm long. *Caryopsis* 1.0-1.5 mm long.

Flowering and fruiting period: Late March-April.

Phleum himalaccum (plate 21)

Huds. Fl. Angl. 23. 1762;

Synonyms: *Phleum asperum* Jacq. Coll. 1:10.1786; FBI. 7:237

An annual glabrous grass, culms, 8.0-22 cm high, usually erect, 4-nodded. *Leaf blades* 8-15 cm long and 3-6 mm wide, pubescent leaf sheath glabrous. *Ligules* 0.5 mm long. *Panicle* 1.8-4.8 cm long and 5-8 mm wide, ovoid or oblong, green. *Spikelets* 5-14 mm long and 1-2 mm wide, 1-flowered. *Glumes*, unequal, gradually narrow into a short awn, scabrid on the side, stiffly ciliate on the keel, softly hairy on the margin, awn 1-1.5 mm long, 3-nerved, lower glume 2 mm long and 0.2 mm wide, upper glume 3 mm long and 1 mm wide. *Lemmas* lanceolate, 2.5 mm long and 1 mm wide, 5-nerved. *Palea* 1.5-2 mm long and 0.8 mm wide. *Anther* 1.0 mm long. *Caryopsis* 0.8 mm long.

Flowering and fruiting period: March-April

Phleum pratense (plate 21)

L., Sp. Pl. 59.1753.

A loosely or densely tufted perennial, culms 15-35 cm high, erect or geniculately ascending, the lower nodes some time swollen and tuberous, 4-nodded. *Leaf blades* 15-20 cm long and 3-7 mm wide, scrabrid on both sides, uper sheath slightly inflated. *Ligule* 1-4 mm long. *Panicle* 2-8 cm long and 4-8 mm wide, cylindrical green. *Spikelets,* 3-3.8 mm long and 0.2-0.5 mm wide, 1-flowered. Glumes narrowly oblong, swifftly ciliate on the keel, the lower softly hairy on the margin, awn 1-2 mm long, 3-nerved. *Lemmas* blunt, 0.7 mm long and 0.2 mm wide, 5-7 nerved, minutely hairy. *Palea* 0.5-0.7 mm long and 0.2 mm wide. *Anther* 2 mm long. *Caryopsis* 0.5 mm long.

Flowering and fruiting period: March-April.

Phragmites australis (plate 22)

(Cav.) Trin. and Stendel, Nom. Bot. ed, 2:324 (1841); Bor in Towns; Guest and Al-Rawi, Fl. Iraq 9:26 (1968), Bor in Rech. f., Fl. Iran 70:352 (1970); Clayton in Milne-Redhead & Polhill, Fl. Trop. East Afr. Gramineae: 117 (1970).

Synonyms: *Arundo phragmites* L., Sp. Pl. 1:81 (1753); *A australis* Car. in Anales Hist, Nat. Madrid 1:100 (1799); *Phragmites communis* Trin; Fund. Agrost., 134 (1820); *Trichoon phragmites* (L.) Rendle, Cat. Afr. Pl. Welw. 2:218 (1899) *Phragmites maxima* (Forssk). Blatter and McCann, Bumbay grasses: 202 (1935) in part, based on *Arundo maxima.* Forssk 1775.

Type: Australia, Nee (MA)

A stout perennial, rhizomatous reed, culms upto 1.5 meters high, glabrous, 3-5 nodded. *Leaf blades* firm usually 50.0 cm long and 10.0 mm wide, acute, leaf sheath, glabrous, 35.0 cm long. *Ligule* 4-5.0 mm long, membranous. *Panicle* large, 43.0 cm long and 5.0 cm wide. *Spikelets* 4.0 mm long and 1.5 mm wide, pedicellate, 23-flowered, gaping. *Glumes* unequal, lancealate, the lower glume 4.0 mm long and 2-5.0 mm wide, 3-nerved, the upper glume 5.0 mm long and 2-3.0 mm wide, 3-nerved. *Lemmas* narrowly lanceolate, 3-4.0 mm long and 1.5-2.0 mm wide, 3-nerved. *Palea* 1.0 mm long. *Anther* 2.2 mm long.

Flowering and fruiting period: Late July-October.

Poa annua (plate 22)

L., Sp. 1:68 (1753); Bor in Towns., Guest and Al-Rawi, Fl. Iraq 9:122 (1968); Bor in Rech. f., Fl. Iran. 70:29 (1970); Cope in Nasir and Ali, Fl. Pak.

Synonyms: *Poa royleana* Steudel, Syn. Pl. Glum. 1:256 (1854).

Type locality: Eroupe.

An annual tufted grass, culms 10-22.0 cm high, glabrous, 3-nodded. *Leaf blades* usually flat, soft, 6.0 cm long and 1.5-3.0 mm wide, hairy, a cute or obtuse, leaf sheath glabrous, 6.0 cm long. *Ligule* 3.0 mm long. *Panicle* ovate to pyramidal, dense or lax, 8.0 cm long and 1-3.0 cm wide with paired branches. *Spikelets* 3.5 mm long and 1.5-2.0 mm wide, 3-flowered; *Glumes* unequal, lanceolate, the lower glume 2.0 mm long and 1.0 mm wide, 1-nerved, the upper glume 3.0 mm long and 1.5 mm wide. *Lemmas* oblong, 2.0 mm long and 1.0 mm wide, glabrous or ciliate on the keel 3-nerved. *Palea* almost as long as the lemma, ciliate along the keels. *Anther* 1.2 mm long. *Caryopsis* 1-5.0 mm long.

Flowering and fruiting period: Early March-April

Poa infirma (plate 23)

Kunth in Humb., Bon Pl. and Kunth Nov. Gen. Sp. 1:158 (1816); Bor in Towns, Guest and Al-Rawi, Fl. Iraq: 124 (1968); Bor in Rech. f., Fl. Iran. 70:30 (1970); Cope in Nasir and Ali, Fl. Pak. 143:30 (1970).

Synonyms: *Catabrosa thomsoni* Hook. f., Fl. Brit. Ind. 7:311 (1896).

Type: Colombia, Kunth.

An annual tufted grass very similar to *Poa annua*. Culms 5.0-15.0 cm high, glabrous, 4-nodded. *Leaf blades* 3.5 cm long and 3.0 mm wide, publescent, leaf sheath glabrous, 2.5 cm long. *Ligules* 3.0 mm long blunt. *Panicle* ovate, dense or lax, 3.0 cm long and 1.5 long with paired branches. *Spikelets* 3.0 mm long and 1.5 mm wide, 3-flowered. *Glumes* lenceolate to oblong, unequal, the lower glume 1.5 mm long 1.0 mm wide, 1-nerved, the upper glume 2.0 mm long and 1.0 mm wide, 3-nerved. *Lemmas* oblong, 2.0 mm wide and 1.0 mm wide, 3-nerved. *Palea* almost as long as the lemma, ciliate along the keel. *Anther* 0.2-0.5 mm long. *Caryopsis* 1.5 mm long.

Flowering and fruiting period: March-April.

Poa nemoralis (plate 23)

L. Sp. 69. 1753; Fl. Brit. Ind. 7:341.

A loosely tufted perennial grass, culms 20.0-30.0 cm high, glabrous, 3-nodded. *Leaf blades* finely to abraptly pointed, 10.0 cm long and 2.0 mm wide, ususally weak, minutely rough or nearly smooth, leaf sheath glabrous, 13.0 cm long. *Ligules* up to 0.5 mm long, membranous. *Panicle* usually nodding, lancedate to ovate, very lax and open, 8.0-14.0 cm long and 2.0-10.0 mm wide, pedicel 1.0 mm long. *Spikelets* lanceolate to ovate or oblong, compressed, 1.5 mm long and 0.5 mm wide, 2-flowered. *Glumes* persistent, equal or slightly unequal, finely pointed, 3-nerved, membranous, rough on the keels; lower glume lanceolate, 1.2 mm long and 1.0 mm wide, upper glume ovate, 1.0-1.5 mm long and 1.0 mm wide. *Lemmas* overlapping, lanceolate-oblong in side view, blunt or slightly pointed, 1.5-2.0 mm long and 1.0 mm wide, 5-nerved. *Paleas* as long as the lemmas. *Anthers* 0.5 mm long.

Flowering and fruiting period: July-September.

Polypogon monspeliensis (Plate 24)

(L.) Desf., Fl. Altant. 1:67 (1798); Borin Towris., Guest & Al Rawi, Fl. Iraq 9:318 (1968); Bor in Rech. f., Fl. Iran. 70:303 (1970); Clayton in Miln-e-Redhead & Polhill, Fl. Trop. East Afr. Gramineae: 100 (1970); Cope in Nasir & Ali, Fl. Pak. 143:467 (1982).

Synonyms:- *Alopecurus monspeliensis* L., Sp. Pl. 1:61 (1753).

Type:- Europe, Linnaeus (LINN).

An annual grass culms 12.0-50.0 cm high, 5-6 nodded. *Leaf blades* 12.0-15.0 cm long and 5.0-12.0 mm wide. Leaf sheath glabrous. *Ligule* 6.0-9.0 mm long. *Panicle* 3.0-12.0 cm long and 0.6-3.0 cm wide. Spikelet 2.5-3.0 mm long and 1.5 mm wide, one flower. Glumes narrowely oblong, equal 2.0 mm long and 0.5 mm wide, 1-2 nerved. *Lemma* broadly elliptic, 1.0 mm and 0.9 mm wide. Awn 4.0 mm long, 5-nerved. *Palea* membranous, 0.9 mm long and 0.6 mm wide. *Anther* 0.5 mm long. *Cryopsis* 1.0 mm long.

Flowering and fruiting period: March-April.

Saccharum sponteneum (plate 24)

L., Mant. 2:183 (1771); Bor in Rech. f., Fl. Iran. 70:516 (1970); Cope in Nasir and Ali, Fl. Pak. 143:263 (1982); Clayton and Renvoize in Polhill, Fl. Trop. East Afr. Gramineae: 704 (1982).

Synonyms: *Imperata spontanea* (L.) P. Beauv., Ess. Agrost. 8(1812); *Saccharum semidecum bens* Roxb; Fl. Ind. 1:241 (1820); *S. canaliculatum* Roxb; I.C. 251; *S. propinquum* Steudel; Syn. Pl. Glum. 1:406 (1855).

Type: India, Koenig (LINN).

A robust rhizomatous perennial grass, culms up to 1 meter or more high, glabrous, 5-7 nodded. *Leaf blades* 54.0 cm long and 3.0-5.0 mm wide, glabrous, publescent at the margins, leaf sheath glabrous, 15.0 cm long. *Ligules* 1.5 mm long hair, triangular. *Panicle* 24.0 cm long and 4.0 cm wide, primarily and further branche including the pedicels all hirsute. *Spikelets* 2.5-3.0 mm long and 1.5 mm wide, the hairs on the callus 2-3 times the length of the spikelet. *Glumes* equal, glabrous, often ciliate along the margins; lanceolate, 2.5 mm long and 1.5 mm wide, 3-nerved. *Lemmas* lanceolate-elliptic, 1.5-2.0 mm long and 1.2 mm wide, upper lemma very narrow, shortly awned. *Anther* 1.5 mm long. *Caryopsis* 1.0 mm long.

Flowering and fruiting period: August-October.

Setaria glauca (plate 25)

(L.) P. Beanv. Ess. Agrost., 51, 170, 128.1812.

Synonyms: *Panicum glaucum* L., *Setaria glaucescens* (Weig.) C.T. Hubb.

An annual grass, culms 10.0-30.0 cm high, glabrous, 3-nodded. *Leaf blades* finely pointed, 11.0 cm long and 4.0 mm wide, flate, hairy towardss the base, minutely rough on the margins, leaf sheath smooth, 6.5 cm long. *Ligule* a dense fring of fine hairs. *Panicle* spike-like, dense, very bristly, erect, cylindrical, 3.0 cm long and 3.0 mm wide. *Spikelets* broadely elliptic back view, blunt, broadly elliptic in side view, 2.5 mm long and 1.5 mm wide, 1-flowered with lower floret mole or barren and the upper bisexual. *Glumes* broadly ovate, unequal lower glume 1-2 mm long and 1.5 mm wide 3-nerved, the upper glume 1.5 long and 1.0 mm wide, 5-nerved. *Lemmas* ovate, as long as the spikelets, 3-nerved. *Paleas* flate, 2.5 mm long and 1.5 mm wide. *Anthers* 1 mm long. *Caryopsis* 0.7 mm long.

Flowering and fruiting period: Late June-August.

Setaria pumila (plate 25)

(Poir.) Roemer & Schultes, Syst. Veg. 2:891 (1817); Clayton & Renvoize in Polhill, Fl. Trop. East Afr. Gramineae: 530(1982).

Synonyms: *Panicum pumilum* Poir., Encycl. Meth. Bot., Suppl. 4:273 (1816); *Panicum pallide-fuscum* Schum., Besker. Guin. Pl., 58 (1827); *P.rubiginosum* steudel, Syn. Pl. Glum. 1:50 (1854); *Setaria rubiginosa* (Steudel) Miq., Fl. Ned. Ind. 3:467 (1857); *S. erythrae* Mattei in Bol. Ort. Bot. Palermo 9:49 (1910); *S. pallide-fusa* (Schumach.) Stapf & Hubb. in Kew Bull. 1930:259 (1930); *S. glaucasensu* praine, Fl. Trop. Afr. 9:814 (1930); Bor in Polhill, Fl.

Iraq 9:500 (1968), mult. auct. non (L.) P. Bea. uv. (1812); *S. leutescens* sensu multi auct., non(Weigel) Hubb. (1916).

Type: Not known, probably France or North Africa, Desfontaines (?P).

A tufted annual grass, culms 10.0-70.0 cm long, glabrous, 5-nodded. *Leaf blades* 22.0 cm long and 2.0-5.0 mm wide, leaf sheath glabrous 11.5 cm long. *Ligule* 1.0-2.0 mm long dense row of hairs. *Panicle* dense, cylindrical, spicate, bristles 3.0-12.0 mm long, yellow 5.0-11.0 cm long and 3.0-5.0 mm wide, 2-flowered. *Glumes* ovate, equal, 0.8-1.0 mm long and 0.5 mm wide, 3-5 nerved. *Lemmas* ovate, as long as the glumes, lower lemma staminate or sterile with a well-developed palea almost as long as the lemma, upper lemma usually strongly rugose rarely smooth. *Anthers* 0.8 mm long. *Caryopsis* 1.0-1.5 mm long.

Flowering and fruiting period: July-September.

Sorghum halepense (plate 26)

(L.) Pers., Syn. Pl. 1:101(1805); Bor in Towns; Guest and Al-Rawi, Fl. Iraq 9: 548 (1968) Bor in Rech. f., Iran. 70:529 (1970), Cope in Nasir & Ali, Fl. Pak. 143:295 (1982).

Synonyms: *Holcus halepensis* L., Sp. Pl. 1:1047 (1753); *Andropogon halepensis* (L.) Brot., Fl-Brit. Ind. 7:182. *S. bicolor* (L.) Moench subsp. *drummondii* (Stendel) de wit in Am. Journ. Bot 65:481 (1978), in part.

Type locality: Syria and Mauritania.

A tufted rhizomatous perennical grass, culms 20.0-70.0 cm high nodes pubescent or glabrous, 9-nodded. *Leaf blades* flat, 45.0 cm long and 7.0 mm wide, pubescent, leaf sheaths 11.5 cm long and glabrous. *Ligule* 2.0 mm long membranous. *Panicle* loose, pyramidal, 23.0 cm long and 13.0 mm wide. *Spikelets* sessile, ovate, soft-hairy, 1.0-4.0 mm long and 1.5 mm wide, awned, pedicellate spikelets 3.5 mm long and 1.0 mm wide, lanceolate, much narrower than the sessile spikelets 2-flowered. *Glumes* ovate, subequal, lower glume 3.2 mm long and 2.0 mm wide, 7-nerved upper glume 3.5 mm long and 2 mm wide, 3-nerved. *Lemmas* equal lower lemma ovate, 2.5 mm long and 1.0 mm wide, upper lemma lanceolate, acute with an awn 12.0 mm long. *Palea* as long as the lemma. *Anther* 2.1 mm long. *Caryopsis* 2.0 mm long.

Flowering and fruiting period: August-October.

Stipa splendens (plate 26)

Trim. in Spreng., Neue Entdeck., 2:54. 1821; Fl. Brit. Ind. 7:232.

Synonyms: *Stipa altaica* Trin.; *Lasiagrostis splendens* (Trim.) Kunth.; *Achnatherum splendens* (Trin.) Ohwi; *S. schlagintweitii* Mez. *var. splendens*.

A tufted robust perennial, culms 20.0-57.0 cm high, glabrous, 4.0-5.0 nodded. *Leaf blades* flat, sheath 3.5 cm long, glabrous. *Ligule* 3.5 mm long, membranous. *Panicle* narrow, dense but sometimes loose, 28.0 cm long and 2.0-5.0 cm wide, the branches usually bare at lower half. *Spikelets* sessile, 2-flowered, 5.0 mm long and 1.2 mm wide. *Glumes* unequal, elliptic lanceolate acute, the lower glume 3.5 mm long and 2.0 mm wide, 1-nerved, upper glume 4.5 mm long and 2.5 mm wide, 3-nerved. *Lemma* narrowly elliptic lancenlate, 0.3 mm long and 0.1 mm wide, conspicuously 2-toothed at the tip, awn straight, 7.0 mm long. *Palea* membranous less conspicuous. *Anther* 1.5 long.

Flowering and fruiting period: August-October.

Urochloa panicoides (plate 27)

P. Beauv., Ess. Agrost. 53, t. 11. f. 1.1812.

Synonyms: *Panicum javanicum* Poir.; Fl. Brit. Ind. 7:35; *Urochloa helopus* Stapf.

A tufted annual grass, culms 20.0-25.0 cm high, often ascanding from prostrate rooting base, glabrous, 6-nodded. *Leaf blades* linear to narrowly lanceolate, 11.0 cm long and 5.0-11.0 mm wide, glabrous, the margin tuberculate-ciliate at least near the base, leaf sheath glabrous, 7.0 cm long. *Ligule* a dense row of short hairs. Infloresence of 2.0-7.0 racenes on a common anis, racemes 6.0-12.0 cm long and 4.0 mm wide, bearing single or sometimes paired *spikelets* on a narrowly winged rhachis, 1.0-2.0 mm long pedicels with white hairs, *Spikelets* elliptic, 2.2 mm long and 1.2 mm wide, acute, 1-flowered. *Glumes* ovate, equal, 1.1 mm long and 0.8 mm wide, the lower glume obture to subacute, 3-nerved, the upper glume often with cross-veins, glabrous, 5-nerved. *Lemmas* ovate, 0.5-1 mm long and 0.7 mm wide. *Palea* membranous, 0.5-1 long. *Anther* 1.0 mm long. *Caryopsis* 1.0 mm long.

Flowering and fruiting period: July-August.

Vetiveria zizanioides (plate 27)

(L.) Nash in small, Fl. So.E.U.S. 67.1903.

Synonyms: *Phalaris zizanioides* L. Mant. 2:183.1771; *Adropogon squarrosus* L.f.,Fl. Brit. Ind. 7:186.1896.

Type: India, Koenig.

A tufted perennial grass, culms upto 1.0 meter high, glabrous, 3-5 nodded. *Leaf blades* flat, erect, 37.0 cm long and 5.0 mm wide, glabrous slightly hairy on the margin, leaf sheaths glabrous 26.0 cm long. *Ligule* dense fringe of hairs *Panicle* oblong, usually contracted, 28.0 cm long and 2.0 cm wide, it longest raceme up to 7.0 cm long. *Spikelets* sessile, 3.8 mm long and 1.0-2.0 mm wide, callus 1.0 mm long. G*lumes* equal, lanceolate, spinulose, 3.0 mm long and 1.5 mm wide, 3-nerved. *Lemmas* lanceolate, 3.0 mm long and 1.5 mm wide, upper lemma awnless. *Palea* membranous, 2.5 mm long and 1.0 mm wide. *Anther* 2.0 mm long.

Flowering and fruiting period: August-November.

4.2 Light Microscopic Observations

The pollen grains of the family Poaceae are monad, heteropolar, spheroidal, rarely elliptical or oblate, with an average diameter 45.0μm, usually monoporate, psilate or clearly ridged producing a rugulate or reticuoid pattern as observed by light microscopy. Surface sculpturing pattern granulate, scabrate, verrucate, rugulate. Pore always annulate, annulus conspicuous, granulate and scabrate, circular,, costa pori present, operculate or non-operculate. Sculpturing elements fine, small, closely, medium or widely spaced. Ten samples of each species were examined, their detailed description is presented in table 7. The photographs of each species are presented in plate no. 28-38.

Description of the pollen grains of species examined under light microscope.

Alopecurus myosuroides (plate 30a)

Symmetry and form: Ellipsoidal.

Dimensions: Polar length=(30-) 31.5 (-33)μm; equatorial length= (26-) 28.5 (-31)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.0μm, non-operculate, with conspicuous annulus 2-5μm wide.

Pore type: Ectoporous.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Aristida adscensionis (plate 30c)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (25-) 26.5 (-28)μm; equatorial length=(25-) 26.5 (-28)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2μm, operculate, annulus not conspicuous.

Pore type: Endoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Aristida funiculata (plate 30b)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (33-) 36 (-39)μm; equatorial length= (33-) 36 (-39)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=3μm, operculate, with prominent annulus.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Avena ludoviciana (plate 38a)

Symmetry and form: Oblate.

Dimensions: Polar length=(38-) 40 (-42)μm; equatorial length=(32-) 34 (-36)μm; P/E ratio 1.17.

Aperture type: Monoporate, circular, diameter=3.0μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.5μm.

Exine surface: Granulate.

Avena sativa (plate 38b)

Symmetry and form: Oblate.

Dimensions: Polar length= (47-) 51 (-55)μm; equatorial length= (45-) 46.5 (-48)μm; P/E ratio 1.09.

Aperture type: Monoporate, circular, diameter=3.5μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.5μm.

Exine surface: Granulate or scabrate.

Bothriochloa pertusa (plate 30f)

Symmetry and form: Spheroidal.

Dimensions: Polar length=(30-) 32.5 (-35)μm; equatorial length= (30-) 32.5 (-35)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.0μm, operculate.

Pore type: Endoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Brachiaria distachya (plate 30d)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (30-) 32.5 (-35)μm; equatorial length= (30-) 32 (-35)μm; P/E ratio 1.01.

Aperture type: Monoporate, circular, diameter=2.5μm, non-operculate.

Pore type: Endoporus

Exine thickness: 2.0μm.

Exine surface: Granulate.

Brachiaria erusiformis (plate 30e)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (21-) 23.5 (-26)μm; equatorial length=(21-) 23.5 (-26)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.5μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Brachypodium distachyon (plate 34c)

Symmetry and form: Spheroidal.

Dimensions: Polar length=(29-) 31.5 (-34)μm; equatorial length=(29-) 31.5 (-34)μm; P/E ratio, 1.00.

Aperture type: Monoporate, circular, diameter=3μm; operculate, annulus not conspicuous.

Pore type: Endoporus.

Exine thickness: 1.5μm.

Exine surface: Coarsely granulate.

Bromus catherticus (plate 34a)

Symmetry and form: Elliptical.

Dimensions: Polar length= (32-) 34 (-36)μm; equatorial length=(28-) 30.5 (33-)μm; P/E ratio 1.11.

Aperture type: Monoporate, circular, diameter=2.5μm, operculate.

Pore type: Endoporus.

Exine thickness: 2.5μm.

Exine surface: Granulate.

Bromus japonicus (plate 31a)

Symmetry and form: Speroidal.

Dimensions: Polar length=(31-) 32.5 (-34)μm; equatorial length= (31-) 32.5 (-34)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.0μm, operculate.

Pore type: Endoporus.

Exine thickness: 2.0μm.

Exine surface: Coarsely granulate.

Bromus denthoniae (plate 34b)

Symmetry and form: Spheroidal.

Dimensions: Polar length=(33-) 35 (-37)μm; equatorial length=(33-) 35 (-37)μm; P/E ratio 1.00.

Aperture type: Monoporate circular, diameter=2.0μm; operculate.

Pore type: Endoporus.

Exine thickness: 2.0μm.

Exine surface: Fine granulate.

Bromus pectinatus (plate 31b)

Symmetery and form: Spheroidal.

Dimensions: Polar length= (32-) 34 (-36)μm; equatorial length (32-) 34 (-36)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.0μm; non-operculate, with an annulus.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Coarsely granulate.

Cenchrus penisctiformis (plate 29a)

Symmetry and form: Spheroidal.

Dimensions: Polar length=(34-) 35.5 (-37)μm; equatorial length=(34-) 35.5 (-37)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter =2.0μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: psilate.

Chrysopogon aucheri (plate 34d)

Symmetry and form: Oblate-elliptical.

Dimmensions: Polar length=(32-) 34.5 (-37)μm; equatorial length=(30-) 32.5 (-35)μm; P/E ratio 1.07.

Aperture type: Monoporate, circular, diameter=2.0μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.5μm.

Exine surface: Fine granulate.

Cymbopogon flexsuosus (plate 34e)

Symmerty and form: Spheroidal

Dimensions: Polar length: (33-) 39 (-45)μm; equatorial length= (33-) 39 (-45)μm; P/F ratio 1.00.

Aperture type: Monoporate, circular, diameter 2.0μm, operculate.

Pore type: endoporus.

Exine thickness: 2.0μm.

Exine surface: Fine granulate.

Cymbopogon schoenanthus (plate 34f)

Symmetry and form: Spheroidal.

Dimensions: Polar length=(30-) 33.5 (-37)μm; equatorial length= (30-) 33.5 (-37)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.0μm; non-operculate.

Pore type: Ectoporus.

Exine thickness: 1.5μm.

Exine surface: Fine granulate.

Cynodon dactylon (plate 28a)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (21-) 23.5 (-26)μm; equatorial length=(21-) 23.5 (-26)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter 2.5μm; non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Coarsely psilate.

Dactyloctenium aegyptium (plate 35a)

Symmetry and form: Spheroidal.

Dimensions: Polar length=(20-) 26.6 (-36)μm; equatorial length=(20) 26.6 (-35)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.0μm, non-operculate, with an annulus.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Fine granulate.

Desmostachya bipinnata (plate 31c)

Symmetry and form: Spheroidal-oblate.

Dimensions: Polar length=(21-) 24.5 (-28)μm; equatorial length=(21-) 24.5 (-28)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.0μm; non-operculate with an annulus.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Psilate.

Dicanthium annulatum (plate 29b)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (21-) 30 (-32)μm; equatorial length=(21-) 30 (-32)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.0μm, non-operculate, with an annulus.

Pore type: Ectoporus.

Exine thickness: 1.5μm.

Exine surface: Fine granulate.

Dicanthium foveolatum (plate 35b)

Symmetry and form: Oblate.

Dimensions: Polar length= (32-) 35.5 (-39)μm; equatorial length=(31-) 33.3 (-36)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.5μm, non-operculate, enclosed by an annulus.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Fine granulate.

Digitaria biformis (plate 28b)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (21-) 28.5 (-36)μm; equatorial length=(21-) 28.5 (-36)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.5μm, non-operculate, encircled by an annulus.

Pore type: Ectoporus.

Exine thickness: 1.5μm.

Exine surface: Coarsely psilate.

Digitaria nodosa (plate 29c)

Symmetry and form: Speroidal.

Dimensions: Polar length= (22-) 23.5 (-25)μm; equatorial length=(21-) 23.5 (-25)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.5μm, non-operculate, encircled by an annulus.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Fine granulate.

Digitaria sanguinelis (plate 31d)

Symmetry and form: Speroidal.

Dimensions: Polar length= (30-) 33.0 (-36)μm; equatorial length=(30-) 33.0 (-36)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.0μm, operculate, encircled by an annulus.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Psilate.

Echinochloa colonum (plate 31e)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (18-) 21.0 (-24)μm; equatorial length=(19-) 21.5 (-24)μm; P/E ratio 1.0

Aperture type: Monoporate, circular, diameter=2.0μm, non-operculate, encircled by an annulus.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Fine granulate.

Echinochloa crus-galli (plate 35c)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (26-) 28.0 (-30)μm; equatorial length=(26-) 27.0 (-30)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.0μm; operculate, encircled by an annulus.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Eleusine indica (plate 31f)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (22-) 24.5 (-27)μm; equatorial length=(22-) 24.5 (-27)μm. P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2μm; operculate, encircled by an annulus.

Pore type: Endoporus.

Exine thickness: 2.0μm.

Exine surface: Fine granulate.

Eragrostis minor (plate 32a)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (21-) 23.5 (-26)μm; equatorial length=(21-) 23.5 (-26)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.0μm, non-operculate, encircled by an annulus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Heteropogon contourtus (plate 38c)

Symmetry and form: Elliptical.

Dimensions: Polar length= (38-) 41.0 (-44)μm; equatorial length=(36-) 38.5 (-41)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.0μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Coarsely granulate.

Imperata cylindrica (plate 35d)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (27-) 32.5 (-38)μm; equatorial length=(27-) 32.5 (-38)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.5μm; operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Fine granulate.

Lolium multiflorum (plate 35e)

Symmetry and form: Elliptical.

Dimensions: Polar length= (28-) 32.5 (-37)μm; equatorial length=(27-) 31.0 (-35)μm; P/E 1.0.

Aperture type: Monoporate, circular, diameter=2.0μm, operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Fine granulate.

Oplismenus burmannii (plate 28c)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (23-) 26.5 (-30)μm; equatorial length=(22-) 25.5 (-29)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.0μm, non-operculate.

Pore type: Endoporus.

Exine thickness: 2.0μm.

Exine surface: Psilate.

Parapholis strigosa (plate 28d)

Symmetry and form: Oblate.

Dimensions: Polar length= (26-) 29.5 (-33)μm; equatorial length=(22-) 27.0 (-32)μm; P/E ratio 1.09.

Aperture type: Monoporate, circular, diameter=2.0μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Psilate.

Paspalidium flavidum (plate 28e)

Symmetry and form: Spheroidal-oblate.

Dimensions: Polar length= (25-) 28.5 (-32)μm; equatorial length=(24-) 27.0 (-30)μm; P/E ratio 1.05.

Aperture type: Monoporate, circular, diameter=2.5μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.5μm.

Exine surface: Psilate.

Paspalum dilatatum (plate 35f)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (31-) 32.5 (-34)μm; equatorial length=(31-) 32.0 (-33)μm; P/E ratio 1.01.

Aperture type: Monoporate, circular, diameter=2.0μm, operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Paspalum distichium (plate 36a)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (32-) 39.0 (-46)μm; equatorial length=(32-) 39.0 (-46)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.0μm, operculate.

Pore type: Endoporus.

Exine thickness: 2.5μm.

Exine surface: Granulate.

Pennisetum americanum (plate 36b)

Symmetry and form: Elliptical.

Dimensions: Polar length= (30-) 33.0 (-36)μm; equatorial length=(28-) 31.0 (-34)μm; P/E ratio 1.06.

Aperture type: Monoporate, circular, diameter=2.0μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Pennisetum lanatum (plate 36c)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (33-) 34.5 (-36)μm; equatorial length=(33-) 34.5 (-36)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.5μm, operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Phalaris minor (plate 36d)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (37-) 39.5 (-42)μm; equatorial length=(37-) 39.0 (-41)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.0μm, operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Phleum himalaccum (plate 36f)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (22-) 25.0 (-28)μm; equatorial length=(22-) 25.0 (-28)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=1.5μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Phleum pratense (plate 32b)

Symmetry and form: Oblate.

Dimensions: Polar length= (26-) 27.5 (-29)μm; equatorial length=(26-) 27.5 (-29)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.0μm, non-operculate.

Pore type: Endoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Phragmites australis (plate 36e)

Symmetry and form: Elliptical.

Dimensions: Polar length= (35-) 39.0 (-43)μm; equatorial length=(33-) 37.0 (-41)μm; P/E ratio 1.05.

Aperture type: Monoporate, circular, diameter=2.5μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Poa annua (plate 32c)

Symmetry and form: Elliptcal.

Dimensions: Polar length= (27-) 29.0 (-31)μm; equatorial length=(26-) 28.5 (-31)μm; P/E ratio 1.01.

Aperture type: Monoporate, circular, diameter=2.5μm, operculate.

Pore type: Endoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Poa infirma (plate 32d)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (22-) 25.0 (-28)μm; equatorial length=(22-) 25.0 (-28)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.0μm, operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Poa nemoralis (plate 32e)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (20-) 22.5 (-25)μm; equatorial length=(20-) 22.0 (-24)μm; P/E ratio 1.01.

Aperture type: Monoporate, circular, diameter=2.0μm, operculate.

Pore type: Endoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Polypogon monspeliensis (plate 28f)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (26-) 28.0 (-30)μm; equatorial length=(26-) 28.0 (-30)μm; P/E ratio 1.0.

Aperture type: Monoporate, circular, diameter=2.0μm, operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Scabrate.

Saccharum spontaneum (plate 37a)

Symmetry and form: Oblate.

Dimensions: Polar length= (27-) 31.5 (-36)μm;equatorial length=(26-) 29.5 (-36)μm; P/E ratio 1.06.

Aperture type: Monoporate, circular, diameter=2.5μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Fine Granulate.

Setaria glauca (plate 38d)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (35-) 38.5 (-42)μm; equatorial length=(35-) 38.0 (-40)μm; P/E ratio 1.01.

Aperture type: Monoporate, circular, diameter=2.0μm, operculate.

Pore type: Endoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Setaria pumila (plate 38e)

Symmetry and form: Oblate.

Dimensions: Polar length= (40-) 44.5 (-49)μm; equatorial length=(40-) 44.5 (-49)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.5μm, operculate.

Pore type: Endoporus.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Sorghum halepense (plate 38f)

Symmetry and form: Oblate.

Dimensions: Polar length= (39-) 61.0 (-82)μm; equatorial length=(36-) 56.44 (-80)μm; P/E ratio 1.07.

Aperture type: Monoporate, circular, diameter=2.5μm, non-operculate.

Pore type: Ectoporus.

Exine thickness: 2.0μm.

Exine surface: Fine granulate.

Stipa splendens (plate 23f)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (25-) 29..5(-34)μm; equatorial length=(25-) 29.5 (-34)μm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.5μm, non-operculate.

Exine thickness: 2.0μm.

Exine surface: Granulate.

Urochloa panicoides (plate 33a)

Symmetry and form: Spheroidal.

Dimensions: Polar length= (25-) 26.5 (-28)mm; equatorial length=(25-) 26.5 (-28)mm; P/E ratio 1.00.

Aperture type: Monoporate, circular, diameter=2.0mm, operculate.

Pore type: Endoporus.

Exine thickness: 2.0mm.

Exine surface: Granulate.

Vetivera zizanoides (plate 33b)

Symmetry and form: Oblate.

Dimensions: Polar length= (24-) 26.0 (-28)mm; equatorial length=(24-) 25.0 (-26)mm; P/E ratio 1.04.

Aperture type: Monoporate, circular, diameter=2.0mm, operculate.

Pore type: Endoporus.

Exine thickness: 2.0mm.

Exine surface: Granulate.

Plates
Light Microscope Micrographs

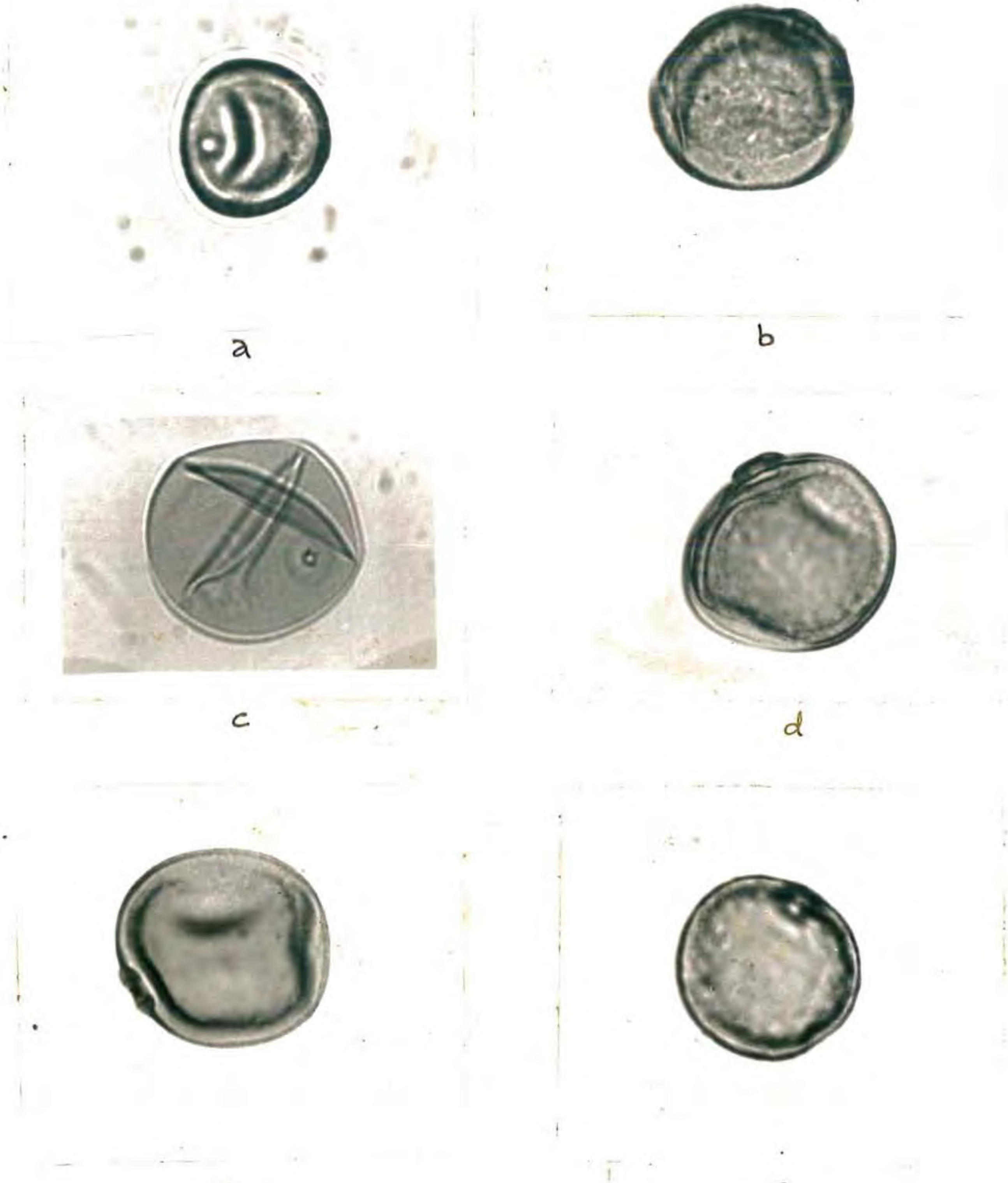


Plate 28. (x 1000) Light microscope micrographs of psilate small size pollen grains of grass species (a) *Cynodon dactylon* (b) *Digitaria biformis* (c) *Oplismenus burmannii* (d) *Parapholis strigosa* (e) *Paspalidium flavidium* (f) *Polypogon monspeliensis*.

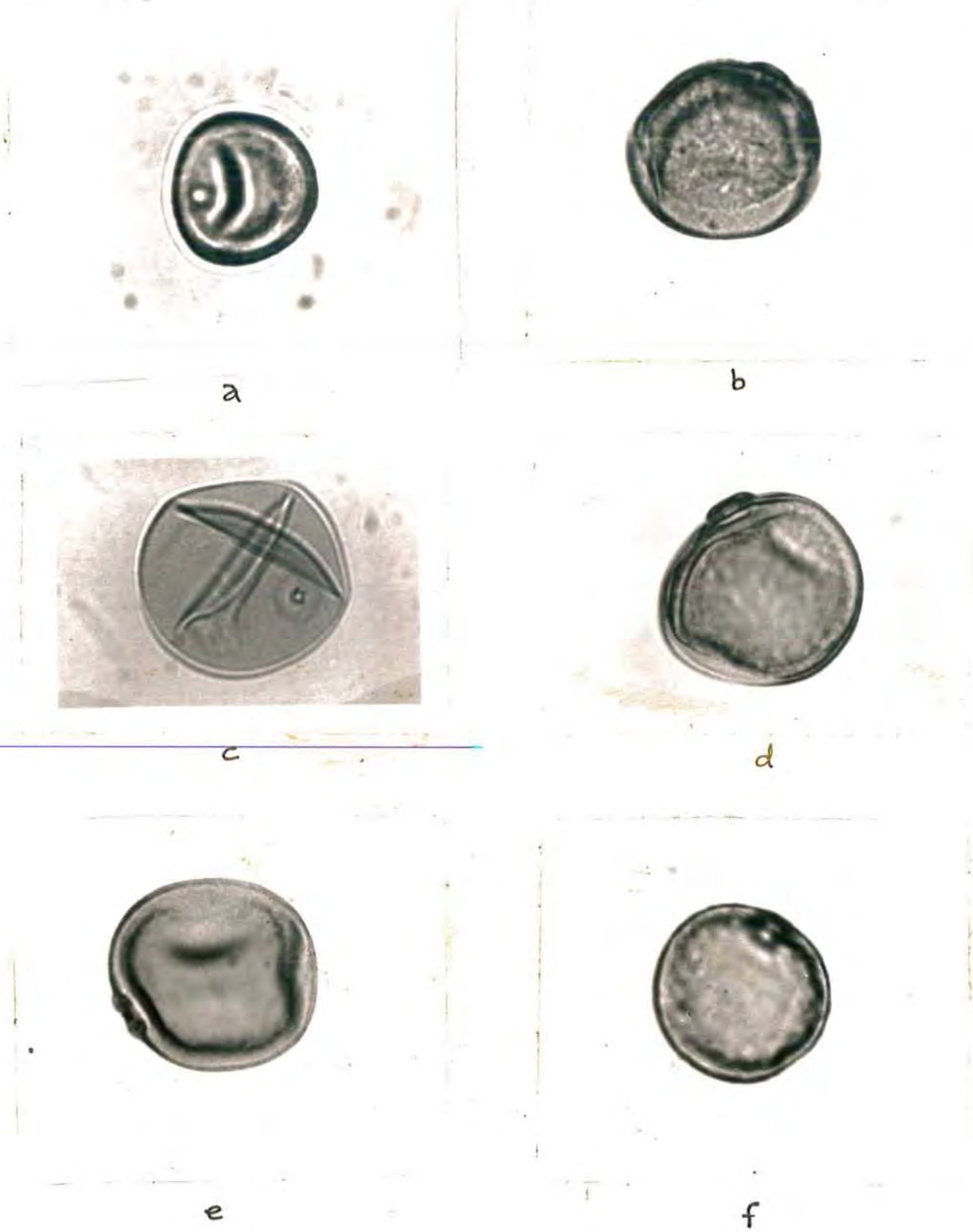


Plate 28. (x 1000) Light microscope micrographs of psilate small size pollen grains of grass species (a) *Cynodon dactylon* (b) *Digitaria biformis* (c) *Oplismenus burmannii* (d) *Parapholis strigosa* (e) *Paspalidium flavidium* (f) *Polypogon monspeliensis*.

a

b

c

Plate 29. (x 1000) Light microscope micrographs of psilate medium size pollen grains of grass species (a) *Cenchrus penisctiformis* (b) *Dicanthium annulatum* (c) *Digitaria nodosa*

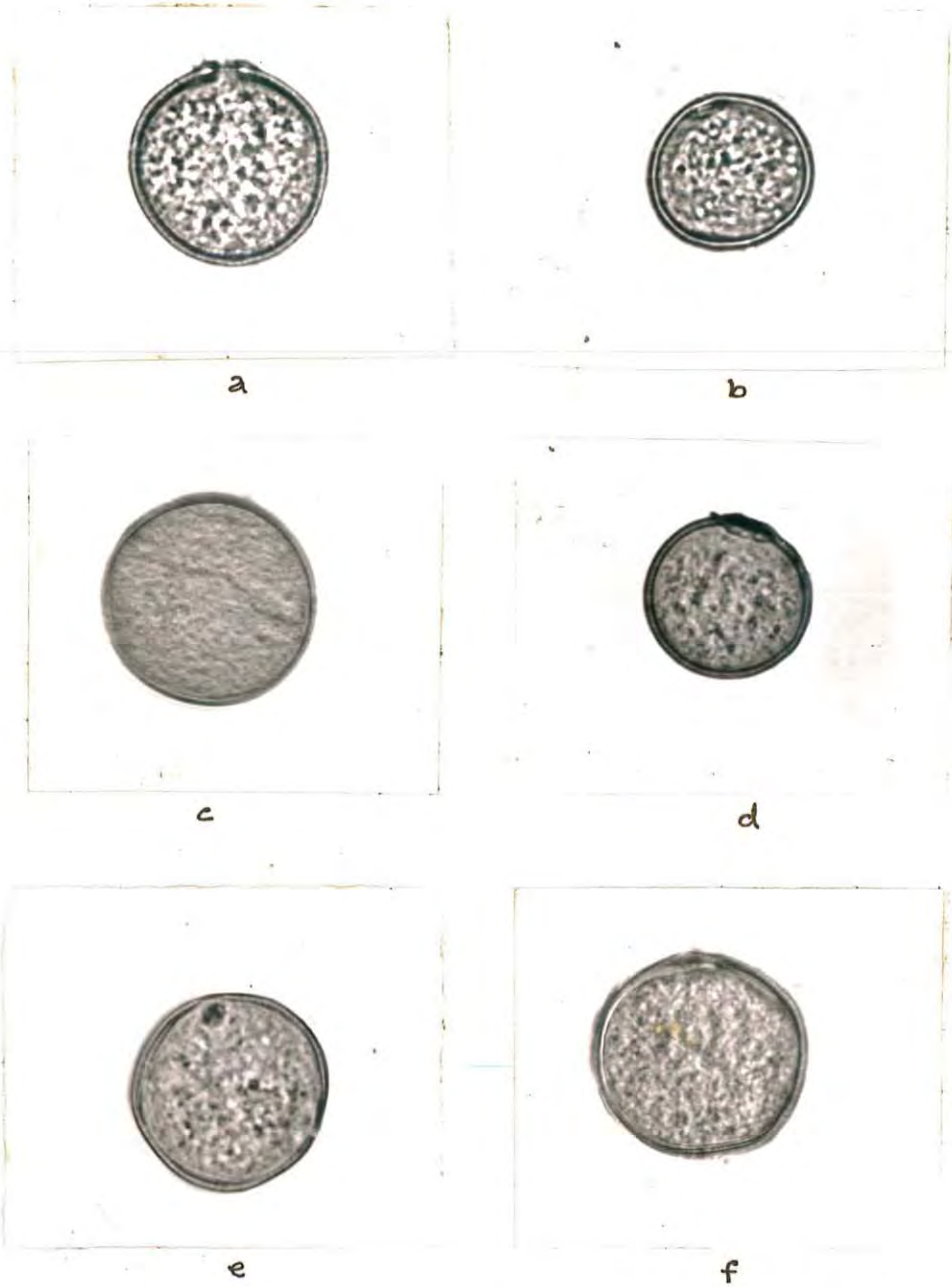


Plate 30. (x 1000) Light microscope micrographs of granulate small size pollen grains of grass species (a) *Alopecurus myosuroides* (b) *Aristida funiculata* (c) *Aristida adscensionis* (d) *Brachiaria distachya* (e) *Brachiaria eruciformis* (f) *Bothriochloa pertusa.*

Plate 31. (x 1000) Light microscope micrographs of granulate small size pollen grains of grass species (a) *Bromus japonicus* (b) *Bromus pectinatus* (c) *Desmostachya bipinnata* (d) *Digitaria sanguinalis* (e) *Echinochloa colonum* (f) *Eleusine indica.*

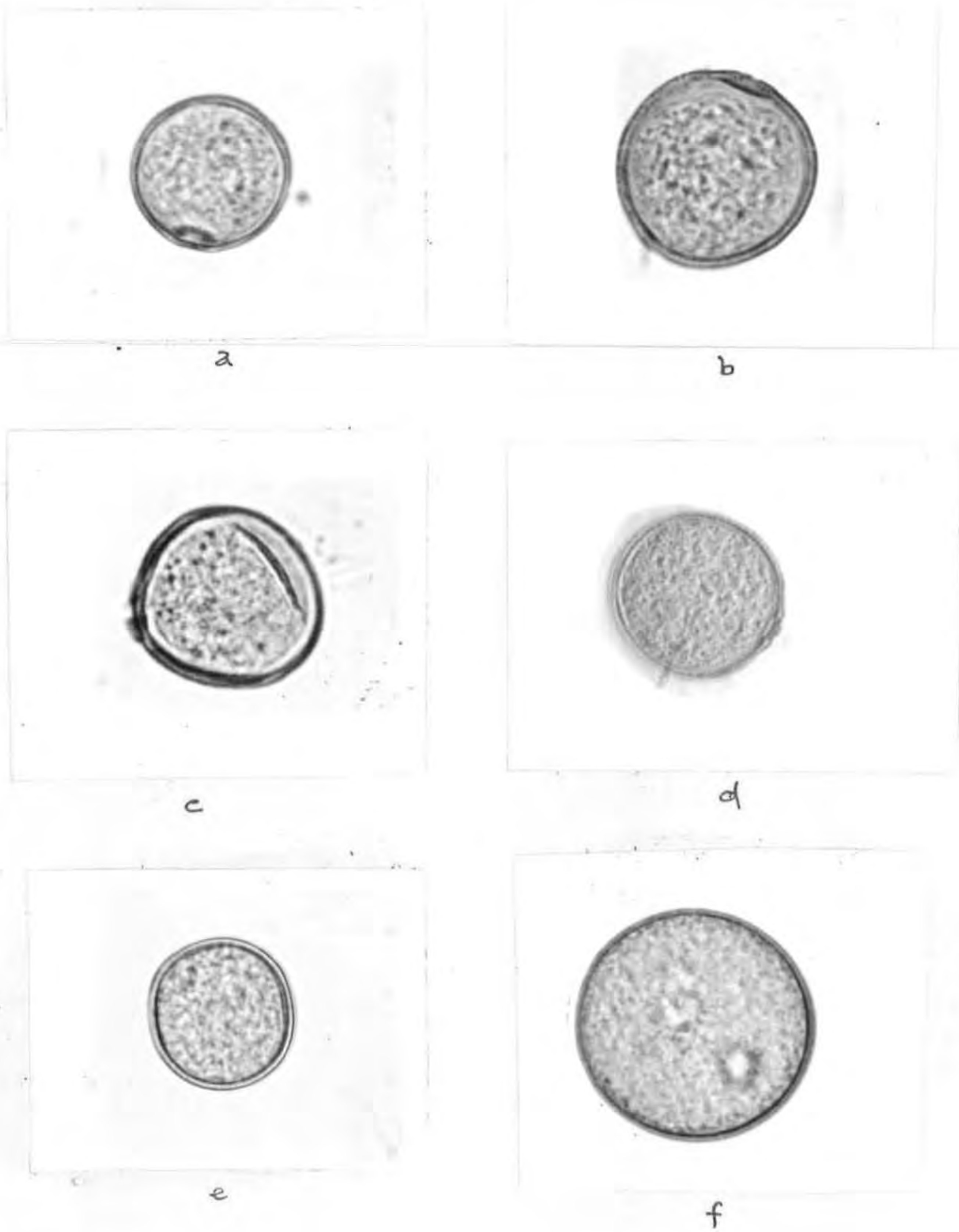


Plate 32. (x 1000) Light microscope micrographs of granulate small size pollen grains of grass species (a) *Eragrostis minor* (b) *Phleum pratense* (c) *Poa annua* (d) *Poa infirma* (e) *Poa nemoralis* (f) *Stipa splendens.*

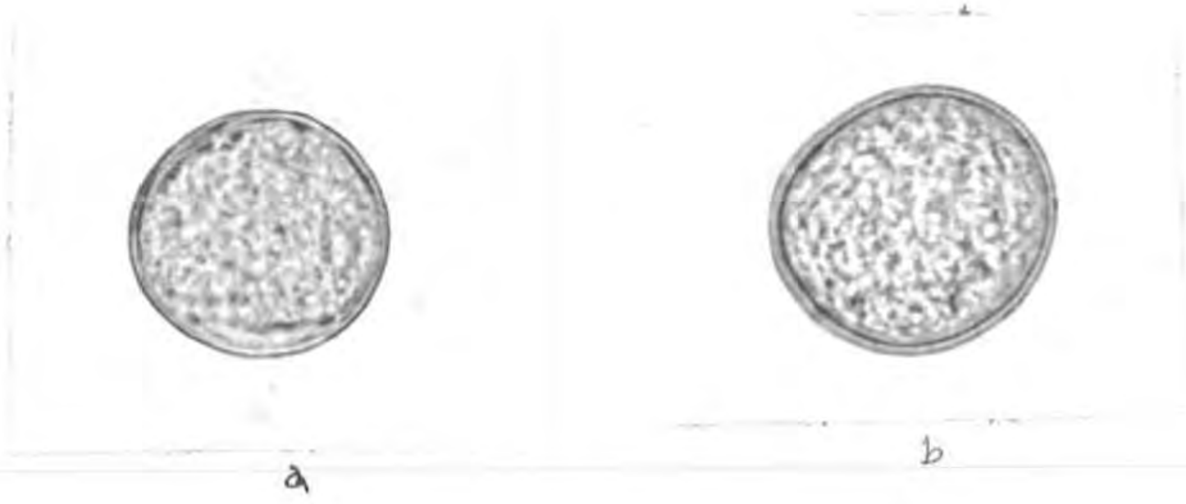


Plate 33. (x 1000) Light microscope micrographs of granulate small size pollen grains of grass species (a) *Urochloa panicoides* (b) *Vetiveria zizanoides*.

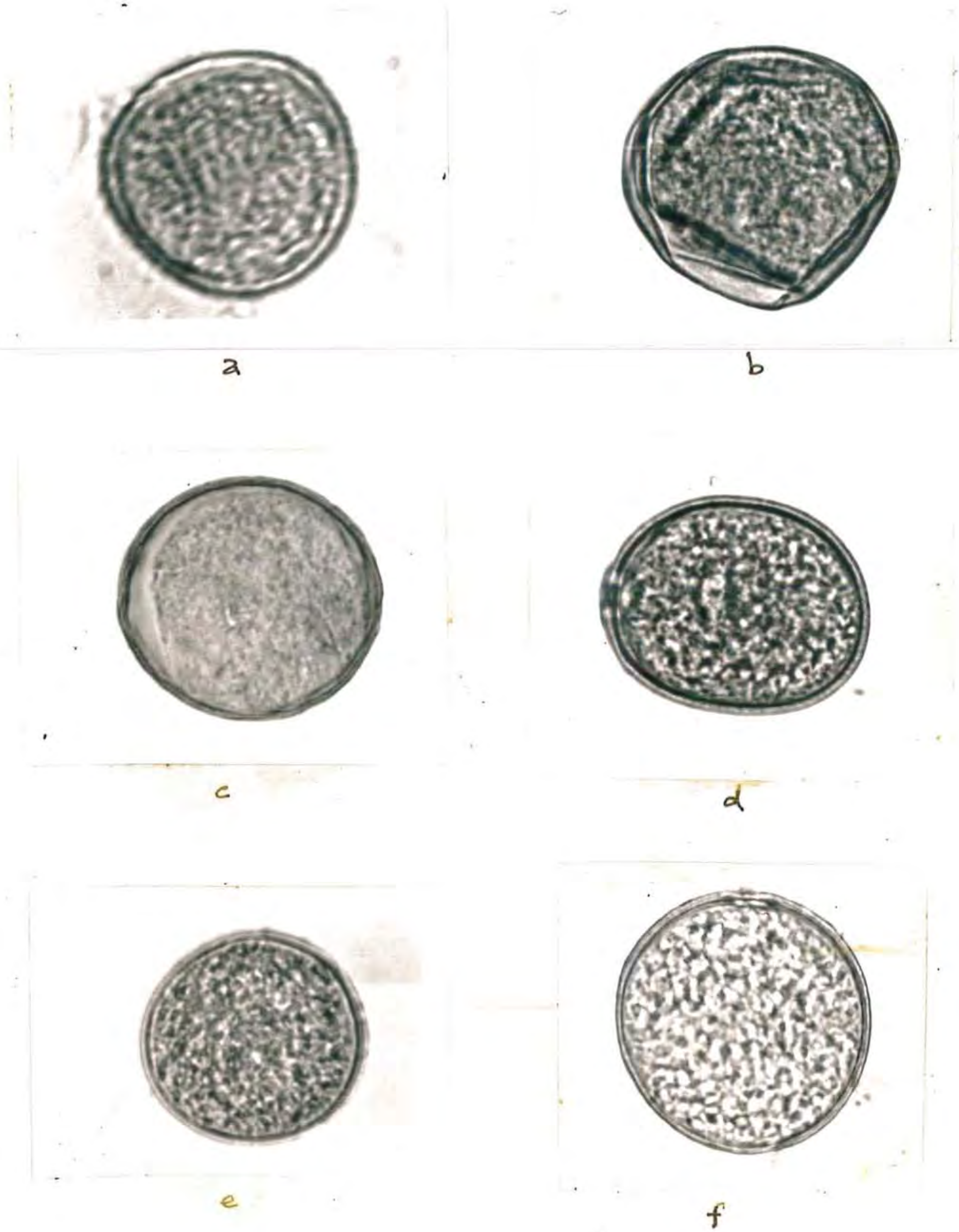


Plate 34. (x 1000) Light microscope micrographs of granulate medium size pollen grains of grass species (a) *Bromus catherticus* (b) *Bromus danthoniae* (c) *Brachypodium distachyon* (d) *Chrysopogon aucheri* (e) *Cymbopogon flexuosus* (f) *Cymbopogon schoenanthus*.

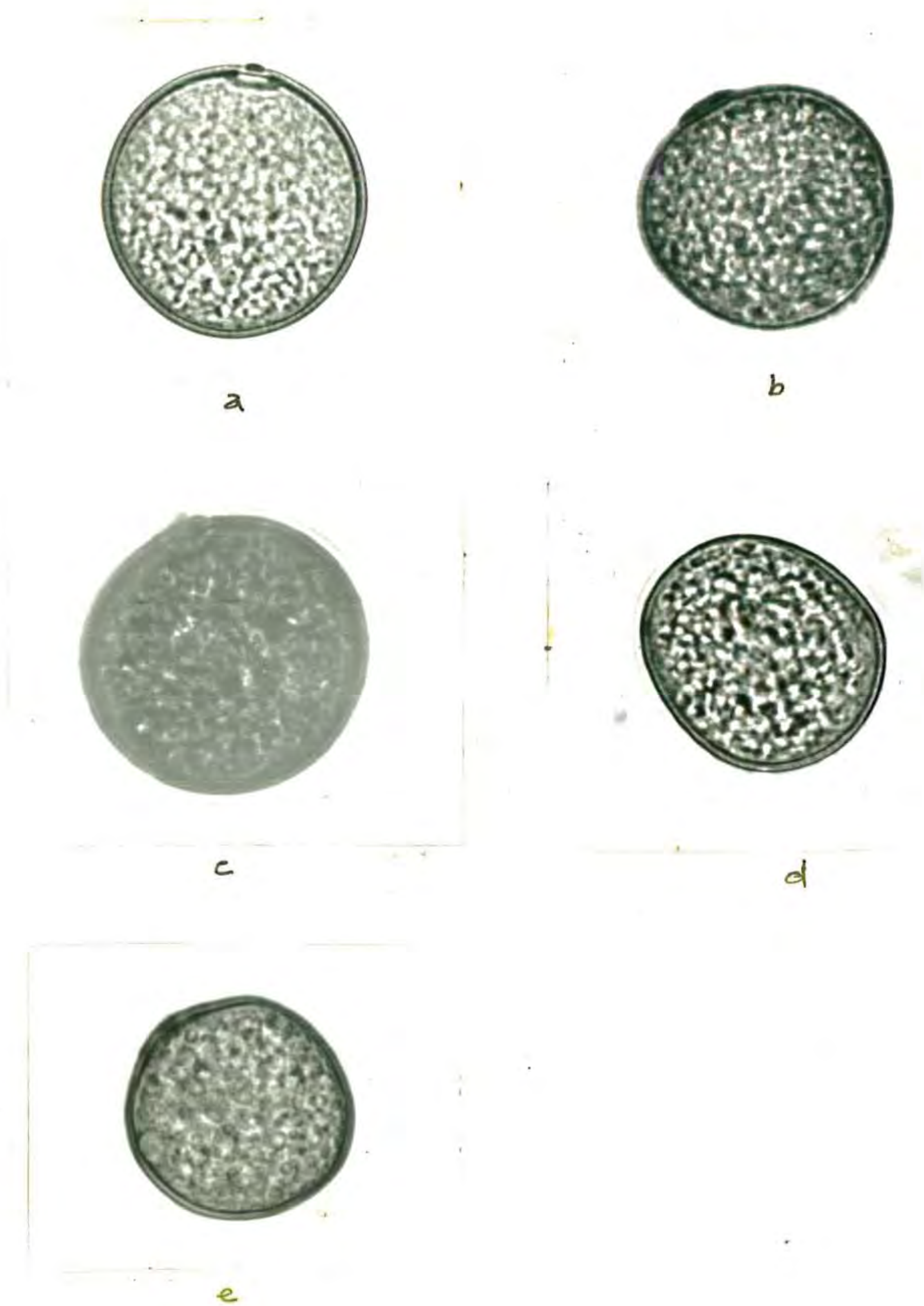


Plate 35. (x 1000) Light microscope micrographs of granulate medium size pollen grains of grass species (a) *Dactyloctenum aegyptium* (b) *Dicanthium foveolatum* (c) *Echinochloa crus-galli* (d) *Lolium multiflorum* (e) *Paspalum dilatatum.*

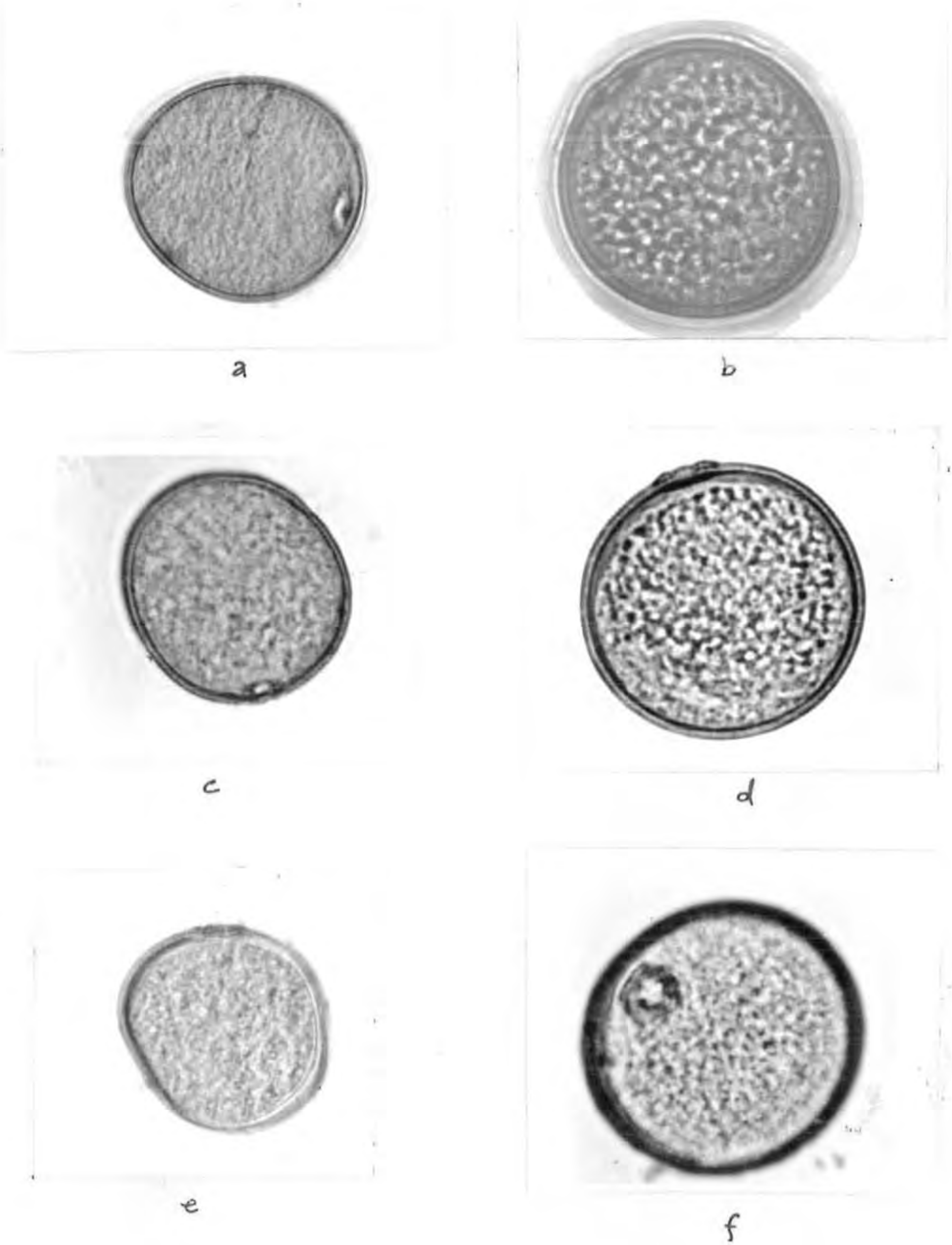


Plate 36. (x 1000) Light microscope micrographs of granulate medium size pollen grains of grass species (a) *Paspalum distichium* (b) *Pennisetum americanum* (c) *Pennisetum lanatum* (d) *Phalaris minor* (e) *Phragmites australis* (f) *Phleum himalaccum*.

a

Plate 37. (x 1000) Light microscope micrographs of granulate medium size pollen grains of grass species (a) *Saccharum spontaneum*.

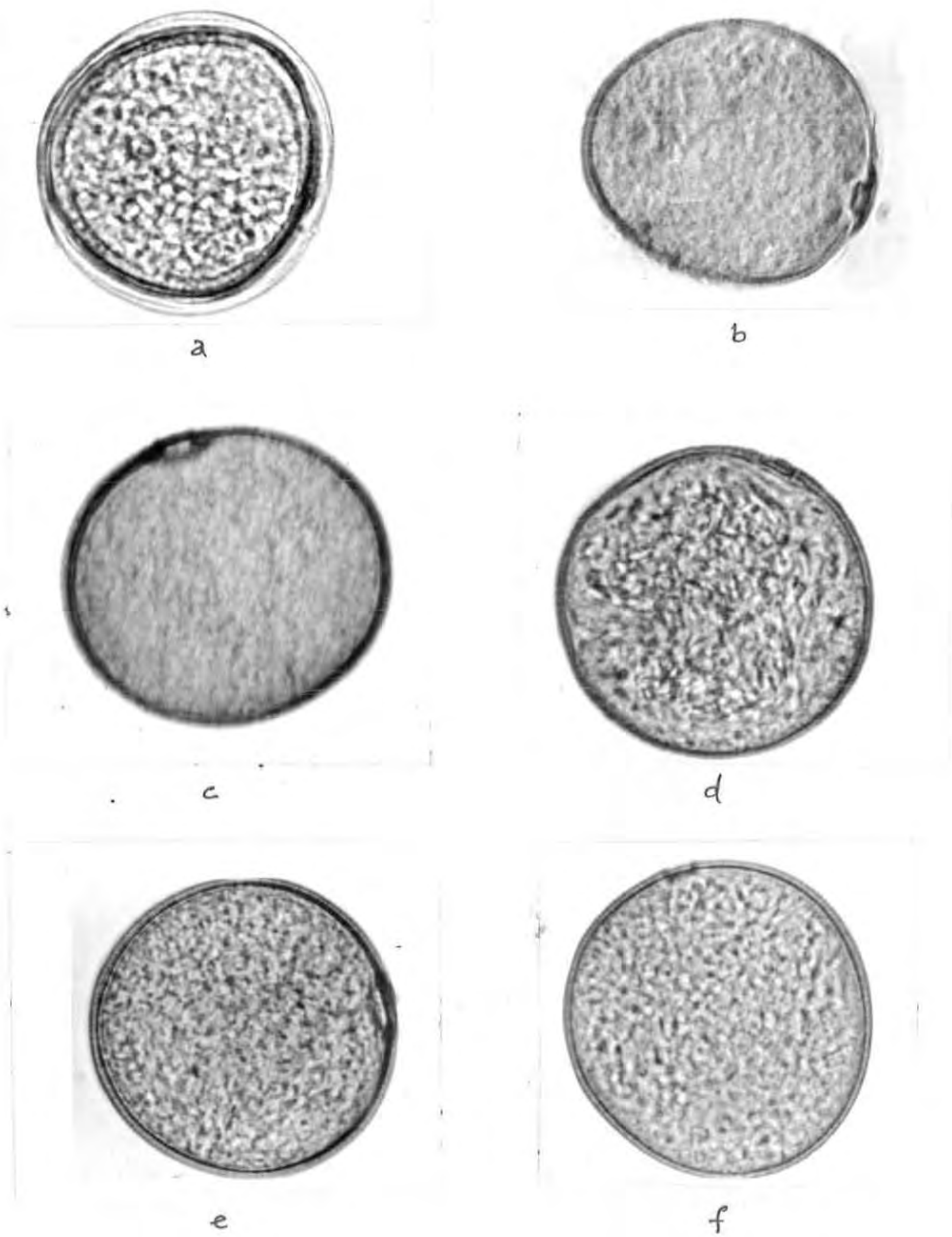


Plate 38. (x 1000) Light microscope micrographs of granulate large size pollen grains of grass species (a) *Avena ludoviciana* (b) *Avena sativa* (c) *Heteropogon contourtus* (d) *Setaria glauca* (e) *Setaria pumila* (f) *Sorghum halepense*.

4.3. Scanning Electron Microscopic Analysis of Pollen Grain Surface.

Scanning electron microscopic analysis of pollen grain surface is very useful for elucidation of exine sculpturing features which could be used to solve taxonomical problems.

Sculpturing of the pollen grain exine surface of the grasses studied is generally granulate scabrate, verrucate, rugulate, micro verrucate or psilate. Scanning Electron Microscope analysis of pollen grains surfaces examined is given in table 7. The micrograph of each species is shown plate Nos. 39-55. The salient surface details of the apertural and apertural regions of 37 genera and 54 species of grasses are presented.

Alopecurus myosuroides (plate 39c)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.66mm width.

Exine ornamentation: Scabrate (coarse granulate), scabrae separate and closely spaced.

Pollen group: Granulate (Coarse granulate)

Aristida adscensionis (plate 39 a,b)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 0.8mm width.

Exine ornamentation: Verrucate, verrucae separate and closely spaced.

Pollen group: Fine granulate

Aristida funiculata (plate 54a)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 0.6 mm width. .

Exine ornamentation: Rugulate, spinules widely spaced.

Pollen group: Rugulate (widely spaced).

Avena ludoviciana (plate 48a)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 2.25mm width.

Exine ornamentation: Granulate, granules separate and mediumly spaced.

Pollen group: Coarse granulate

Avena sativa (plate 48b)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.78mm width.

Exine ornamentation: Granulate, granules separate mediumly spaced.

Pollen group: Fine granulate.

Bothriochloa pertusa (plate 40b)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 0.8mm width.

Exine ornamentation: Granulate, granules separate closely spaced.

Pollen group: Coarse-granulate.

Brachiaria distachya (plate 39d)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.42mm width.

Exine ornamentation: Verrucate, verrucae separate and closely spaced.

Pollen group: Verrucate (fine granulate).

Brachiaria eruciformis (plate 40c)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.0 mm width.

Exine ornamentation: Verrucate, verrucae separate and overlapping.

Pollen group: Verrucate (Coarse granulate).

Brachypodium distachyon (plate 48c)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 2.27m m width.

Exine ornamentation: Granulate, granules separate mediumly spaced.

Pollen group: Coarse granulate.

Bromus catherticus (plate 40d)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 0.8mm width.

Exine ornamentation: Granulate, granules separate closely spaced.

Pollen group: Fine granulate.

Bromus japonicus (plate 41a)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 1.57m m width.

Exine ornamentation: Verrucate, verrucae separate and closely spaced.

Pollen group: Fine granulate.

Bromus pectinatus (plate 41b)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 1.76mm width.

Exine ornamentation: Scabrate (coarse-granulate) scabrae separate and closely spaced.

Pollen group: Scabrate (coarse granulate).

Bromus danthoniae (plate 54b,c)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 1.33m m width.

Exine ornamentation: Granulate, granules separate widely spaced.

Pollen group: Fine granulate.

Cenchrus penisctiformis (plate 41c)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 2.22mm width.

Exine ornamentation: Verrucate, verrucae separate and closely spaced.

Pollen group: Verrucate (coarse granulate).

Chrysopogon aucheri (plate 42a)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 0.8 mm width.

Exine ornamentation: Granulate, granules separate closely spaced.

Pollen group: Fine granulate.

***Cymbopogon flexuosus* (plate 54d)**

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 1.42m m width.

Exine ornamentation: Verrucate, verrucae separate and widely spaced.

Pollen group: Verrucate (coarse granulate).

***Cymbopogon schoenanthus* (plate 49a,b)**

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 2mm width.

Exine ornamentation: Verrucate, verrucae separate and mediumly spaced.

Pollen group: Verrucate (coarse granulate).

***Cynodon dactylon* (plate 41d)**

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 2.5 mm width.

Exine ornamentation: Verrucate, verrucae separate and colsely spaced.

Pollen group: Verrucate (coarse granulate).

***Dactyloctenium aegyptium* (plate 42b)**

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 3mm width.

Exine ornamentation: Scabrate, scabrae separate and closely placed.

Pollen group: Scabrate (coarse granulate).

***Desmostachya bipinnata* (plate 42c)**

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 1.02mm width.

Exine ornamentation: Verrucate, verrucae separate and closely placed.

Pollen group: Verrucate (coarse granulate).

***Dicanthium annulatum* (plate 43a)**

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.17mm width.

Exine ornamentation: Scabrate, scabrae separate and closely placed.

Pollen group: Scabrate (coarse granulate).

Dicanthium foveolatum (plate 42d)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 1.7mm width.

Exine ornamentation: Scabrate, scabrae separate and closely placed.

Pollen group: Scabrate (coarse granulate).

Digitaria biformis (plate 48d)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.30mm width.

Exine ornamentation: Granulate, granules separate widely spaced.

Pollen group: Granulate (coarse granulate).

Digitaria nodosa (plate 49c)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 1.42mm width.

Exine ornamentation: Granulate, granules separate and mediumly spaced.

Pollen group: Verrucate (coarse granulate).

Digitaria sanguinalis (49d)

Apertural region: Non-operculate, endoaperture, ± circular, encircled by an annulus of 2.0mm width.

Exine ornamentation: Granulate, granules separate mediumly spaced.

Pollen group: Fine granulate.

Echinochloa crus-galli (plate 43c)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 1.53mm width.

Exine ornamentation: Granulate, granules separate and closely spaced.

Pollen group: Scabrate (coarse granulate).

Echinochloa Colonum (43b)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.17mm width.

Exine ornamentation: Scabrate, scabrae separate and closely spaced.

Pollen group: Scabrate (coarse granulate).

Eleusine indica (plate 50a)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 0.86mm width.

Exine ornamentation: Verrucate, verrucae separate and mediumly spaced.

Pollen group: Fine granulate.

Eragrostis minor (plate 50b)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 2.66mm width.

Exine ornamentation: Scabrate, scabrae separate mediumly spaced.

Pollen group: Scabrate (fine granulate).

Heteropogon contourtus (50c,d)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 2.99mm width.

Exine ornamentation: Scabrate, scabrae separate mediumly spaced.

Pollen group: Scabrate (fine granulate).

Imperata cylindrica (plate 51a,b)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.6 mm width.

Exine ornamentation: Granulate, granules separate mediumly spaced.

Pollen group: Fine granulate.

Lolium multiflorum (plate 51c)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 1.76mm width.

Exine ornamentation: Granulate, granules separate mediumly spaced.

Pollen group: Fine granulate.

Oplismenus burmannii (plate 43d)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 2.63mm width.

Exine ornamentation: Verrucate, verrucae separate closely spaced.

Pollen group: Verrucate (coarse granulate).

Parapholis strigosa (plate 55a,b)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 1.33mm width.

Exine ornamentation: Granulate, granules separate widely spaced.

Pollen group: Fine granulate.

Paspalidium flavidum (plate 44a)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.53mm width.

Exine ornamentation: Scabrate, scabrae separate and closely spaced.

Pollen group: Scabrate (coarse granulate).

Paspalum dilatatum (plate 44b)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.56mm width.

Exine ornamentation: Verrucate, verrucae separate and closely spaced.

Pollen group: Verrucate.

Paspalum distichium (plate 51d)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 1.5mm width.

Exine ornamentation: Granulate, granules separate mediumly spaced.

Pollen group: Fine granulate.

Pennisetum americancum (plate 52a,b)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.99mm width.

Exine ornamentation: Scabrate, scabrae separate mediumly spaced.

Pollen group: Scabrate (coarse granulate).

Pennisetum lanatum (plate 44c)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.66mm width.

Exine ornamentation: Scabrate, scabrae separate and closely spaced.

Pollen group: Scabrate (coarse granulate).

Phalaris minor (plate 44d)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 2.28mm width.

Exine ornamentation: Granulate, granules separate mediumly spaced.

Pollen group: Fine granulate.

Phleum himalaccum (plate 52c,d)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 2.99mm width.

Exine ornamentation: Verrucate, verrucae separate and mediumly spaced.

Pollen group: Verrucate (coarse granulate).

Phleum pratense (plate 45a)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 1.87mm width.

Exine ornamentation: Verrucate, verrucae separate and closely spaced.

Pollen group: Verrucate (course granulate).

Phragmites australis (plate 53b)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 1.6mm width.

Exine ornamentation: Verrucate, verrucae separate and mediumly spaced.

Pollen group: Verrucate (coarse granulate).

Poa annua (plate 45b)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 1.30mm width.

Exine ornamentation: Verrucate, verrucae separate and closely spaced.

Pollen group: Verrucate (coarse granulate).

Poa infirma (plate 45c)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 0.92m m width.

Exine ornamentation: Verrucate, verrucae separate and closely spaced.

Pollen group: Verrucate (coarse granulate).

Poa nemoralis (plate 45b)

Apertural region: Non-operculate, endoaperture, ± circular, encircled by an annulus of 1.66mm width.

Exine ornamentation: Verrucate, verrucae separate and closely spaced.

Pollen group: Verrucate (coarse granulate).

Polypogon monspeliensis (plate 46a)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 2.35m m width.

Exine ornamentation: Scabrate, scabrae separate and closely spaced.

Pollen group: Scabrate (coarse-granulate).

Saccharum spontaneum (plate 46b)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.33mm width.

Exine ornamentation: Granulate, granules separate closely spaced in patches.

Pollen group: Fine granulate.

Setaria glauca (plate 46c)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 2.0mm width.

Exine ornamentation: Granulate, granules separate mediumly spaced in patches.

Pollen group: Fine granulate.

Setaria pumila (plate 46d)

Apertural region: Operculate, endoaperture, ± circular, encircled by an annulus of 1.66m m width.

Exine ornamentation: Verrucate, verrucae separate and closely spaced.

Pollen group: Verrucate coarse granulate).

Sorghum halepense (plate 43b,c)

Apertural region: Non-operculate, ectoaperture, ± circular, encircled by an annulus of 1.5 mm width.

Exine ornamentation: Granulate, granules separate closely spaced in patches.

Pollen group: Fine granulate.

Stipa splendens (plate 47a)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 2.10mm width.

Exine ornamentation: Granulate, granules separate closely spaced in patches.

Pollen group: Fine granulate.

Urochloa panicoides (plate 47b)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 2.00mm width.

Exine ornamentation: Granulate, granules separate and closely spaced.

Pollen group: Fine granulate.

Vetiveria zizanoides (plate 55c,d)

Apertural region: Operculate, ectoaperture, ± circular, encircled by an annulus of 1.52mm width.

Exine ornamentation: Granulate, granules separate widely spaced.

Pollen group: Fine granulate.

Plates
(Scanning Electron Microscope Micrographs)

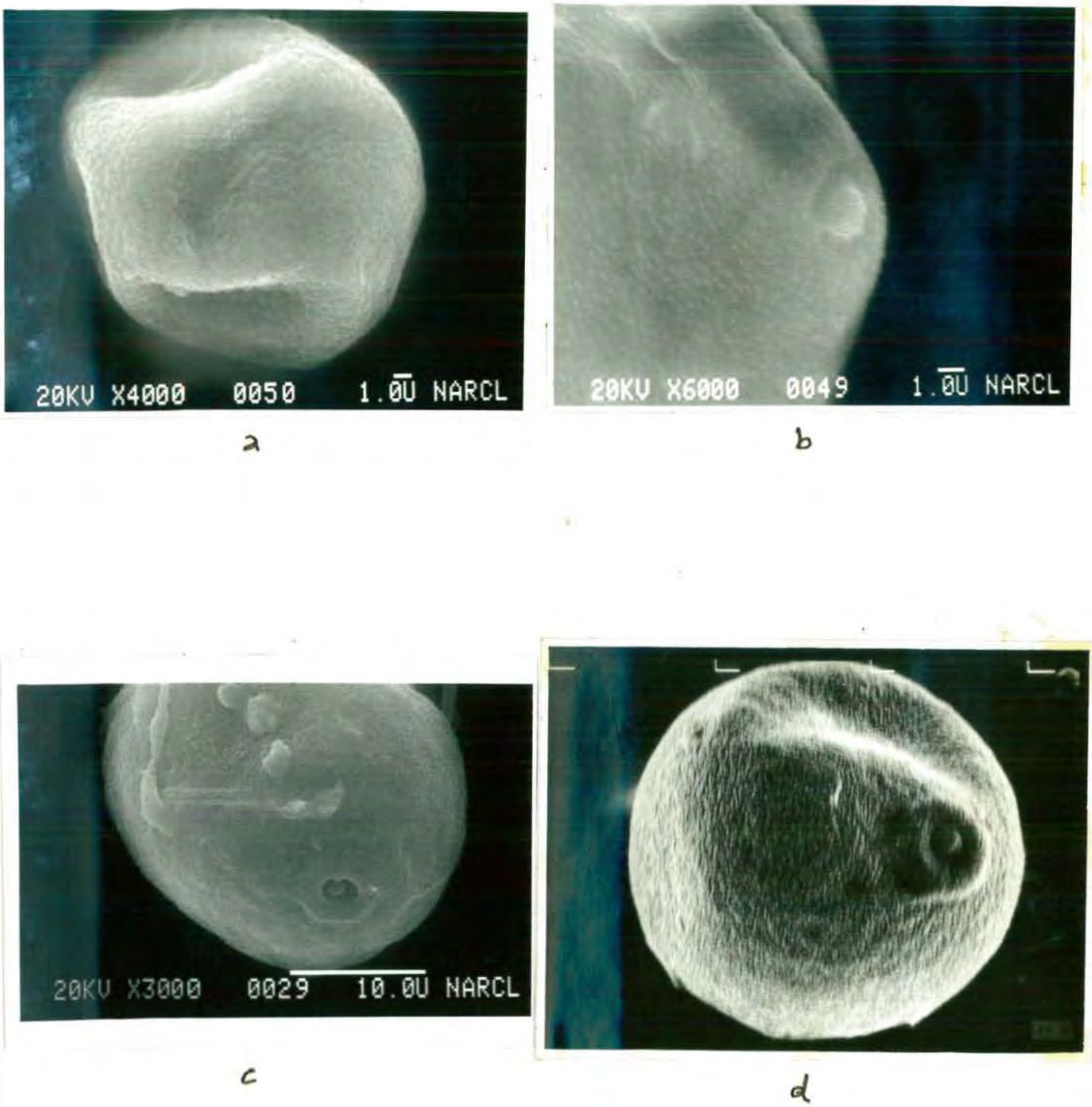


Plate 39. Scanning electron micrographs of unacetolysed grass pollens (a) *Aristida adscensionis* x 4000 (b) *Aristida adscensionis* pollen surface x 6000 (c) *Alopecurus myosuroides* x 3000 (d) *Brachiaria distachya* x 3500. (scale: a, b, bar=1.0μm)

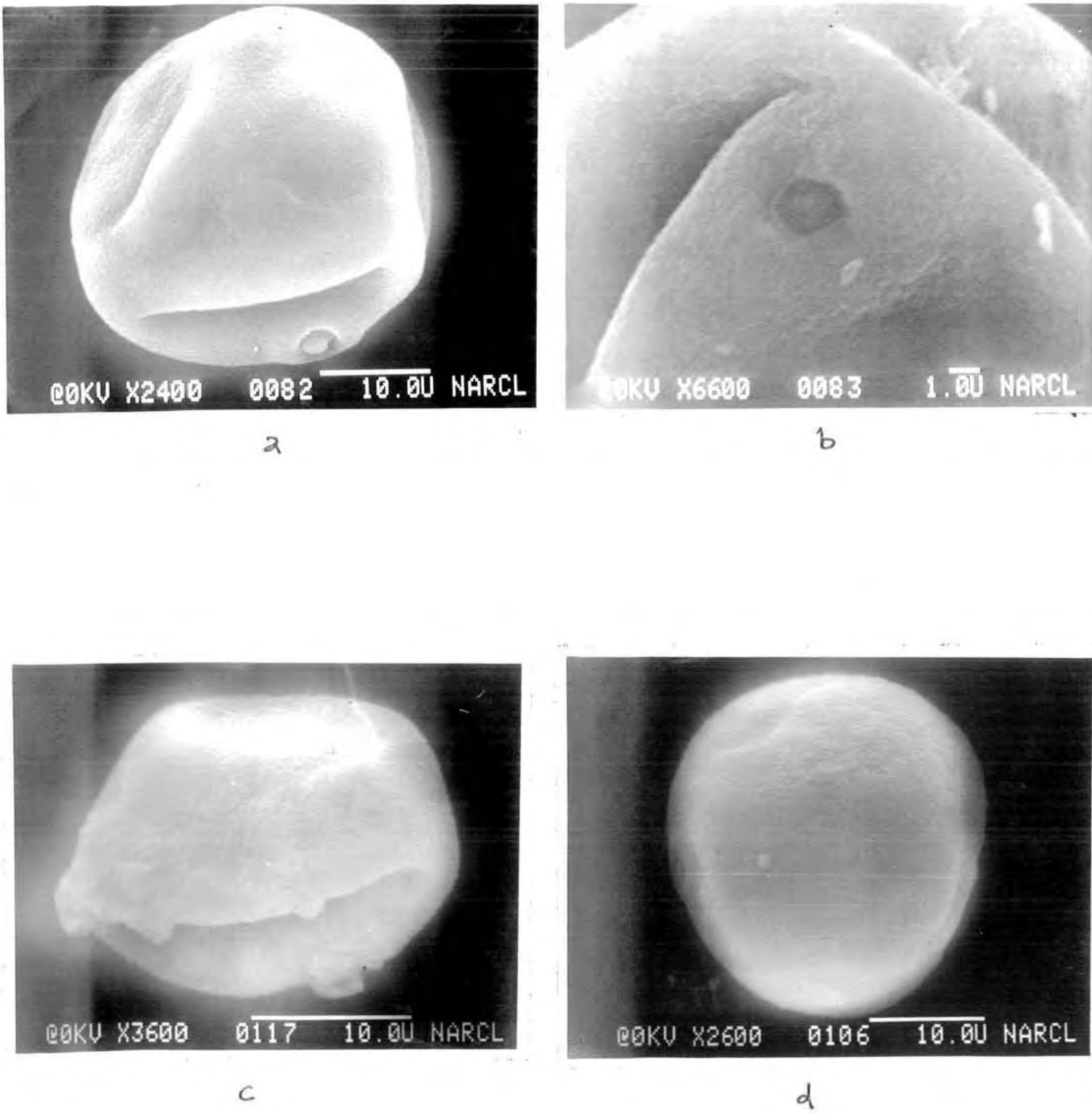


Plate 40. Scanning electron micrographs of unacetolysed grass pollens (a) *Bothriochloa pertusa* x 2400 (b) *Bothriochloa pertusa* surface x 6600 (c) *Brachiaria eruciformis* x 3600 (d) *Bromus catherticus* x 2600 (scale: a, c, d, bar=10.0mm, b, bar=1.0mm)

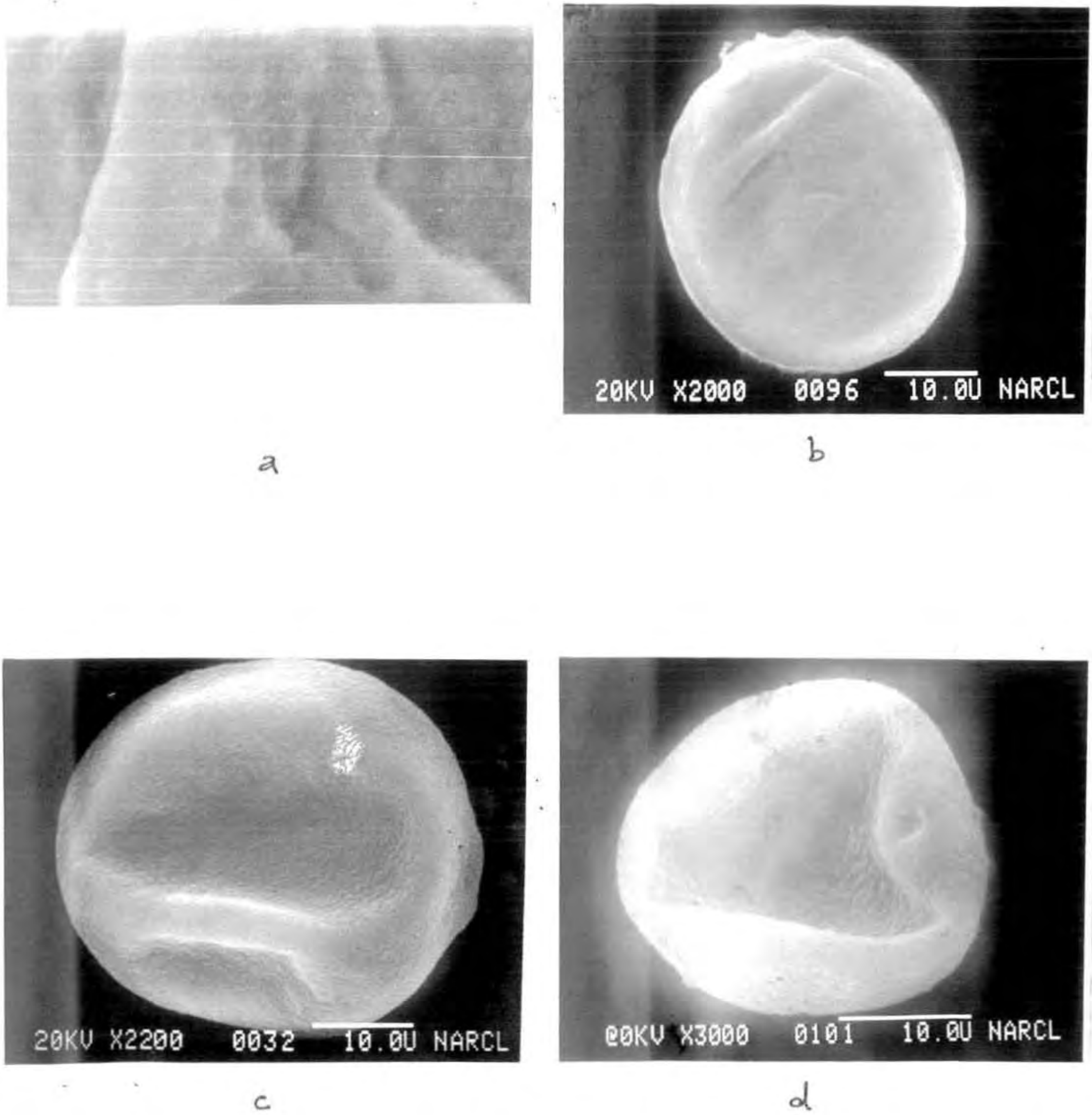


Plate 41. Scanning electron micrographs of unacetolysed grass pollens (a) *Bromus japonicus x 2400* (b) *Bromus pectinatus* x 2000 (c) *Cenchrus penisctiformis* x 2200 (d) *Cynodon dactylon* x 3000 (scale: b, c, d, bar=10.0μm)

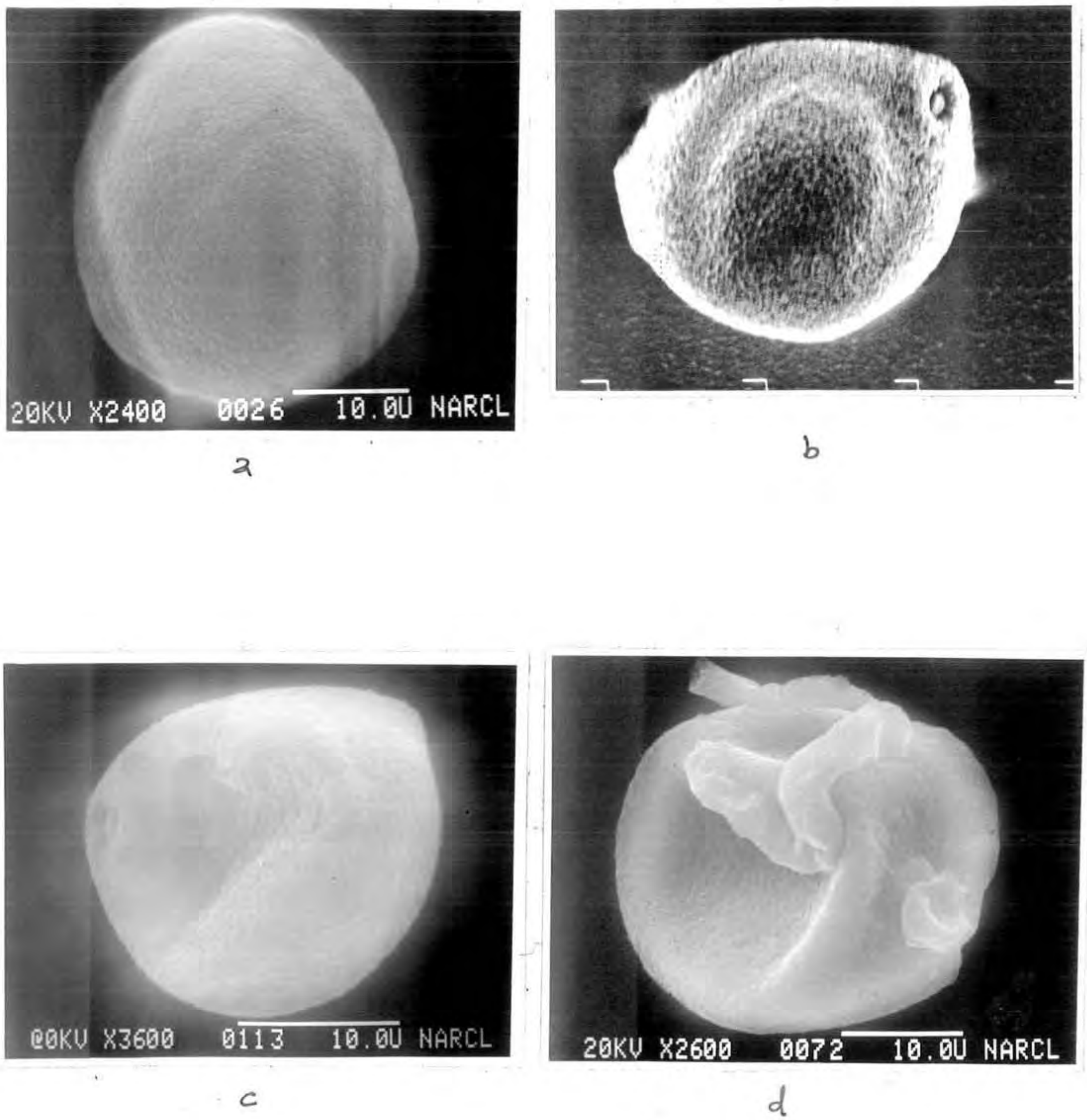


Plate 42. Scanning electron micrographs of unacetolysed grass pollens (a) *Chrysopogon aucheri* x 2400 (b) *Dactyloctenium aegyptium* x 3500 (c) *Desmostachya bipinnata* x 3600 (d) *Dicanthium foveolatum* x 2600 (scale: a, c, d, bar=10.0μm)

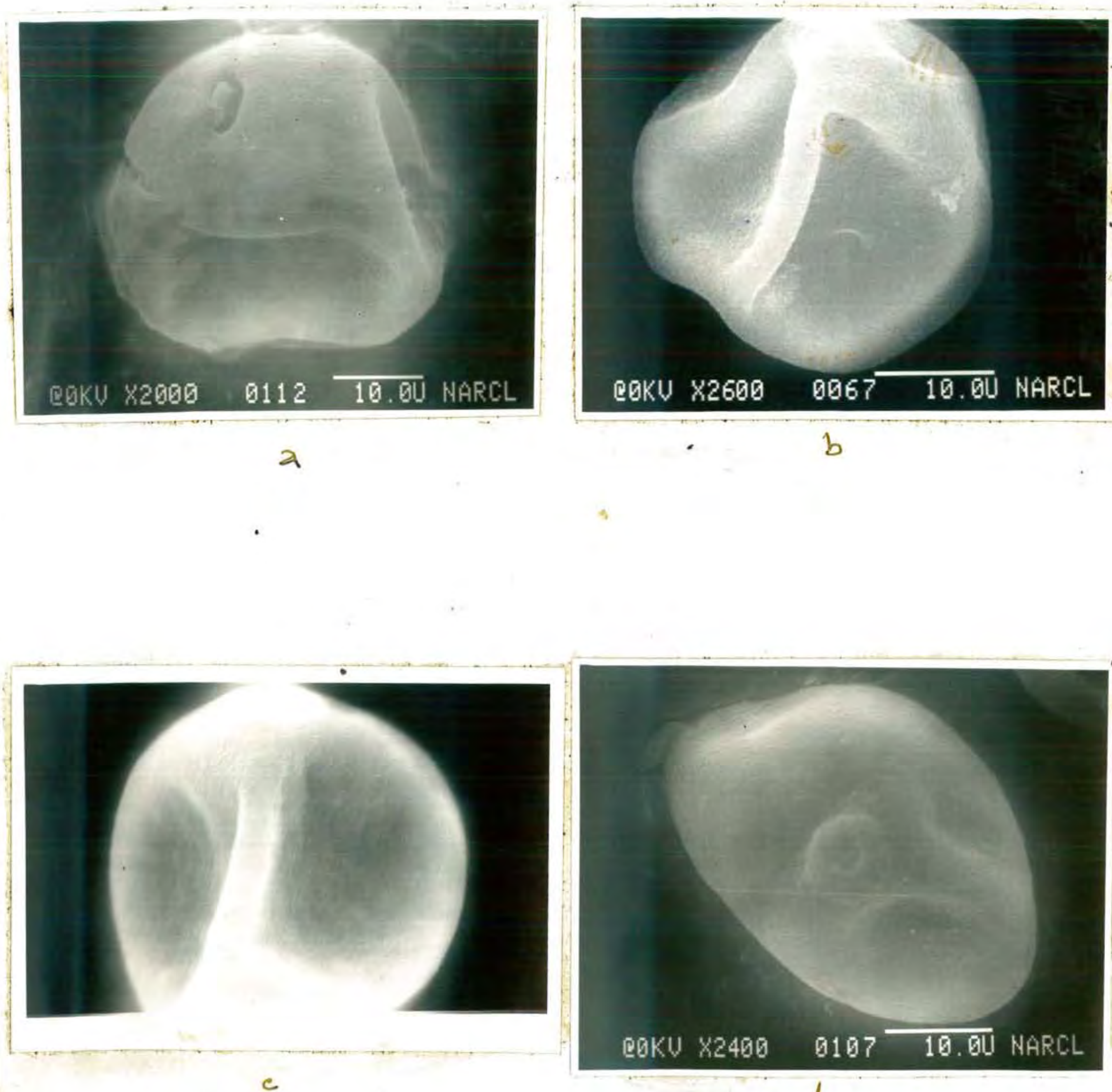


Plate 43. Scanning electron micrographs of unacetolysed grass pollens (a) *Dicanthium annulatum* x 2000 (b) *Echinochloa colonum* x 2600 (c) *Echinochloa crus-galli* x 2400 (d) *Oplismenus burmannii* x 2400 (scale: a, b, c, d, bar=10.0μm)

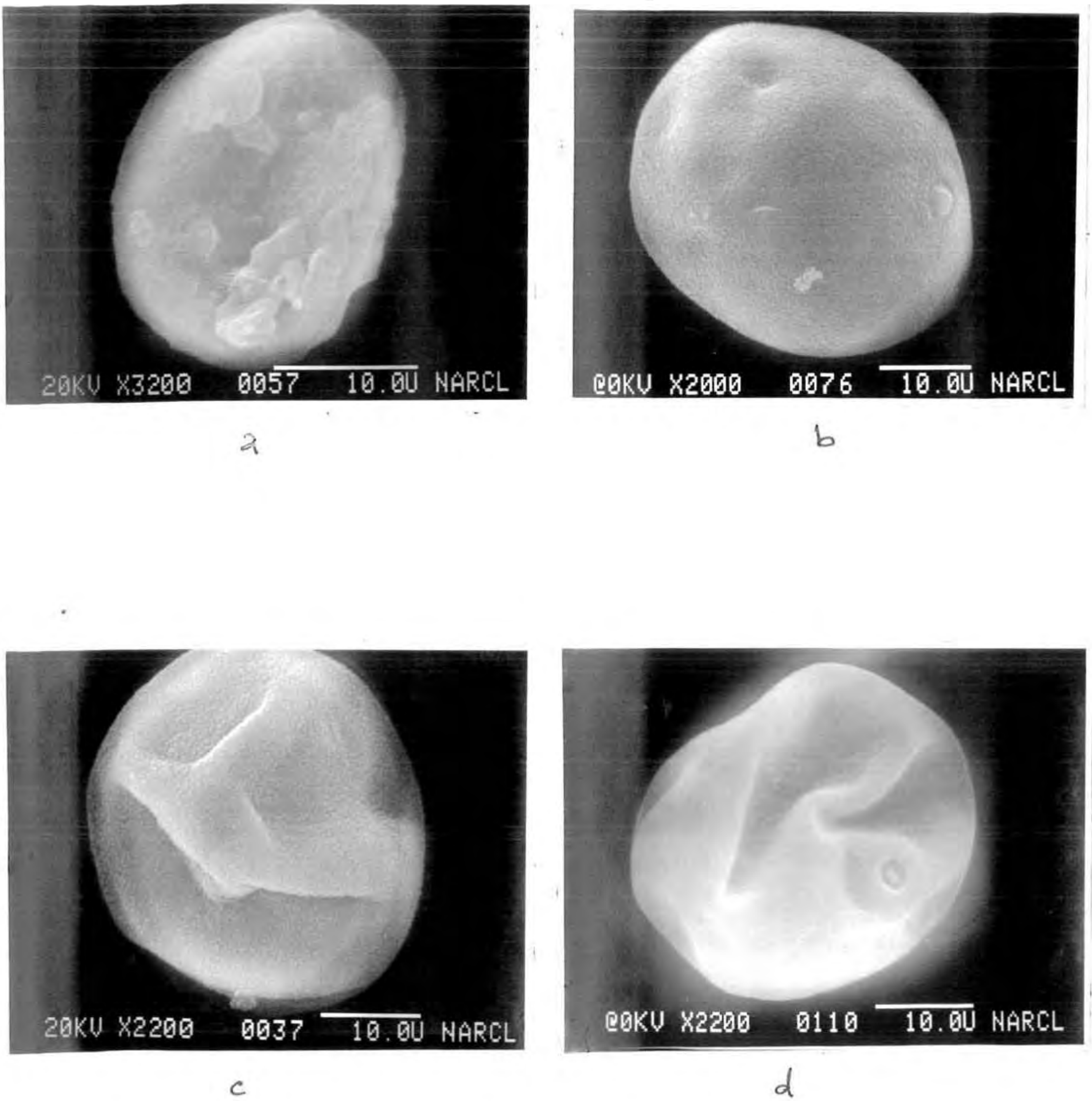


Plate 44. Scanning electron micrographs of unacetolysed grass pollens (a) *Paspalidium flavidum* x 3200 (b) *Paspalum dilatatum* x 2000 (c) *Pennisetum lanatum* x 2200 (d) *Phalaris minor* x 2200 (scale: a, b, c, d, bar=10.0μm)

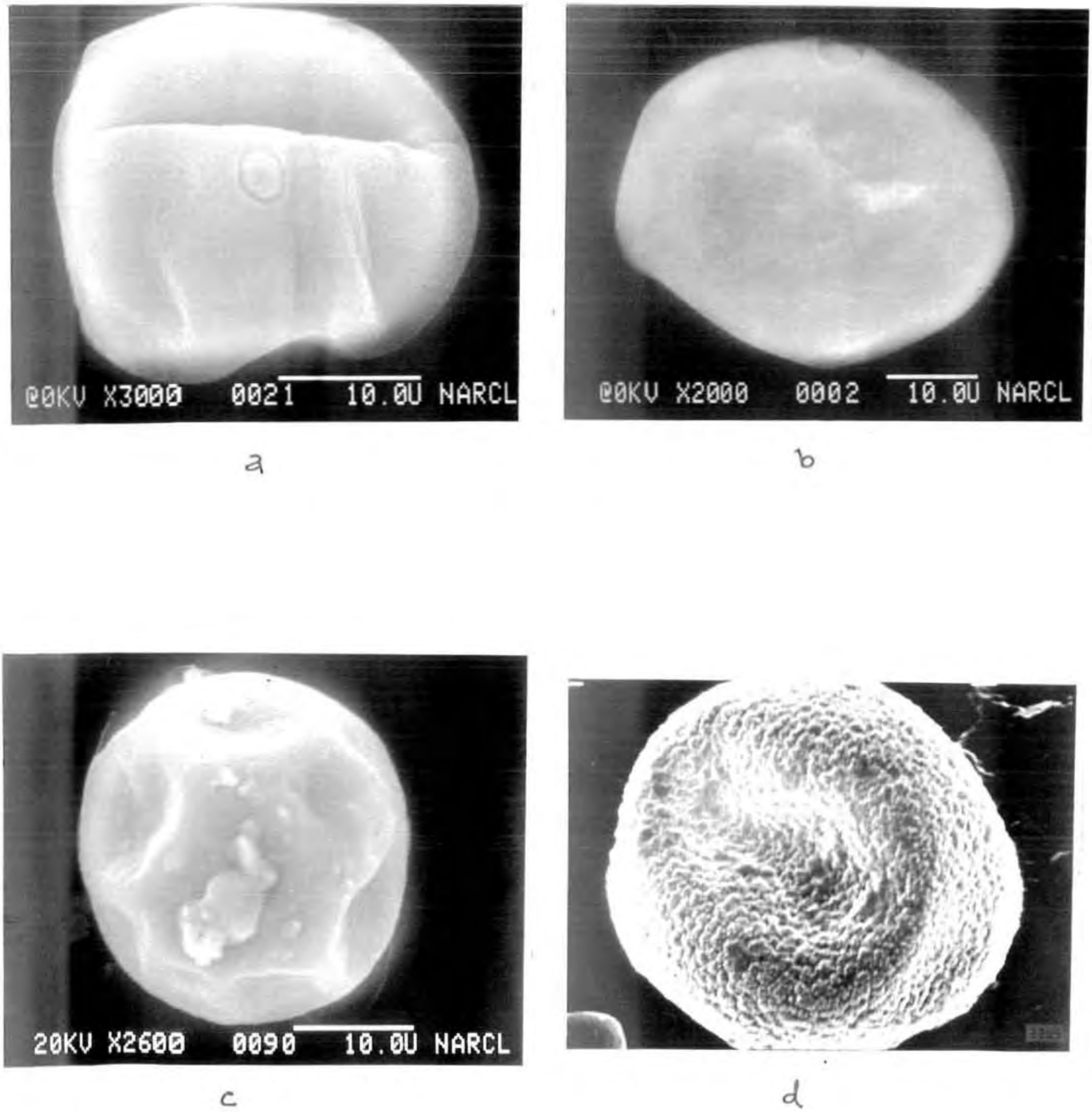


Plate 45. Scanning electron micrographs of unacetolysed grass pollens (a) *Phleum pratense* x 2000 (b) *Poa annua* x 3000 (c) *Poa infirma* x 2600 (d) *Poa menoralis* x 5000 (scale: a, b, c, bar=10.0μm)

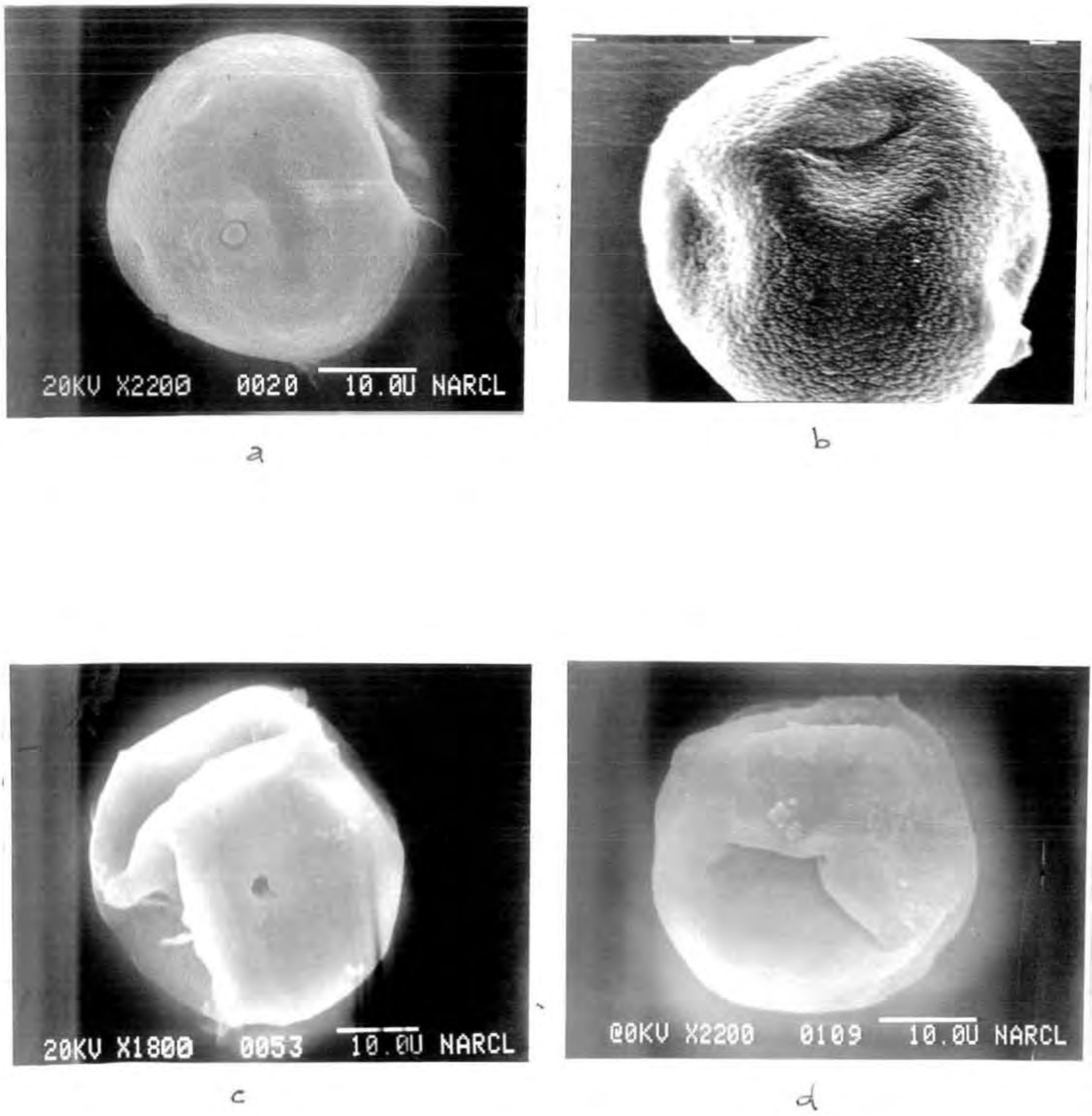
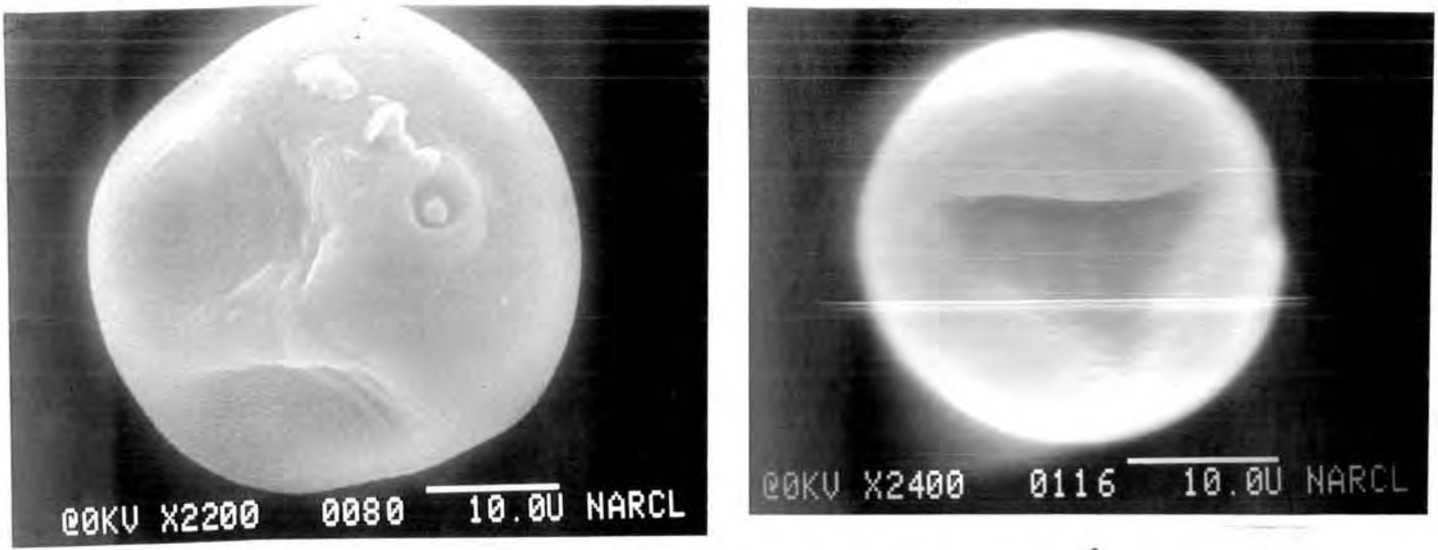


Plate 46. Scanning electron micrographs of unacetolysed grass pollens (a) *Polypogon monspeliensis* x 2200 (b) *Saccharum spontaneum* x 3500 (c) *Setaria glauca* x 1800 (d) *Setaria pumila* x 2200 (scale: a, c, d, bar=10.0μm)



a b

Plate 47. Scanning electron micrographs of unacetolysed grass pollens (a) *Stipa splendens* x 2200 (b) *Urochloa panicoides* x 2400 (scale: a, b, bar=10.0μm)

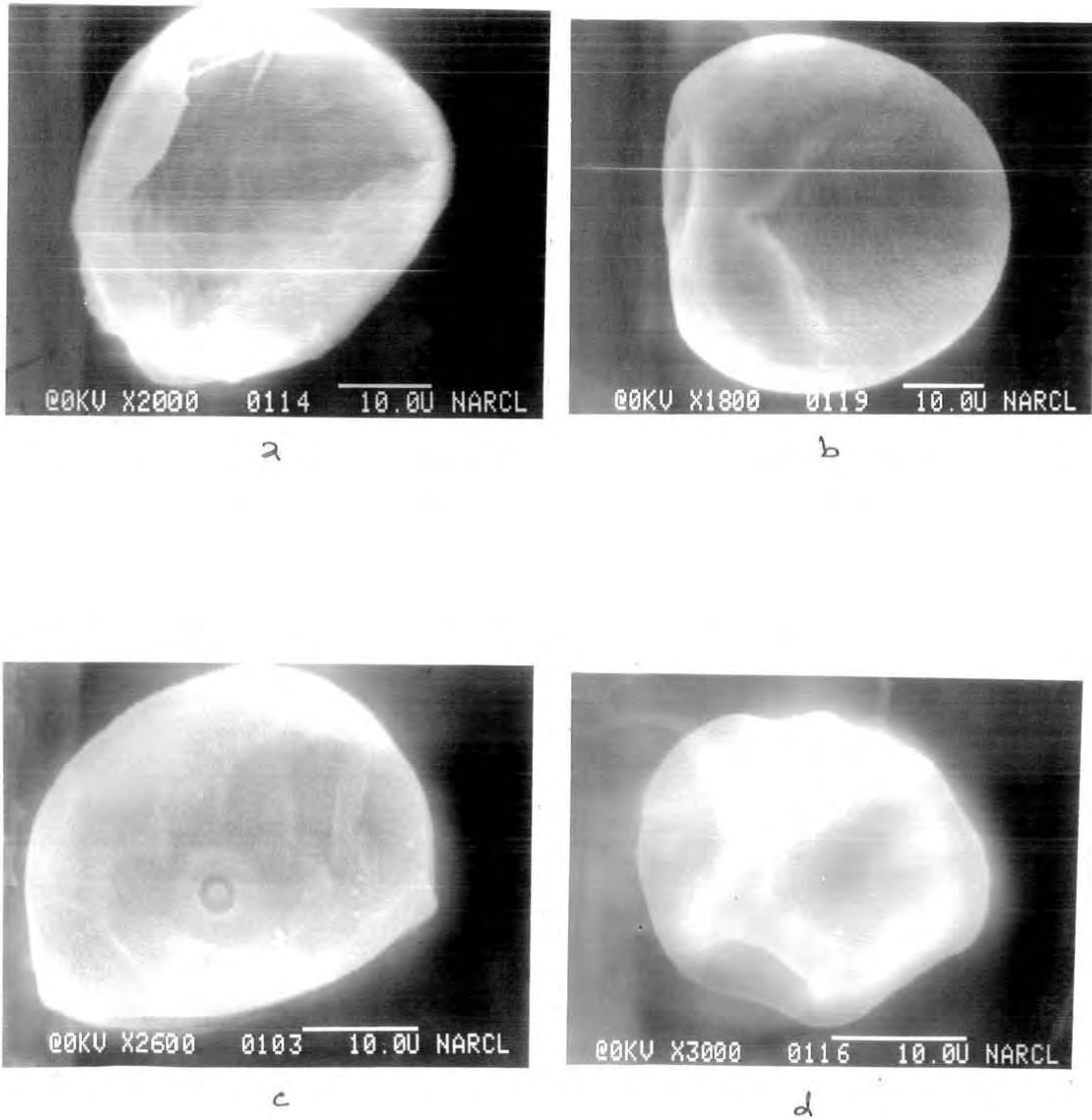


Plate 48. Scanning electron micrographs of unacetolysed grass pollens (a) *Avena ludoviciana* x 2000 (b) *Avena sativa* x 1800 (c) *Brachypodium distachyon* x 2600 (d) *Digitaria biformis* x 3000 (scale: a, b, c, d, bar=10.0μm)

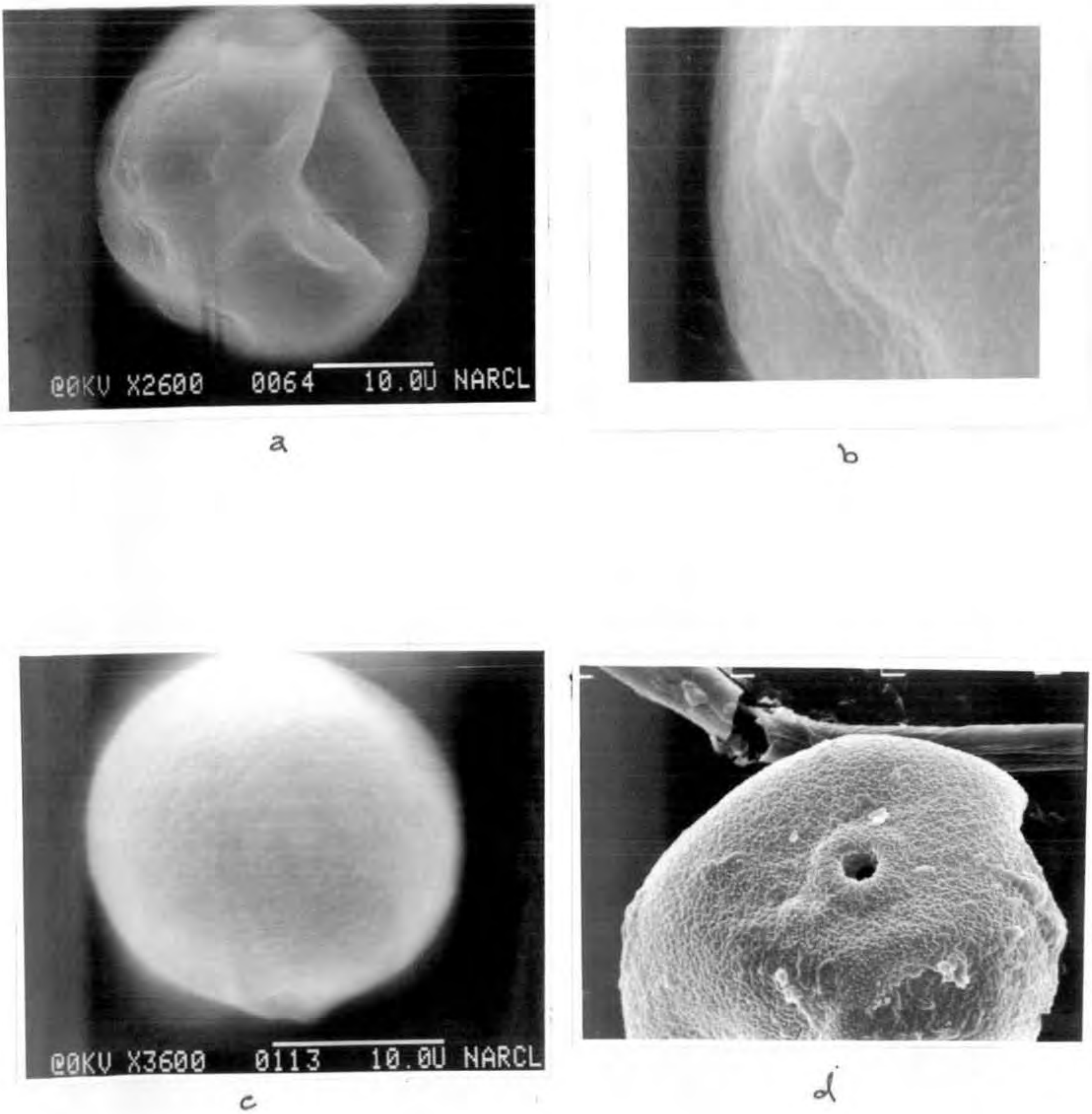


Plate 49. Scanning electron micrographs of unacetolysed grass pollens (a) *Cymbopogon schoenanthus* x 2600 (b) *Cymbopogon schoenanthus* surface x 6000 (c) *Digitaria nodosa* x 3600 (d) *Digitaria sanguinalis* x 3500 (scale: a, c, bar=10.0mm)

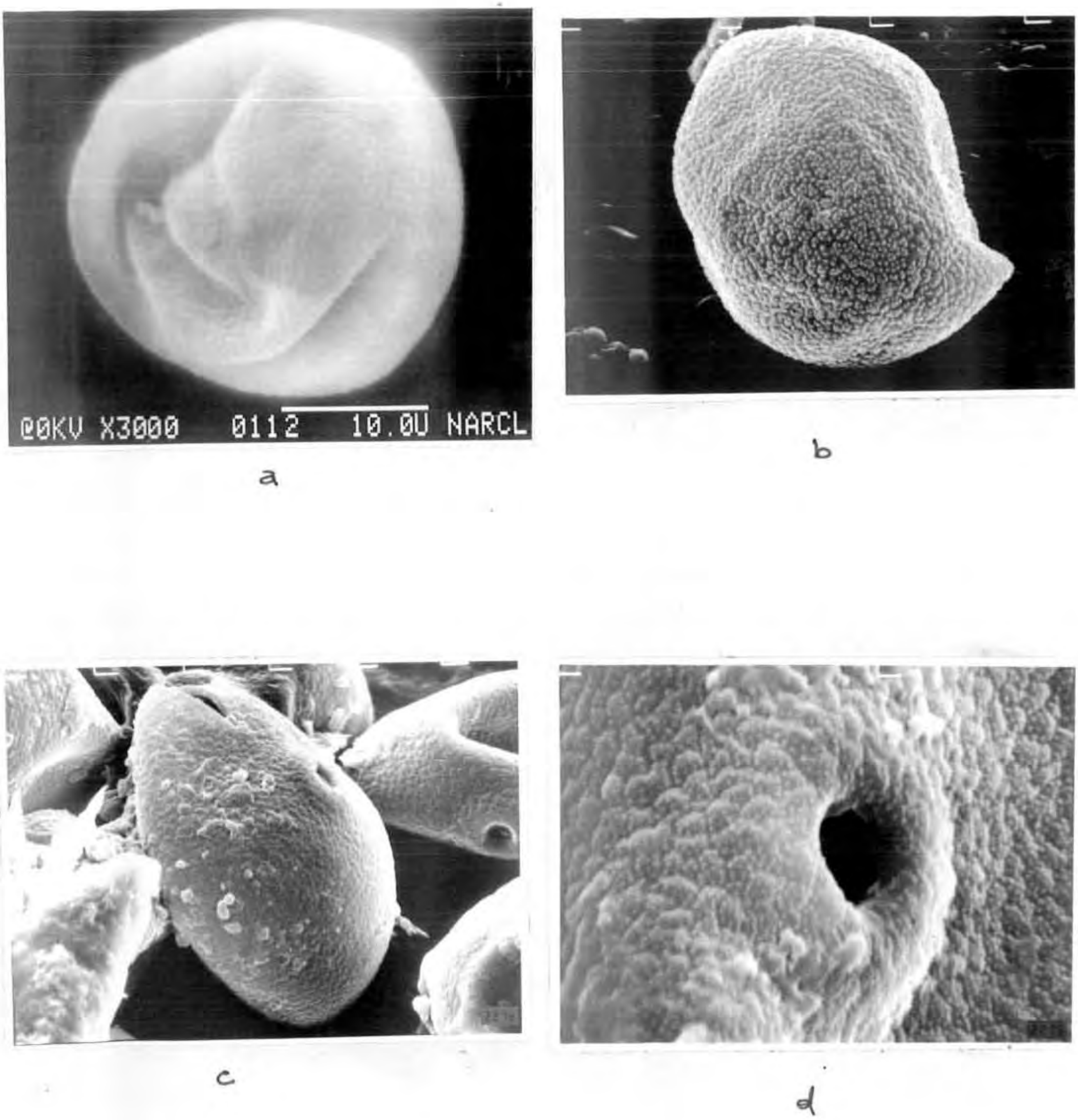


Plate 50. Scanning electron micrographs of unacetolysed grass pollens (a) *Eleusine indica* x 3000 (b) *Eragrostis minor* x 3500 (c) *Heteropogon contourtus* x 2500 (d) *Heteropogon contourtus* surface with pore x 500 (scale: a, b, bar=10.0μm)

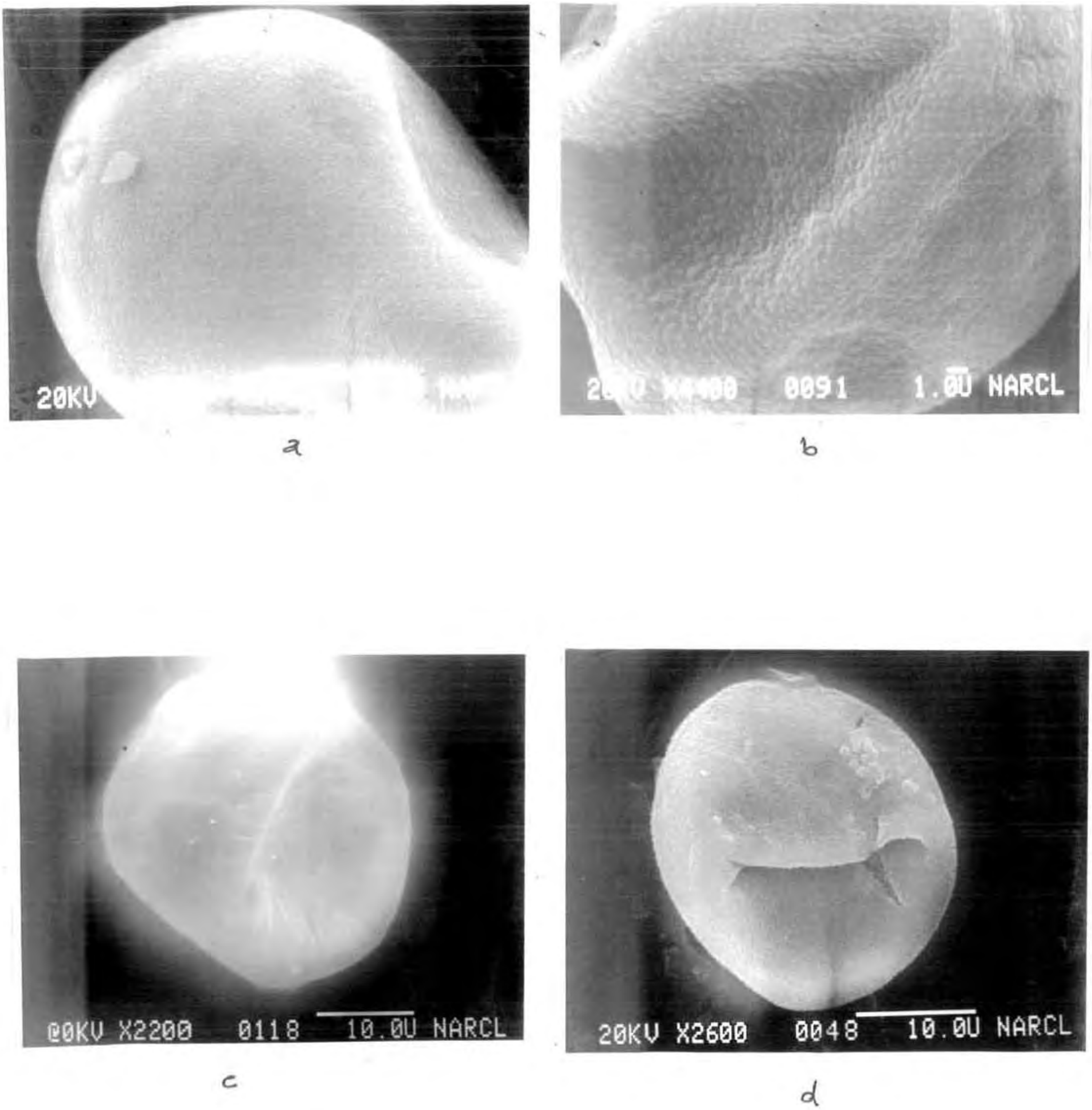
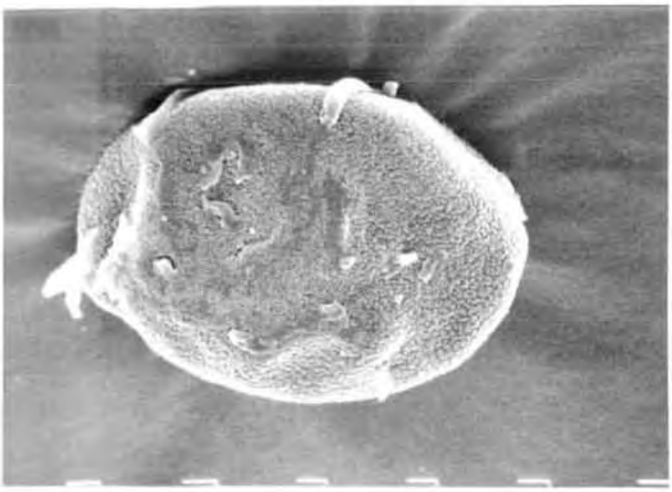
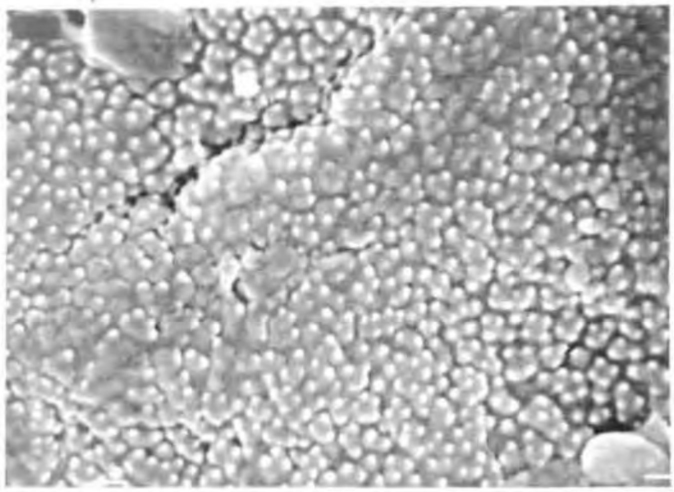
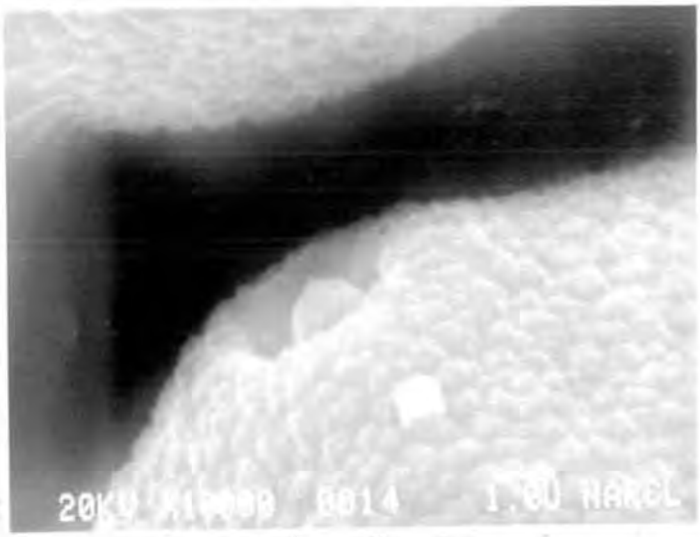


Plate 51. Scanning electron micrographs of unacetolysed grass pollens (a) *Imperata cylindrica* x 3200 (b) *Imperata cylindrica* surface x 4400 (c) *Lolium multiflorum* x 2200 (d) *Paspalum distichium* x 2600 (scale: a, c, d, bar=10.0mm, b, bar=1.0mm)





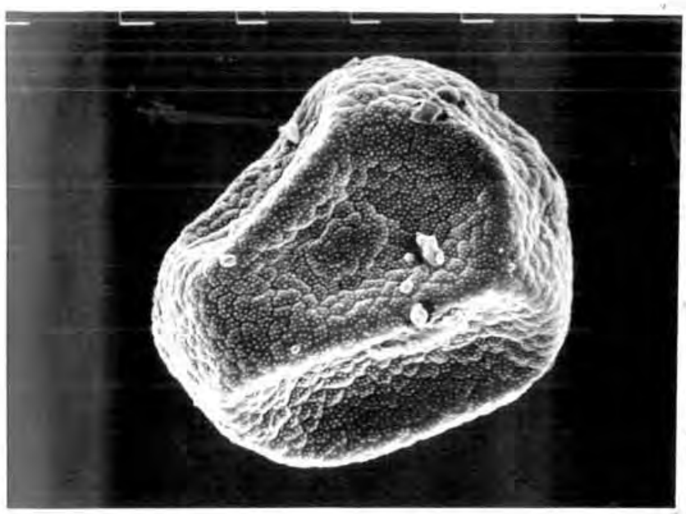
a b



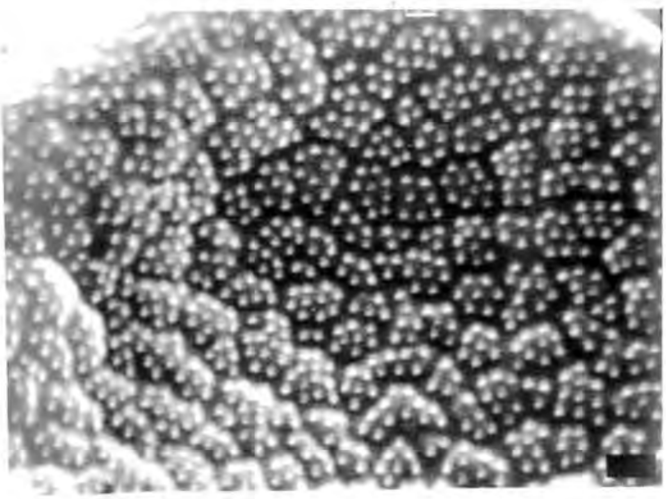
c d

Plate 52. Scanning electron micrographs of unacetolysed grass pollens (a) *Pennisetum americanum* x 2000 (b) *Pennisetum americanum* surface x 10,000 (c) *Phleum himalaccum* x 1600 (d) *Phleum himalaccum* surface x 10,000 (scale: c, d, bar=10.0μm)

a



b



c

Plate 53. Scanning electron micrographs of unacetolysed grass pollens (a) *Phragmites australis* x 3000 (b) *Sorghum halepanse* x 2000 (c) *Sorghum halepense* surface x 7500 x 7500 (scale: a, d, bar=10.0mm)

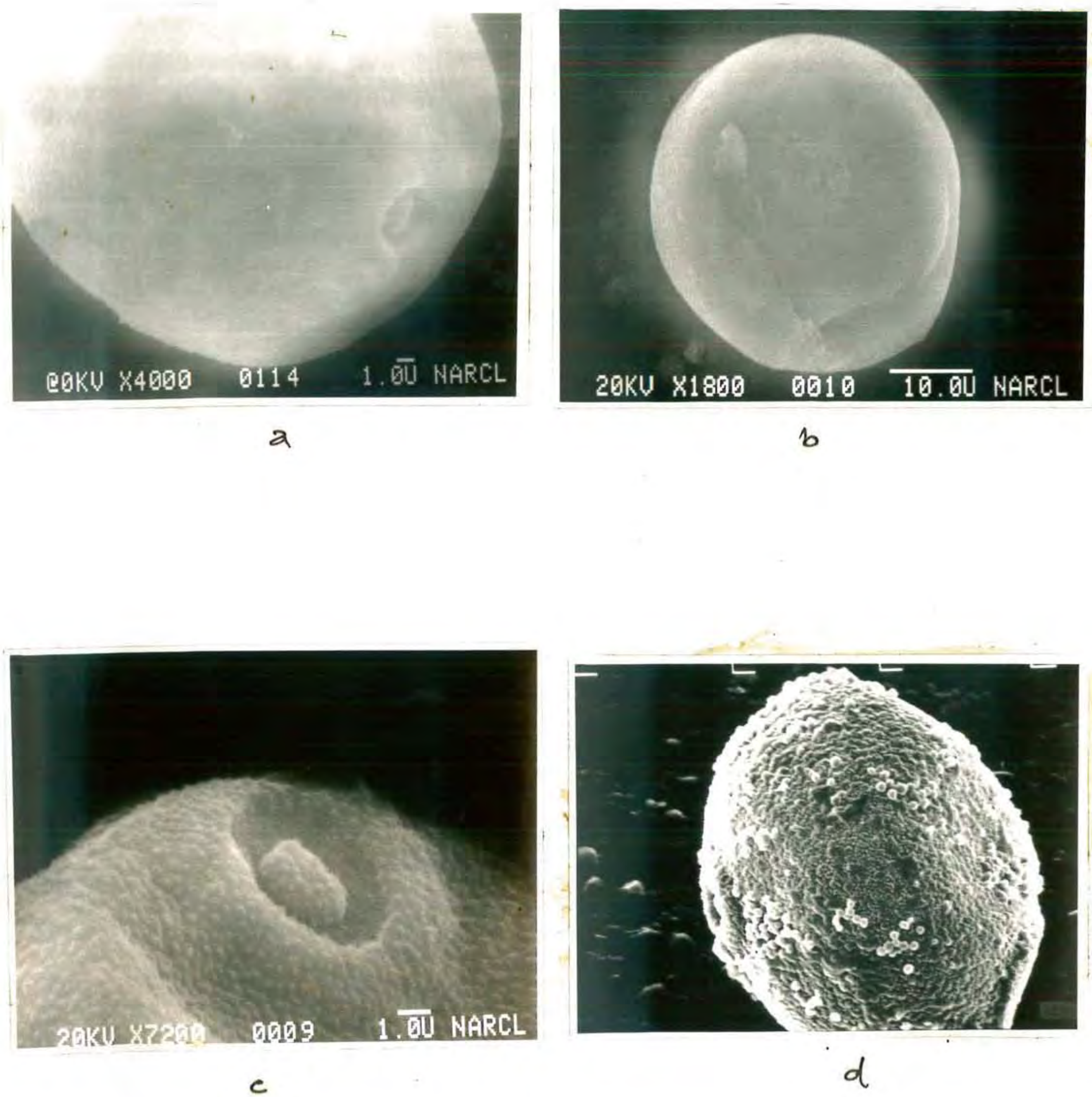
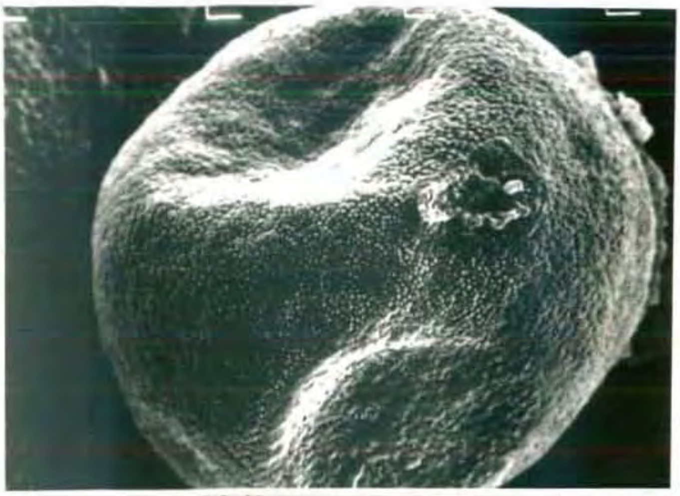


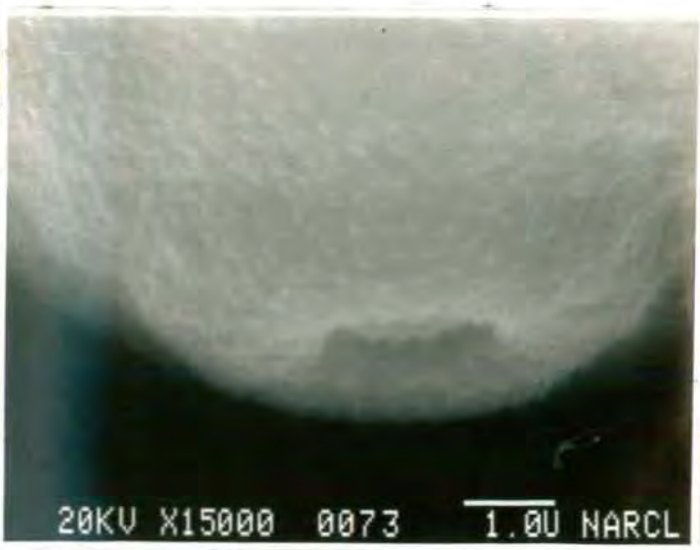
Plate 54. Scanning electron micrographs of unacetolysed grass pollens (a) *Aristida funiculata* x 4000 (b) *Bromus danthoniae* x 1800 (c) *Bromus danthoniae* surface x 2700 (d) *Cymbopogon flexuosus* x 5000 (scale: a, b, bar=10.0μm)



a

b

c



d

Plate 55. Scanning electron micrographs of unacetolysed grass pollens (a) *Parapholis strigosa* x 3500 (b) *Parapholis strigosa* surface x 7500 (c) *Vitiveria zizanoides* x 3200 (d) *Vetiveria zizanoides* surface x 1500 (scale: c, bar=10.0μm, d, bar=1.0μm)

Table 5

Vegetative morphology of the taxa studied

Sub-Family	Tribe	Taxon	Plant hight (cm)	Culm pubescence	No. of nodes	Leaf length & width (cm×mm)	Leaf blade pubescence	Leaf sheath Pubescence	Ligule length (mm)
Festucoideae	Festuceae	Bromus catherticus	40-70	Glabrous	5	20-30×3.5-5	Pubescent	Glabrous	6
		Bromus danthoniae	15-35	"	3-4	12.5×1.4-3	"	Pubescent	0.9-1
		Bromus japonicus	22-35	"	2-3	22×2-3	Hairy	Smooth	1.5-2.5
		Bromus pectinatus	15-35	"	5	13×2	Pubescent	Hairy	1.5
		Poa annua	10-22	"	3	12×1.5-3	Hairy	Glabrous	3
		Poa infirma	5-15	"	4	6×3	Pubescent	Glabrous	3
		Poa nemoralis	20-30	"	3	23.2-25×2	Glabrous	Glabrous	0.5
		Lolium multiflorum	10-15	"	4-5	21×2-4	Pubescent	Glabrous	1.5
	Aveneae	Avena ludoviciana	20-65	Pubescent	6	30×4-11	Rough	Glabrous	6
		Avena sativa	30-81	Smooth	4	42×1.5	Pubescent	Glabrous	5
		Polypogon monspeliensis	12-50	Glabrous	5-6	12-15×5-12	Dorsally glabrous ventrally pubescent	"	6-9
		Phalaris minor	20-50	Ovate hairy	5	23.5×1.8	"	"	3.0
		Alopecurus myosuroides	10-25	Glabrous	3	11-15×2.5-4	Glabrous	"	1.5-2
		Phleum himalaccum	8-22	Glabrous	4	8-15×3-6	Pubescent	Glabrous	0.5
		Phleum pratense	15-35	Glabrous	4	15-20×3.7	Pubescent	Glabrous	3-4
	Triticeae	Brachypodium distachyon	10-38	Glabrous	5	12.5×2-3	Pubescent	Glabrous	1-1.5
	Stipeae	Stipa splendens	20-57	Glabrous	4-5	85×10	Pubescent	Glabrous	3.5
	Monermeae	Parapholis strigosa	20-35	Glabrous	4	21.5×4	Glabrous	Glabrous	0.2
Panicoideae	Paniceae	Digitaria bi formis	15-40	Glabrous	4-6	19×3-5	Pubescent	Pubescent	3.2
		Digitaria nodosa	10-30	Glabrous	5	19×3-5	Pubescent	"	0.2 long row of hairs
		Digitaria sanguinalis	15-50	Glabrous	7	17×4	Pubescent	Glabrous	1.5
		Brachiaria distachya	10-30	Pubescent	5-6	14×13	Pubescent	Pubescent	a row of hairs
		Brachiaria erusiformis	20-50	Glabrous	7-8	10.5×5	"	"	a row of small hairs
		Paspalum dilatatum	20-40	Glabrous	3	23.4×5.7	Smooth	Glabrous	1.0
		Paspalum distichium	10-20	Glabrous	3	13×3-5	Glabrous	Glabrous	1.0
		Oplismenus burmannii	20-60	Glabrous	20	11.3×18	Pubescent	Glabrous	1.2
		Pennisetum americanum	50-100	Glabrous	5	40-50×10	Pubescent	Glabrous	a row of long hairs
		Pennisetum lanatum	30-80	Glabrous	5	17-21×2.5	Pubescent	Pubescent	"

Sub-Family	Tribe	Taxon	Plant hight (cm)	Culm pubescence	No. of nodes	Leaf length & width (cm×mm)	Leaf blade pubescence	Leaf sheath Pubescence	Ligule length (mm)
Panicoideae	Paniceae	Echinochloa colonium	10-50	Glabrous	3-5	4-28×2-8	Glabrous	Glabrous	Absent
		Echinochloa crus-galli	20-50	Glabrous	4	17×1.9-3	Glabrous	Glabrous	1.0
		Setaria glauca	10-30	Glabrous	3	17.5×4	Pubescent	Glabrous	a dense fring of hairs
		Setaria pumila	10-70	Glabrous	5	33.5×2-5	"	Glabrous	1-2
		Cenchrus penisctiformis	15-30	Glabrous	2	20×2	"	Glabrous	a dense fring of short hairs
		Urochloa panicoides	20-50	Glabrous	6	18×5-11	Glabrous	Glabrous	row of small hairs
		Paspalidium flavidum	10-50	Glabrous	3	13.6×7	Pubescent	Glabrous	"
	Andropogoneae	Imperata cylindrica	10-30	Glabrous	2-3	14.5×3-3.5	"	Glabrous	0.1
		Saccharum spontaneum	80-100	Glabrous	5-7	69×3-5	Glabrous	Glabrous	1.5
		Barthiochloa pertusa	15-18	Glabrous	3	4.5×2-3	Glabrous	Smooth	a row of small hairs
		Heteropogon contourtus	30-80	Glabrous	3-4	17×4	Pubescent	Glabrous	"
		Chrysopogon aucheri	30-58	Glabrous	5	11-13×2-2.5	"	Glabrous	Ciliate
		Cymbopogon flexuosus	20-80	Glabrous	3-7	29×7	Glabrous	Glabrous	3
		Cymbopogon schoenanthus	20-35	Glabrous	5-7	18.8×2.5	Pubescent	Glabrous	1.5
		Dicanthium annulatum	30-48	Glabrous	4	14.7×2-3	"	Smooth	1-2
		Dicanthium foveolatum	15-60	Glabrous	7	31×3	"	"	"
		Sorghum halepense	20-70	Glabrous	26	11.3×18	"	Glabrous	1.5-2t
		Vetiveria zizanoides	40-100	Glabrous	3-5	63×5	Glabrous	Glabrous	a dense fling of hairs
Eragrostoideae	Eragrosteae	Eragrostis minor	6-35	Glabrous	3	21×2	Pubescent	Glabrous	a row of small hairs
	Chlorideae	Eleusine indica	10-50	Glabrous	2-4	21.5×5	Glabrous	Glabrous	triangular row of hairs
		Dactyloctenium aegyptium	20-45	Glabrous	3-4	18×5	Pubescent	Glabrous	0.5
		Cynodon dactylon	10-25	Smooth	5	7.8×2-4	Glabrous	Glabrous	a dense row of hairs
		Desmostachya bipinnata	22-40	Glabrous	3	29×5	Glabrous	Glabrous	semi circular row of hairs
	Aristideae	Aristida adscensionis	15-30	Glabrous	3	28×1-1.5	Pubescent	Glabrous	a row of short hairs
		Aristida funiculata	10-30	Glabrous	2	15×1-2	"	Glabrous	"
Arundinoideae	Arundineae	Phragmites australis	100-400	Glabrous	3-5	85×10	Glabrous	Glabrous	10-50

Table 6

Floral morphology of the taxa studied

Sub-Family	Tribe	Taxon	Length & width of panicle (cm×mm)	Length & width of spikelet (mm× mm)	No. of spikelets	Pedicel length (mm)	No. of florets	Lower glume shape	Lower glume length & width (mm×mm)	Upper glume shape	Upper glume length & width (mm×mm)
Festucoideae	Festuceae	Bromus catherticus	10-20	15-35×5-6	15-20	5-15	5-10	narrowly lanceolate in side view	8-15×1.9-2	narrowly lanceolate	11-16×3
		Bromus danthoniae	2.7-8×1.9-2	17.5-32.5	-	20	5-15	lanceolate	4.5-7.5×1.2-1.8	narrowly ovate	5.5-8.5×3-3.5
		Bromus japonicus	6-10	12-24×2-4	14	25-30	7-14	lanceolate	4.5-6×1-1.5	ovate	5-8×1-2
		Bromus pectinatus	5-8×3-5	10-15×1.5-2	11	10-22	4-6	narrowly lanceolate	5-6×1-1.5	oblanceolate	7-11×1-2
		Poa annua	8×1-3	3.5×1.5-2	3	1.5	3	lanceolate	2×1	oblong	3×1.5
		Poa infirma	3×1-5	3×1.5	4	1.5	3	"			
		Poa nemoralis	8-14×7-10	1.5×0.5	3-20	1	2	"	1.2×1	ovate	1-1.5×1
		Lolium multiflorum	7-14×2.5-4	12×3.5	12	sessile	6	"	3-4×1.5	obtuse narrowly oblong	12×2
	Aveneae	Avena ludoviciana	17×5	20×5	25	28	2	lanceolate finely acute	20×6	lanceolate finely acute	18×6
		Avena sativa	30×10	18×4	59	11	2	lanceolate	18×5	lanceolate	12×6
		Polypogon monspeliensis	3-12×0.6-3	2×1	6-15	2.4	1	narrowly oblong	2×0.5	narrowly oblong	1.9×0.2
		Phalaris minor	2-4.5×1-2 cm	4×2.5	20-30	2	1	narrow oblog	4.5×2	ovate	1-2×0.5-1
		Alopecurus myosuroides	2-6×3-5	5×3	4-40	sessile	1	oblong	4×1.2	oblong	3×2
		Phleum himalaccum	1.8-4.8×5-8	5-14×1-2	5	-	1	narrowly oblong	2×0.2	broadly oblong	3×1
		Phleum pratense	2-8×4-8	3-3.8×0.2-0.5	6	-	1	"	1	narrowly oblong	1.2×1.5
	Triticeae	Brachypodium distachya	2-2.8×4	9×3	11-17	sessile	10	lanceolate	6×1.2	lanceolate	7×1.2
	Stipeae	Stipa splendens	28×2-5	5×1.2	many	"	2	lanceolate	3.5×2	lanceolate	4.5×2.5
	Monermeae	Parapholis strigosa	14×1.5	4×1.5	36	"	1	oblong	3.2×1.5	oblong	3×1.5
Panicoideae	Paniceae	Digitaria bi formis	12.5×2-5	3×1	many	2	1	ovate	1.5-2×1	ovate	1.5×1
		Digitaria nodosa	12.5×2.5	1.5-2×1	"	0.4-0.5	1	"	0.5-1×0.8	"	1.5×1
		Digitaria sanguinalis	7×1-5	3×1.1	many (21-15) per raceme	1-2	1	"	0.2	ovate	1.5×1
		Brachiaria distachya	4.5×1	3.1×2	35	sessile	1	"	2.2×2	ovate	0.2×0.1
		Brachiaria erusiformis	2×4	1.8-2×1.2	many	1.2	1	lanceolate	0.3×0.2	ovate	0.2×0.1
		Paspalum dilatatum	6-12×1.5	3-3.5×2	20-60	1	1	ovate	3-3.5×2	"	3-3.5×2
		Paspalum distichium	5-9×1-1.5	2-3×1-2	15-30	0.5	1	"	2-3×1-2	"	2-3×1-2
		Oplismenus burmannii	9×5	2.5×1.5	many	sessile	1	lanceolate to ovate with awn	2×1-1.5	lanceolate to ovate	1.2-1.5×1
		Pennisetum americanum	1-0-20×2cm	3.5-4.5	many	1-1.5	2	lanceolate	3.5×1-1.5	lanceolate	4×1.5-2
		Pennisetum lanatum	3-5×0.5-1	3-5×2-2.5	"	1-1.5	2	"	3.5×1-1.5	lanceolate	4×2

Floral morphology of the taxa studied

Sub-Family	Tribe	Taxon	No. of lower glume veins	No. of upper glume veins	Shape of lemma	Lemma length & width (mm ×mm)	Awn length (mm)	No. of lemma veins	Palea length & width (mm ×mm)	Anther length (mm)	Carypsis length (mm)
		Bromus catherticus	5	9	narrowly lanceolate	12-15×3	0.9-1	9	7×10	0.2-0.9	1.2-5
		Bromus danthonica	3-5	7-9	Oblancolate in side view	9-12.2×2.7-5	Central awn1.5-2.5 cm lateral awn 4-10	9	6-9.2×0.9-1.2	0.9-1	5-8
		Bromus japonicus	3	7	Oblanceolate	7-8-×4	13	7	5×3	1	6
	Festuceae	Bromus pectinatus	3	5	narrowly oblanceolate	6-10×1.5-2	7-12	5	0.5×0.2	0.5-1	3
		Poa annua	3	3	Lanceolate oblong	1.5-2×1	-	5	1.5-2×1	0.5	-
		Poa informa									
Festucoideae		Poa nemoralis	3	3	Lanceolate oblong	1.5-2×1	-	5	1.5-2×1	0.5	-
		Lolium multiflorum	4	7	Lanceolate	6×2.5	7	5	6×2.5	3.2	-
		Avena ludoviciana	9	6	Oblong	15×5	3.5cm	6	12×3	3	3
		Avena sativa	8	7	Oblong	8×4	2.7cm	4	5×3	2.5	1-2
		Polypogon monspeliensis	1	1-2	Broadly elliptic	1×0.9	4	5	0.9×0.6	0.2-0.5	1
	Aveneae	Phalaris minor	2	2	Ovate	3×2	0.5	2	1×0.5	0.8-1	1-1.5
		Alopecurus myosuroides	3	7	Ovate	4×2	4	4-5	-	2.5	-
		Phleum himalaccum	3	3-7	Lanceolate	6×1.5	24	6	5×1	3	2
		Phleum pratense	3	5-7	Oblong	0.7×0.2	1-2	5-7	0.5-0×0.2	2	0.5
	Triticeae	Brachypodium distachya	5	7	Lanceolate	9×3	12	3	-	1.2	6
	Stipeae	Stipa splendens	3	Cross veins	Ovate	0.5-1×0.7	-	many	0.5	1	1.0
	Monermeae	Parapholis strigosa	3	3	Oblong	3×1.5	-	3	3×1.5	1.2	-
		Digitaria bi-formis	3	5	Lanceolate	2.5×1	-	7	membranus very small	0.2	-
		Digitaria nodusa	3	5	Lanceolate	2.5-3×1.1	-	5	2.5×1	1	2
		Digitaria sanguinalis	1	3	Ovate	1.5-2×1	0.3	7	"	0.2	3
		Brachiaria distachya	5	7	Ovate	1.5-2×1	-	5	1.5×1	1-1.2	2
		Brachiaria erusiformis	3	5	Ovate	0.2×0.1	-	-	-	1	1.5-2
		Paspalum dilatatum	3	3	Ovate	3-3.2×2	-	3	-	0.5	2
		Pennisetum americanum	5	5	Lanceolate	3-5×1-2	12	9-10	3-5×1-2	3.5	-
		Pennisetum lanatum	5	5	Lanceolate	2.5-4×1-2	12	8-9	2.5-4×1-2	3.5	-
		Paspalum distichium	3	3	Ovate	2-3×1-2	-	3	-	0.2	-
Panicoideae	Paniceae	Oplismenus burmannii	3	5	Lanceolate	2.5×1	-	3	2.5×1	1.2	-

Sub-Family	Tribe	Taxon	Length & width of panicle (cm×mm)	Length & width of spikelet (mm× mm)	No. of spikelets	Pedicel length (mm)	No. of florets	Lower glume shape	Lower glume length & width (mm×mm)	Upper glume shape	Upper glume length & width (mm×mm)
		Echinochloa colonium	6.5×10	2×1.5	many	0.5	2	Ovate	1.5×1	Ovate	1.5-2×1.5
		Echinochloa crus-galli	6-20×8	3-4×1.5-2	many	0.5	2	Ovate	1.5×1	Ovate	1.5-2×1.5
		Setaria glauca	3×3	2.5×1.5	many	Sessile	2	Ovate	1-2×1.5	Ovate	1.5×1
Panicoideae	Paniceae	Setaria pumila	5-11×3.5	2.2×1.5	many	"	2	Ovate	0.8-1×0.5	Ovate	0.8-1×0.5
		Cenchrus penisctiformis	8×1	5×3	3-9	"	1-2	Lanceolate	3×1.5	Lanceolate	4×2
		Urochloa panicoides	6-12×4	2.5×1.2	many	1.2	1	Ovate	1.1×0.8	Ovate	1.1×0.8
		Paspalidium flavidium	8-15×3	2-3×1.5	8-9	Sessile	2	Ovate	1.5×1.2	Ovate	2-2×1.8-2
		Imperata cylindrica	10×10	4×1	many	1	2	Lanceolate	3-4×1.5	Lanceolate	4×1.5
		Saccharim spontanum	24×4	2.5-3×1.5	many	1-2	2	"	2.5×1.5	"	2.5×1.5
		Bothriochloa pertusa	3×15	3-6×1-2	9-13	Sessile	2	Oblanceolate	2.5-4×1	Oblanceolate	2.5-3.1×1-1.5
	Andropogoneae	Heteropogon contourtus	4×13	9×3	10	"	2	Lanceolate	8×2.5	Lanceolate	8×2.5
		Chrysopogon aucheri	8-11×1-2	5-8×1-2	22-30	0.9-30	3	Broadly Oblong	5-8×1.5	Oblong	6×1
		Cymbopogon flexuosus	6×1-2	4.5×2	many	2.2	1-3	Lanceolate	4.3×1.5	Lanceolate	4×1.5
		Cymbopogon schoenanthus	3.5×0.8	Spathioles 2.5-3cm 5×1.2	2-5/raceme	Sessile	2	"	3.5×2	"	3.5×1.8-2
		Dicanthium annulatum	3-4×1.5	3-8×1.2	10-13	"	2	"	3-4×1	"	3×1
		Dicanthium foveolatum	13×3	2.5-4×1	9-18	"	2	"	3.5×1-1.5	"	2.2×1.5
		Sorghum halepense	23×13	1=4×1.5-2.5	many	"	2	Ovate	3.2×2	Ovate	3.5×2
		Vetiveria zizanoides	28×20	3.8×1.2	11/raceme	1.5	1	Lanceolate	3×0.5	Lanceolate	3×1.5
	Eragrosteae	Eragrostis minor	4-14×5	5×1.5-2	12-100	2.2	10	Ovate	1-2×0.5-1.5	Ovate	1.5-2×1
		Eleusine indica	5-10×1	3.5×1-1.5	many	0.2	3	Lanceolate acute	2×0.8	Lanceolate subacute	2-2.5×1.5
		Dactyloctenium aegyptium	2.3×5	3×1.2	many	Sessile	3	Lanceolate	1.5×0.8	Lanceolate to Ovate	2×0.8
Eragrostoideae	Chlorideae	Cynodon dactylon	4.5×1-1.5	2-2.8×1.5	30	0.3	1	"	1.5-2.3×0.8	Lanceolate	1.5-2.3×0.8
		Desmostachya bipinnata	9×10	2.2×1	many	Sessile	4	Ovate	1×0.5	Ovate	1.5×1
	Aristideae	Aristida adscensionis	8-20×1-1.5	8×1-1.5	5-50	3	1	Lanceolate	4-4.5×1.5	Lanceolate	7×1.5
		Aristida funiculata	5-15×1-2	6-7×1-1.5	12-50	4.5	1	"	4.5×1-1.5	"	7×1
Arundinoideae	Arundineae	Phragmites australis	44×50	4×1.5	many	2-3	2-3	"	4×2-5	"	5×2-3

Sub-Family	Tribe	Taxon	No. of lower glume veins	No. of upper glume veins	Shape of lemma	Lemma length & width (mm×mm)	Awn length (mm)	No. of lemma veins	Palea length & width (mm ×mm)	Anther length (mm)	Carypsis length (mm)
		Echinochloa colonium	3	5	Ovate	2×1.5	15	5	2×1.5	1	2
		Echinochloa crus-galli	3-5	5	"	3×1.5	20	5-7	3×1.5	1	2
		Setaria glauca	3	5	"	2.5×1.5	-	3	2.5×1.5	1	0.7
Panicoideae	Paniceae	Setaria pumila	3	5	"	0.8-1×0.5	-	3	0.8-1×0.5	0.8	1-1.5
		Cenchrus penisciformis	3	7	Lanceolate	4×2	1	7	3×1.5	2.2	1-2
		Urochloa panicoides	1	3	Lanceolate	0.3×0.1	7	-	-	1.5	-
		Paspalidium flavidium	3	5	Ovate	2.5×2	-	-	1.8-2	0.2	-
		Imperata cylindrica	5	5	Lanceolate	3.5×2	-	-	2.5×2	2.2	-
		Saccharim spontanum	3	3	Lanceolate	1.5-2×1.2	very short	-	-	1.5	1
		Bothriochloa pertusa	5-6	6	Oblanceolate	2.5×1	16	6	2.5×1	1.5	-
	Andropogoneae	Heteropogon contourtus	9	9	Lanceolate	8×3	8cm	-	4×1.5	2.5	-
		Chrysopogon aucheri	5	3-7	"	6×1.5	24	6	5×1	3	2
		Cymbopogon flexsuosus	5	3	"	4.2×1.5	16	3	3.5×1.5	2	1-2
		Cymbopogon schoenanthus	9	3	"	2.5×1	-	whitish nerve not clear	-	1.8	1-2
		Dicanthium annulatum	3	7	"	2-3×1	18	7	2.5×1	1.5	-
		Dicanthium foveolatum	5	5	"	2.5×1	18	5	1.5×0.8	1.2	-
		Sorghum halepense									
		Vetiveria zizanoides	3	3	Lanceolate	3×1.5	-	3	2.5×1	2	-
	Eragrosteae	Eragrostis minor	1	3	Ovate	1.2-1.5×1	-	3	-	0.2	-
		Eleusine indica	3	3	"	2.3-3×1-1.5	0.2	3	2×1	0.2	1.5
		Dactyloctenium aegyptium	3	3	"	2.5×1.8	-	3	2×1	0.2-0.5	1
Eragrostoideae	Chlorideae	Cynodon dactylon	1	1	Boat shape	2×1.2	-	3	2×1.2	1.5	-
		Desmostachya bipinnata	1	1	Ovate	1.8-2×1.2	-	3	0.8-1×0.5	1	-
	Aristideae	Aristida adscensionis	1	1	Cylindricl	7×0.5-1	15	3	-	1.5	6
		Aristida funiculata	1	1	"	7×1-2	15	3		2	5
Arundinoideae	Arundineae	Phragmites australis	3	3	Narrowly lanceolate	3-4×1.5-2	-	3	1×0.5	2.2	-

Table 7

Pollen Morphological Data of Taxa Studied by Light & Scanning Electron Microscope

S. No	Taxon	Pollen type	Aperture type	Pore type	Pollen shape	Pore Size		Polar axis (μm)	Equatorial axis (μm)	P/E ratio	Operc-ulum	Annulus		Exine Ornamen-tation	Exine Thickness (μm)	Surface Pattern	No. of pores	Pollen group
						Length (μm)	Width (μm)					Diamter (μm)	Thickness (μm)					
1	Alopecurus mysuroides	Granulate	Porate	Ectoporus	Elliptical	7.0	2.0	(26-) 28.5 (-31)	(33-) 26 (-39)	1.10	-	7.0	1.66	Scabrate (coarse granulate)	2.0	CST	Monop-orate	Coarse granulate
2	Aristida adscensionis	Scabrate	"	Endoporus	Spheroidal	3.0	2.0	(33-) 26 (-39)	(33-) 26 (-39)	1.00	+	3.0	0.8	Verrucate	2.0	CST	"	Fine granulate
3	Aristida funiculata	Granulate	"	Ectoporus	Spheroidal	7.0	2.0	(25-) 26.5 (-28)	(25-) 26.5 (-28)	1.00	-	7.0	0.6	Rugulate	2.5	WST	"	Rugulate spinulate
4	Avena ludoviciana	"	"	Ectoporus	Oblate	3.0	2.5	(38-) 40 (-42)	(32-) 34 (-36)	1.17	-	3.0	2.25	Granulate	2.5	MST	"	Coarse granulate
5	Avena sativa	"	"	Ectoporus	Oblate	8.0	3.0	(47-) 51 (-55)	(45-) 46.5 (-49)	1.09	-	8.0	2.78	Granulate	2.5	MST	"	Fine granulate
6	Bothriochloa pertusa	"	"	Endoporus	Spheroidal	5.0	2.5	(30-) 32.5 (-35)	(30-) 32.5 (-35)	1.00	+	5.0	2.8	Granulate	2.0	CST	"	Coarse granulate
7	Brachiaria distachya	"	"	Ectoporus	Spheroidal	5.0	2.5	(30-) 32.5 (-35)	(30-) 32 (-34)	1.01	+	5.0	2.42	Verrucate	2.0	CST	"	Verrucate fine granulate
8	Brachiaria erusiformis	"	"	Ectoporus	Spheroidal	8.0	2.5	(21-) 23.5 (-26)	(21-) 23.5 (-26)	1.00	-	8.0	2.05	Verrucate	2.0	CST	"	Verrucate (coarse Granulate)
9	Brachypodium distachyon	"	"	Endoporus	Spheroidal	3.0	3.0	(29-) 37.5 (-34)	(29-) 31.5 (-34)	1.00	+	3.0	2.2	Granulate	1.5	MST	"	Coarse granulate
10	Bromus catherticus	"	"	Ectoporus	Ellipsoidal	6.0	2.5	(32-) 34 (-36)	(28-) 30.5 (-33)	1.11	+	6.0	2.8	Granulate	2.5	CST	"	Fine granulate
11	Bromus japonicus	"	"	Endoporus	Spheroidal	4.0	2.0	(31-) 32.5 (-34)	(31-) 32.5 (-34)	1.00	+	4.0	1.57	Verrucate	2.0	CST	"	"

+ = Operculum present   CST = Closed spaced type   WST = Widely spaced type
- = Operculum absent   MST = Medium spaced type

Pollen Morphological Data of Taxa Studied by Light & Scanning Electron Microscope

S. No	Taxon	Pollen type	Aperture type	Pore type	Pollen shape	Pore Size		Polar axis (µm)	Equatorial axis (µm)	P/E ratio	Operculum	Annulus		Exine Ornamentation	Exine Thickness (µm)	Surface Pattern	No. of pores	Pollen group
						Length (µm)	Width (µm)					Diamter (µm)	Thickness (µm)					
12	Bromus pectinatus	Granulate	Porate	Ectoporus	Spheroidal	6.0	2.0	(32-) 34 (-36)	(32-) 34 (-36)	1.00	+	6.0	1.76	Scabrate	2.0	CST	Monoporate	Coarse granulate
13	Bromus Danthoniae	Granulate	"	Endoporus	Spheroidal	36.0	2.0	(33-) 32.5 (-37)	(33-) 32.5 (-37)	1.00	+	6.0	1.33	Granulate	2.0	WST	"	Fine granulate
14	Cenchrus Penisctiformis	Psilatete	"	Ectoporus	Spheroidal	72.0	2.0	(34-) 35.5 (-37)	(34-) 35.5 (-37)	1.00	-	2.0	2.22	Verrucate	2.0	CST	"	Verrucate
15	Chrysopogon aucheri	Granulate	"	Ectoporus	Oblate	38.0	2.0	(32-) 34.5 (-37)	(30-) 32.5 (-35)	1.07	-	8.0	0.8	Granulate	2.5	CST	"	Fine granulate
16	Cymbopogon flexsuosus	Granulate	"	Endoporus	Spheroidal	85.09	2.0	(33-) 39 (-45)	(33-) 39 (-45)	1.00	+	5.0	1.42	Verrucate	2.0	WST	"	Verrucate
17	Cymbopogon schoenanthus	Granulate	"	Ectoporus	Spheroidal	56.0	2.0	(30-) 33.5 (-37)	(30-) 33.5 (-37)	1.00	+	6.0	2.0	Verrucate	1.5	MST	"	Verrucate
18	Cynodon dactycon	Cloudy psilate	"	Ectoporus	Spheroidal	56	2.5	(21-) 23.5 (-26)	(21-) 23.5 (-26)	1.00	-	6.0	2.5	Verrucate	2.0	CST	"	Verrucate
19	Dactyloctenium aegypteum	Granulate	"	Ectoporus	Spheroidal	85.0	2.0	(20-) 26.6 (-35)	(20-) 26.6 (-35)	1.00	+	5.0	2.0	Scabrate	2.0	CST	"	Coarse (coarse granulate)
20	Desmostachya bipinnata	Psilate	"	Endoporus	Spheroidal	34.0	2.0	(21-) 24.5 (-28)	(21-) 24.5 (-28)	1.00	+	4.0	1.02	Verrucate	2.0	CST	"	Verrucate
21	Dicanthium annulatum	Psilate	"	Ectoporus	Spheroidal	65.0	2.0	(28-) 30 (-32)	(28-) 30 (-32)	1.00	-	5.0	1.17	Scabrate	1.5	CST	"	Scabrate (Coarse granulate)
22	Dicanthium foveolatum	Granulate	"	Endoporus	Oblate	46.0	2.5	(32-) 35.5 (-39)	(31-) 33 (-36)	1.00	+	6.0	1.7	Scabrate	2.0	CST		Scabrate

+ = Operculum present
- = Operculum absent

CST = Closed spaced type
MST = Medium spaced type

WST = Widely spaced type

Pollen Morphological Data of Taxa Studied by Light & Scanning Electron Microscope

S. No	Taxon	Pollen type	Aperture type	Pore type	Pollen shape	Pore Size		Polar axis (µm)	Equatorial axis (µm)	P/E ratio	Operc-ulum	Annulus		Exine Ornamen-tation	Exine Thickness (µm)	Surface Pattern	No. of pores	Pollen group
						Length (µm)	Width (µm)					Diamter (µm)	Thickness (µm)					
23	Digitaria biformis	Coarse psilate	Porate	Ectoporus	Spheroidal	4.0	3.0	(22-) 28.5 (-36)	(21-) 28.5 (-36)	1.00	-	4.0	1.30	Granulate	1.5	WST	Monop-orate	Granulate
24	Digitaira nodosa	Psilate	"	Ectoporus	Spheroidal	4.0	2.0	(18-) 20.5 (-23)	(18-) 20.5 (-23)	1.00	+	4.0	1.42	Verrucate	2.0	MST	"	Verrucate
25	Digitaria sanguinelis	Cloudy granulate	"	Endoporus	Spheroidal	5.0	2.0	(30-) 33 (-36)	(30-) 33 (-36)	1.00	-	5.0	2	Rugulate	2.0	MST	"	Fine granulate
26	Echinochloa colonum	Cloudy psilate	"	Ectoporus	Spheroidal	3.0	2.0	(18-) 21 (-24)	(19-) 21.5 (-24)	1.00	-	3.0	1.17	Scabrate	2.0	CST	"	Scabrate (coarse granulate
27	Echinochloa crus-galli	Psilate	Porate	Ectoporus	Spheroidal	6.0	2.0	(26-) 28.0 (-30)	(26-) 28.0 (-30)	1.1	+	3.0	1.53	Scabrate	2.0	CST	"	Scabrate
28	Eleusine indica	Granulate	"	Ectoporus	Spheroidal	3.0	2.0	(22-) 24.5 (-27)	(22-) 24.5 (-27)	1.00	+	3.0	0.86	Verrucate	2.0	MST	"	Fine granulate
29	Eragrostis minor	"	"	Endoporus	Spheroidal	4.0	2.0	(21-) 23.5 (-26)	(21-) 23.5 (-26)	1.00	+	4.0	1.66	Scabrate	2.0	MST	"	Scabrate
30	Heterpogon contourtus	Granulate	"	Ectoporus	Elliptical	7.0	2.0	(38-) 41 (-44)	(36-) 38.5 (-41)	1.00	-	7.0	1.99	Scabrate	2.0	MST	"	Scabrate
31	Imperata cylindrica	"	"	Ectoporus	Spheroidal	6.0	2	(27-) 32.5 (-38)	(27-) 32.5 (-38)	1.00	+	6.0	1.6	Granulate	2.0	MST	"	Fine granulate
32	Lolium multiflorum	"	"	Ectoporus	Ellipsoidal	5.0	2.0	(28-) 32.5 (-37)	(27-) 31 (-35)	1.02	+	5.0	1.76	Granulate	2.0	MST	"	Fine granulate
33	Oplismenus burmamii	Psilate	"	Ectoporus	Oblate	5.0	2.0	(23-) 26.5 (-30)	(22-) 25.5 (-29)	1.02	+	5.0	2.63	Verrucate	2.0	CST		Verrucate

+ = Operculum present CST = Closed spaced type WST = Widely spaced type -= Operculum absent MST = Medium spaced type

Pollen Morphological Data of Taxa Studied by Light & Scanning Electron Microscope

S. No	Taxon	Pollen type	Aperture type	Pore type	Pollen shape	Pore Size		Polar axis (µm)	Equatorial axis (µm)	P/E ratio	Operc-ulum	Annulus		Exine Ornamen-tation	Exine Thickness (µm)	Surface Pattern	No. of pores	Pollen group
						Length (µm)	Width (µm)					Diamter (µm)	Thickness (µm)					
34	Parapholis strigosa	Cloudy psilate	Porate	Ectoporus	Oblate	4.0	2.0	(26-) 29.5 (-33)	(22-) 27 (-32)	1.09	+	4.0	1.33	Granulate	2.0	WST	Monop-orate	Fine granulate
35	Paspalidium flavidum	Psilate	"	Ectoporus	Oblate	5.0	2.5	(25-) 28.5 (-32)	(24-) 27 (-30)	1.05	-	5.0	1.53	Scabrate	2.5	CST	"	Scabrate
36	Paspalum dilatatum	Granulate	"	Ectoporus	Spheroidal	5.0	2.0	(31-) 32.5 (-34)	(31-) 32 (-33)	1.01	+	5.0	1.56	Verrucate	2.0	CST	"	Verrucate
37	Paspalum distichium	"	"	Endoporus	Spheroidal	6.0	2.0	(32-) 39 (-46)	(32-) 39 (-46)	1.00	+	6.0	1.5	Granulate	1.5	MST	"	Fine granulate
38	Pennisetum americanum	"	"	Ectoporus	Elliptical	4.0	2.0	(30-) 33 (-36)	(28-) 31 (-34)	1.06	-	4.00	1.99	Scabratee	2.0	MST	"	Coarse granulate
39	Pennisetum lanatum	"	"	Ectoporus	Spheroidal	7.0	3.0	(33-) 34.5 (-36)	(33-) 34.5 (-36)	1.00	-	7.0	2.66	Scabrate	2.0	CST	"	Scabrate (Coarse granulate)
40	Phalaris minor	"	"	Ectoporus	Spheroidal	7.0	2.0	(37-) 38.1 (-42)	(37-) 38.1 (-42)	1.00	+	7.0	1.28	Granulate	2.0	MST	"	Fine granulate
41	Phleum himaliccum	"	"	Ectoporus	Spheroidal	4.0	1.5	(22-) 25 (-28)	(22-) 25 (-28)	1.00	+	4.0	1.99	Verrucate	2.0	MST	"	Verrucate
42	Phleum pratense	"	"	Endoporus	Oblate	3.0	2.0	(26-) 27.5 (-29)	(27-) 27 (-28)	1.01	+	3.0	1.87	Verrucate	2.0	CST	"	Verrucate
43	Phragmites australis	Cloudy granulate	"	Ectoporus	Ellipsoidal	6.0	2.5	(35-) 39 (-43)	(33-) 37 (-40)	1.05	+	6.0	2.6	Varrucate	2.0	MST	"	Verrucate
44	Poa annua	Granulate	"	Endoporus	Ellipsoidal	4.0	2.0	(27-) 29 (-31)	(26-) 28.5 (-31)	1.01	+	4.0	1.30	Granulate	2.0	CST		Fine granulate

+ = Operculum present
- = Operculum absent
CST = Closed spaced type
MST = Medium spaced type
WST = Widely spaced type

Pollen Morphological Data of Taxa Studied by Light & Scanning Electron Microscope

S. No	Taxon	Pollen type	Aperture type	Pore type	Pollen shape	Pore Size		Polar axis (μm)	Equatorial axis (μm)	P/E ratio	Operc-ulum	Annulus		Exine Ornamen-tation	Exine Thickness (μm)	Surface Pattern	No. of pores	Pollen group
						Length (μm)	Width (μm)					Diamter (μm)	Thickness (μm)					
45	Poa informa	Scaborate	Porate	Endoporus	Spheroidal	5.0	2.0	(22-) 25 (-28)	(22-) 25 (-28)	1.00	+	5.0	0.92	Verrucate	2.5	CST	Monop-orate	Verrucate
46	Poa nemoralis	Granulate	"	Endoporus	"	4.0	2.0	(20-) 22.5 (-25)	(20-) 22 (-24)	1.01	-	4.0	1.66	Verrucate	2.0	CST	"	Verrucate
47	Polypogon monspeliensis	Psilate	"	Endoporus	Spheroidal	3.0	2.0	(22-) 25 (-28)	(21-) 24.5 (-28)	1.02	+	3.0	1.35	Scabrate	2.0	MST	"	Scabrate
48	Saccharum spontaneum	"	"	Ectoporus	Oblate	6.0	2.0	(27-) 31.5 (-36)	(26-) 29.5(-33)	1.06	-	6.0	1.33	Granulate	2.0	CST	"	Fine granulate
49	Setaria glauca	"	"	Ectoporus	"	6.0	2.0	(35-) 38.5 (-42)	(35-) 38 (-40)	1.01	+	6.0	2.0	Granulate	2.0	MST	"	Fine granulate
50	Setaria pumila	"	"	Endoporus	"	6.0	2.5	(40-) 44.5 (-49)	(40-) 44.5 (-49)	1.00	+	6.0	2.66	Verrucate	2.0	CST	"	Verrucate
51	Sorghum halepense	"	"	Ectoporus	"	6.0	3.0	(39-) 61 (-82)	(36-) 56.4 (-80)	1.07	-	6.0	2.5	Granulate	2.0	MST	"	Fine granulate
52	Stipa splendens	"	"	Endoporus	Spheroidal	5.0	2.5	(25-) 29.5 (-34)	(25-) 29.5 (-34)	1.00	-	5.0	2.10	Granulate	2.0	CST	"	Fine granulate
53	Urochloa panicoides	"	"	Ectoporus	Spheroidal	5.0	2.0	(25-) 26.5 (-28)	(25-) 26.5 (-28)	1.00	+	5.0	2.00	Granulate	2.0	CST	"	Fine granulate
54	Vetiveria zizanoides	"	"	Ectoporus	Oblate	4.0	2.0	(24-) 26 (-28)	(24-) 25 (-26)	1.04	+	4.0	1.52	Granulate	2.0	WST	"	Fine granulate

+ = Operculum present
- = Operculum absent
CST = Closed spaced type
MST = Medium spaced type
WST = Widely spaced type

Chapter Five

(Discussion and conclusion)

Discussion and conclusion

The discussion considers data from grass morphology and palynology.

Gramineae is one of the largest cosmopolitan Angiosperm families having nearly 10,000 species. However according to Tzveler, 1989, it includes 898 genera and 10,300 species. The present thesis is the first palynological monograph of the family Gramineae, covering 54 species belonging to 37 genera from Islamabad. The previous taxonomic revision of the family was limited, therefore, in this study an attempt is made to revise and update the systematic position of the family. Moreover palynological study of the grasses of Islamabad was not conducted so far, therefore, for this purpose, taxonomically and palynologically significant characters were critically analyzed and many new considered and then a synthesis based on the correlation of these characters was made.

For determining the polarity of character takes extensive laboratory as well as field work. The field collection was done under the guidance and supervision of Dr. Mir Ajab Khan and Dr. Syed Zahoor Hussain, professor of Botany Reading University England and UNDP consultant for this project. The grasses are a very important group of Angiosperms and their identification is needed by the workers from different fields of Biological Sciences. However, the main purpose of this study is to distinguish allergy causing and other grasses of Islamabad. Because Islamabad is considered to be a pollen allergy causing area and the grasses are one of the most allergy causing groups of plants. The fresh plants with polliniferous material were collected from different sectors of Islamabad with special consideration of those sectors or areas where pollen allergy was reported on an almost epidemic scale. Plants were pressed as voucher specimens and microscopic slides for light and stubs for electron microscopic examination were prepared respectively. The attempts were made to evaluate and integrate the pollen data with those from vegetative and floral morphology. During this research project, the identification, classification, description and interpretation of the grass pollens were undertaken. The characters were first arranged in hypothetical sequences and then the polarity of characters were defined on the basis of correlation between the different character states. The resulting pattern of the groups based on the taxonomical and palynological data is manifested in the key to the genera and species. The salient points and conclusion of the present study are as follows:

Grasses are characterized by specialized units of infloresence called spikelets, arranged in different kinds of compound inflorescence. Inflorescence provides useful characters in many genera of family Poaceae. Apart from the general type of inflorescence, these characters includes differences in posture of the pedicels during and after anhesis, the angle and degree of branching and the manner of opening and development. Inflorescence types have been classified by Richett (1944, 1955) and are discussed by Eames (1961), who also considered the phylogeny of the inflorescence.

Mostly the classification within the family is based upon the characteristics of spikelets and their arrangements. The spikelets is a specialized condensed inflorescence unit represented in its various forms and modifications within the family Gramineae. It is generally composed of two to many (rarely single) florets. The various modifications of this basic unit lend to the diversity of the spikelet characteristics. The florets number varies from indefinite to a few to two or even one per spikelet.

With rare exceptions, the spikelets are generally arranged in compound inflorescence. These may constitute a raceme of spikelets, or a head of spikelets. The racemes or spikes or heads of spikelets may further be arranged in various forms. Here the family is classified into 7 groups depending on the arrangement and development of spikelets in different kinds of compound inflorescence. The classification is based on inflorescence types only and, therefore, no doubt it is an aritificial classification or grouping of grasses by only considering different kinds of inflerescences (Shaukat Ali, 1991). The purpose of this type of grouping is to simplify the identification of grasses superficially to sort out the allergy causing and non-allergy causing grasses of Islamabad. Although palynology of grasses of Islamabad was the nucleus of my research work but for the purpose of understanding the group I have to do the morphology of the taxa studied. Therefore, I have carried out the vegetative and floral morphology of the taxa. This grouping of grasses on the basis of inflorescence type was helpful in identification of grasses generally. The character of inflorescence types have been mainly utilized by Ali, 1991, for the classification of, Grasses of Saudi Arabia. Key to the genera of the family based on vegetative and floral morphology characters and key to the genera based on palynological characters (David, Roubik and Jorge Enrique Morenop, 1991) are given at the end

Group one includes the following five species: *Phragmites australis, Sorghum halepense, Saccharum spontaneum, Vetiveria zizanoides* and *Imperata cylindrica*. These species are tall grasses except *Imperata cylindrica* which is a short grass. Group one species could be separated by their panicle appearance, shape or form. *Sorghum halepense* and *Vetiveria zizanoides* show open, large, dense and non cotton like panicles. *Imperata cylindrica* is easily indentified and can be separated from rest of the species by its cotton like, open and cylindrical panicle. Where as *Phragmites australis* and *Saccharum spontaneum* exhibit open, dense but not large and cylindrical panicles. The grasses of group one are mainly distributed in humid and wet habitats. These five species follow C_3 pathway during photosynthesis indicating their closeness on ecological basis and their phylogenetically close relationship because these are included in the same sub-family Panicoideae and furthermore *Saccharum spontaneum, Vetiveria zizanoides, Sorghum halepense* and *Imperata cylindrica* are in the same tribe Andropogoneae with the exception of *Phragmites australis* which belong to tribe Arundineae.

All the grasses in this group have ectoporus pollens and their pollen size are almost similar except *Sorghum halepense* with average pollen size is 61.0μm as mentioned in table 7. They also belong to the panicoid group of grasses (Reeder 1957, 1962). All this data support their right position in group one.

The groups two-seven are smaller grasses, usually without woody culms and the inflorescence where panicles are not very large. The plants with inflorescence of terminal and or axillary paired spikes have been assigned to the group two. *Cymbopogon schoenanthus, cymbopogon flexuosus, Paspalum dilatatum, Paspalum distichium, Echinochloa colonum, Echinochloa crus-galli, Urochloa panicoides , Pasplidum flavidum, Brachiaria distachya* and *Brachiaria erusciformis* have been included in this group. The grasses of group two are distributed mainly in wet and some plants in aquatic habitat such as *Paspalum distichium, Echinochlea crus-galli*. All of them belong to C_3 pathway of photosynthesis indicating their closeness on ecological basis. They are also phylogenetically closely related because all of them are included in the same sub-family Panicoideae and *Paspalum dilatatum, Paspalum distichium, Echinochloa colonum, Echinochloa crus-galli, Urochloa panicoides, Paspalidum flavidum, Brachiaria distachya* and *Brachiaria eruciformis* to the tribe *Paniceae* but *Cymbopogon schoenanthus* and *Cymbopogon flexuosus* to different tribe *Andropogoneae.*

All the grasses in group two have ectoporus or endoporus pollens and their pollen size is almost similar except *Echinochloa coloum* as mentioned in table 7. They also belong to the panicoid group of grasses. All these information supports the right position of all the species included in group two.

Group three include grasses with inflorescence of digitate or subdigitate spikes, more than two on each terminal and/or axillary peduncle. These are *Cynodon dactylon, Dactyloctenium aegyptium, Elusine indica, Bothriochloa pertusa, Dicanthium annulatum* and *Dicanthium foveolatum*. *Digitaria* is distinguished from cynodon by its membranous ligules as compared to the ligules as fringe of hairs in cynodom. *Dactyloctenium* have spikes ending in the naked tip of rhachis where as Eleusine has spikes ending with spikelets. *Bothriochloa* is distinguished by its glabrous nodes from *Dicanthium* which has pubescent nodes. Grasses of group three are distributed mainly on humid and moist habitats. All of them belong to C_3 pathway of photosynthesis (Tieszen L., Senyimba, M. etal. 1979) indicating their closeness on ecological basis. The are phylogenetically not closely related because these are included in two different sub-families *Panicoideae* and *Eragrostoideae*.

Digitaria nodosa, Digitaria biformis, Digitaria sanguinalis belong to the tribe Paniceae and *Bothriochloa pertusa, Dicanthium annulatum* and *Dicanthium foveolatum* to the tribe *Andropogoneae* of the sub-family *Panicoideae* while *Dactyloctenum aegyptium* and *Eleusine indica* belong to the tribe *Chlorideae* of the sub-family *Eragraostoideae*. All the grasses in group three have both the ectoporus and endoporus pollen with medium size [(28-) 29.5 (-37)]μm.

Group four is characterized by dense, subspherical, ovate or ellipsoidal head like inflorescence. *Aristida adscensionis, Aristida funiculata, Eragrostis minor, Desmostachya bipinnata,* have been included in this group. Grasses of group four are distributed mainly in less humid and dry open habitats. All of them belong to C_4 pathway of photosynthesis (Tieszen etal 1979) indicating their closeness on ecological basis. They are also phylogenctically closely related because all of them belong to the same sub-family Eragrostoideae. All of the grasses in group four have endoporus pollens.

Group five is characterized by narrow or cylindrical spicate dense panicles. *Phalaris minor, Phleum himalaccum, Phleum pratense, Alopecurus myosuroides, Polypogon monspeliensis, Setaria glauca, Setaria pumila, Pennisetum americanum, Pennisetum lanatum, Cenchrus penistiformis* fall in this group. *Phalaris minor* is distinguished by its awnless spikelets from *Alopecurus myosuroides* which has awned spikelets. *Setaria* is distinguished by its bristles persisting on the axis after the spikelets have fallen where as in *Pennisetum* both bristles and spikelets fall off together. In *Cenchrus pennisetiformis* involucral bristles are flattened and united at the base, often forming a cup whereas in *Pennisetum* involucral bristles are free from each other. The grasses of group five are distributed mainly in humid and wet or sometime in aquatic habitats, e .g., *Polypogon monspeliensis*. All of them belong to C_3 pathway of photosynthesis (Tieszen etal., 1979) indicating their closeness on ecological basis. *Phalaris minor, Alopecurus myosuroides, Phleum himalaccum, Phleum pratense* and *polyporgon monenspeliensis*, phylogenetically related because they belong to the same sub-family Festucoideae but distinct from *Setaria glauca, setaria pumila, Pennisetum americanum, Pennisetum lanatum* and *Cenchrus penisctiformis* because they belong to the sub-family *Panicoideae*.

All the grasses of group five have ectoporus pollens except endoporus pollen of *Phleum pratense* and *Polypogon monspeliensis*.

Group six comprises the plants which have inflorescence of open or compacted terminal panicles or leafy false panicles sometimes accompanied by axillary panicles or axillary female inflorescence. *Chrysopogon aucheri, Avena ludoviciana, Avena sativa, Poa annua, Poa infirma* and *Poa nemoralis* are included in this group. The grasses of group six are distributed in less humid and moist habitat. All of these grasses belong to C_3 pathway of photosynthesis indicating their closeness on ecological basis. *Avena ludoviciana, Avena sativa, Poa annua, Poa infirma,* and *Poa nemoralis* are phylogenetically closely related because they belong to the same sub-family Festucoideae but not related phylogenetically with

Chrysopogon aucheri because the latter belongs to the sub-famaily Panicoideae. *Avena ludoviciana, Avena sativa* and *Chrysopogon auchri* have ectoporus pollen grains while *Poa annua, Poa infirma and Poa nemoralis* have endoporus pollen grains.

Group 7 taxa includes; *Brachypodium distachyon, Bromus catherticus, Bromus pectinatus, Bromus denthoniae, Bromus japonicus, Stipa splendens, Parapholis strigosa,* and *Lolium multiflorum.* These plants have inflorescence with single terminal and or axillary spikes or narrow spike-like panicles or narrow or open raceme or spike of spikes/spikelets. The grasses of group seven are distributed mainly in humid and wet habitat and all of them belong to C_3 pathway of photosynthesis indicating their closeness on ecological basis. They are also phylogenetically closely related because they are included in the same sub-family *Festucoideae*. All the grasses in group 7 have ectoporus and endoporus pollen grains and their pollen size almost similar i.e. of medium size [(28-) 32.5 (-37)]µm except *Parapholis strigosa* [(26-) 29.5 (-33)] and *Stipa splendens* [(25-) 29.5 (-34)]µm.

On the basis of phenology (study of periodicity in plants as related to climatic events, e.g., time of leafing, flowering, fruiting, budding, grasses of Islamabad can be divided into two groups

i) Vernal grasses (spring grasses)

ii) Aestival grasses (summer grasses)

The grasses included in these groups are given in following table.

Table 8

Poaceae	
Vernal grasses (spring grasses)	**Summer grasses (Aestival grasses)**
Alopecurus myosuroides	Aristida adscensionis
Avena ludoviciana	Aristida funiculata
Avena sativa	Bothriochloa pertusa
Brachypodium distachyon	Brachiaria distachya
Bromus catherticus	Brachiaria erusiformis
Bromus Japonicus	Cymbopon flexuosus
Bromus denthoniae	Cymbopogon schoenanthus
Broumus pectinatus	Dactyloctenum aegyptim
Cenchrus penisctiformis	Dicanthium foveolatum
Chrysopogon aucheri	Digitaria biformis
Desmostachya bipinnata	Digitaria nodosa
Dicanthium annulatum	Digitaria sanguinalis
Imperata cylindrica	Echinochloa colonum
Lolium multiflorum	Echinochloa crus-galli
Paspalum dilatatum	Eleusine indica
Pennisetum lanatum	Eragrostis minor
Phalaris minor	Heteropogon contortus
Phleum himalaccum	Oplismenis burmannii
Phleum pratense	Parapolis strigosa
Poa annua	Paspalidium flavidum
Poa infirma	Paspalum distichium
Polypogon monspaliensis	Pennisetum americanum
	Phragmites australis
	Poa nemoralis
	Saccharum spontaneum
	Setaria glauca
	Setaria pumila
	Sorghum halepense
	Stipa splendens
	Urochloa panicoides
	Vetiveria zizanoides

Grasses can also be divided into allergy causing and non-allergy causing grasses because pollen grains of most grasses are dispersed by wind and consequently large quantities become air borne and readily accessible to the human respiratory tract where they may induce an allergic response in atopic individuals. When grass pollens are moistened, they release a range of proteins from extracellular wall sites including various antigens (Knox and Heslop-Harrisen, 1977). From the data of Wright and Clifford (1965), it is clear that pollens from closely related grasses are more likely to produce similar allergic response then those from more distinctly related groups. These groups include the following taxa.

Table 9

Allergy causing grasses	**Non-allergy causing grasses**
Bromus japonicus	Allopecurus myosuroides
Bromus pectinatus	Aristida funiculata
Bromus catherticus	Aristida adscensionis
Cynodon dactylon	Bothriochloa pertusa
Lolium multiflorum	Brachiaria distachya
Paspalum dilatatum	Brachiaria erusciformis
Paspalum distichium	Brachypodum distachyon
Echinochloa crus-galli	Cymbopogon flexuosus
Phalaris minor	Cymbopogon schoenanthus
Phragmities australis	Dactyloctenum aegyptium
Poa annua	Desmostachya bipinnata
Sorghum halepense	Dicanthium annulatum
Setaria glauca	Dicanthium foveolatum
Imperata cylindrica	Digitaria nodosa
Avena sativa	Digitaria biformis
Cenchrus penistiformis	Digitaria sanguinalis
	Echinochloa colonum
	Echinochloa crus-galli
	Heteropogon contourtus
	Oplismenus burmannii
	Parapholis strigosa
	Paspalidium flavidum
	Saccharum spontaneum
	Stipa splendens
	Urochloa panicoides
	Vetiveria zizanoides
	Polypogon monspeliensis

The families of flowering plants may have different morphological pollen types i.e. eurypalynous (various types of pollen grains) or a single pollen type i.e., stenopalynous. Gramineae is a stenopalynous family and the general pollen surface patterning show very little variations, not only at the specific but also at the generic or even at the tribal level (Erdtmann 1952). Pollen grain of grasses are mostly very similar in appearance under light microscopy, (Faegri and Iverson 1966). Scanning electron microscopy provides better surface sculpturing and therefore, it is more helpful to assign grass pollens to major taxonomic series/groups.

The pollen morphological data of taxa studied by light microscopy shows that all the grasses/tribes are stenopalynous and, therefore, it is very difficult to distinguish the genera on the basis of pollen structure. However on the basis of characters revealed by light microscopy two types of pollen are identified in Gramineae which can be grouped as (a) Endoporus (b) Ectoporus.

Of the 54 species, 18 species showed an endoporus type apertures (*Aristida adscensionis, Bothriochloa pertusa, Brachypodium distachyon, Bromus japonicus, Bromus danthoniae, Cymbopogon flexuosus, Desmostachya bipinnata, Dicanthium foveolatum, Digitaria sanguinalis, Eragrostis minor, Paspalum distichium, Phleum pratense, Poa annua, Poa infirma, Poa nemoralis, Setaria pumila, Stipa splendens*, and *Polypogon monspeliensis*) and 36 species with ectoporus type which are *Alopecurus myosuroides, Aristida funiculata, Avena ludoviciana, Avena sativa, Brachiaria distachya, Brachiaria eruciformis, Bromus catherticus, Bromus pectinatus, Cenchrus penistiformis, Chrysopogon aucheri, Cymbopogon schoenanthus, Cynodon dactylon, Dactyloctenium aegyptium, Dicanthium annulatum, Digitaria biformis, Digitaria nodosa, Echinochloa colonum, Echinochloa crus-galli, Eleusine indica, Heteropogon contourtus, Imperata cylindrica, Lolium multiflorum, Oplismenus burmanii, Parapholis strigosa, Paspalidium flavidum, Paspalum dilatatum, Pennisetum americanum, Pennisetum lanatum,Phalaris minor, Phleum himalaccum, Phragmites australis, Saccharum spontaneum, Setaria glauca, Sorghum halepense, Urochloa panicoides*, and *Vetiveria zizanoides*. These two basic type groups could again be subdivided into (a) psilate and (b) granulate subtypes. Endoporus type pollen grains are mostly granulate and rarely psilate (out of 18 endoporus pollen type species only 2 species show psilate surface pattern in their pollens (*Cymbopogon flexuosus*, and *Desmostachya bipinnata*) likewise ectoporus pollen grains are generally granulate and rarely psilate. Out of 36 ectoporus types species 28 species are granulate (*Alopecurus myosusoides, Aristida funiculata, Avena ludoviciana, Avena sativa, Brachiaria distachya, Brachiaria eruciformis, Bromus catherticus, Bromus pectinatus, Chrysopogon aucheri, Cymbopogon schoenanthus, Dactyloctenium aegyptium, Digitaria nodosa, Eleusine indica, Heteropogon contourtus, Imperata cylindrica, Lolium multiflorum, Paspalum dilatatum, Pennisetum americanum,* *Pennisetum lanatum, Phalaris minor, Phleum hamalacum, Phragmites australis, Saccharum spontaneum, Setaria gluaca, Sroghum halepense, Urochloa panicoides, Vetiveria zizanoides,* and *Echinochloa crus-galli*) and only 8 psilate surface pattern (*Cenchrus pennictiformis, Cynodon dactylon, Dicanthium annulatum, Digitaria biformis, Echinochloa colonum, Oplismenus burmanii, Parapholis strigosa,* and *Paspalidium flavidum*)

Comparing pollen types and sub-types with each other it has been found that all the pollen grains of grasses look more or less similar in shape and structure but they differ in size. On the basis of size differences taxa studied in the present survey have been divided into three groups: (i) Small-sized pollens [(18-) 22.5 (-27)]µm. These are: *Alopecurus myosurvides, Aristida funiculata, Brachiaria eruciformis, Cynodon dactylon, Dactyloctenum aegyptium, Desmostachya bipinnata, Digitaria biformis, Digitaria nodosa, Echinochloa colonum, Echinochloa crus-galli, Eleusine indica, Eragrostis minor, Imperata cylindrica, Oplismenus burmannii, Parapholis strigosa, Paspalidium flavidum, Phleum himalaccum, Phleum pratense, Poa annua, Poa infirma, Poa nemoralis, Saccharum spontaneum, Stipa splendens, Urochloa panicoides, Vetiveria zizanoides,* and *Polypogon monspeliensis* (ii) Medium size pollen

[(28-) 29.5 (-37)]µm. These are: *Aristida adscensionis, Bothriochloa pertusa, Brachiaria distachya, Brachypodium distachyon, Bromus catherticus, Bromus japonicus, Bromus pectinatus, Bromus danthoniae, Cenchrus penisctiformis, Chrysopogon aucheri, Cymbopogon flexuosus, Cymbopogon schoenanthus, Dicanthium annulatum, Dicanthium foveolatum, Lolium multiflorum, Paspalum dilatatum, Paspalum distichium, Pennisetum americanum, Pennisetum lanatum, Phalaris minor, Phragmities australis,* and *Setaria glauca)* (iii) Large-sized pollen [(38-) 60.0 (-82)]µm. These are: *Avena ludoviciana, Avena sativa, Heteropogon contourtus, Setaria pumila,* and *Sorghum halepense*.

This grouping of pollens on the basis of their sizes overlap more or less with the endoporus and ectoporus grouping. All the 3 types i.e., small, medium, and large pollens are randomly distributed within the endoporus and ectoporus groups. In certain species e.g. *Cynodon dactylon* pollen size has proved helpful in distinguishing polyploid taxa from diploid ones (Sachdeva and Bhatia, 1979). Fibras (1937) demonstrated that the pollen of wild grasses measured 20-30μm and that of cereal measured over 35.0 μm. However, Faegri & Iverson (1975) considered 40.0 μm as a dividing line between the two. My findings are generally similar to that of Faegri and Iversen but I have also observed that in all the tribes studied so far, there seems to be all sorts of overlapping as for as the grains size concerned.

Scanning electron microscope proved a useful tool for palynologists as it reveals a detailed examination of sculpturing of pollen exines. The pollen surface pattern data of taxa studied by scanning electron microscope show differences in exine ornamentation and in surface pattern. Three main types of pollen are recognized on the basis of exine ornamentation and surface pattern:

(i) Closely spaced type (CST)

(ii) Medium spaced type (MST)

(iii) Widely spaced type (WST)

Each of these three basic types have been further subdivided into operculate and non-operculate sub-types. Present findings are similar as observed by Faegri and Iverson (1964) who found that grasses and cereals had predominantly granulate sculpturing. Nevertheless the taxonomic significance of grass pollen is very limited as demonstrated by Page (1978). This is also evident from table 7, which shows that at the tribe level on the basis of exine ornamentation and surface pattern, even if arranged in sequence, the tribes form no definite order. All types of surface pattern or exine ornamentations occur within the same tribe. All the three types of surface patterns i.e., closely, medium or widely spaced types are present within one tribe. However all the three types of surface patterns are helpful within the tribe at generic level, i.e., in the tribe Festuceae (3 genera, 8 species), closely spaced type sculpturing was observed except in *Bromus danthoniae* and *Lolium multiflorium* which have widely spaced granule and medium spaced granule pattern respectively. Tribe *Aveneae* (5 genera, 7 species) showing medium spaced type sculpturing except *Alopercurus myosuroides* and *Phleum pratense* which have closely-spaced type sculpturing. In tribes *Triticeae, Stipeae* and *Monermeae* (one species each) medium spaced type sculpturing was present. In tribe Paniceae (10 genera, 17 species) with closely-spaced type sculpturing, except in *Digitaria sanguinalis* and *Paspalum distichium* which have medium-spaced type sculpturing and in

Digitaria biformis which has widely space-type pattern. In tribe *Andropogoneae* (8 genera, 10 species) *Bothriochloa pertusa, Dicanthium annulatum, Dicanthium foveolatum, Chrysopogon aucheri* and *Saccharum spontaneum* have closely-spaced type sculpturing where as, *Cymbopogon schoenanthus, Heteropogon contourtus, Imperata cylindrica* and *Sorghum halepense* have medium-spaced type sculpturing while *Cymbopogon flexuosus* has widely spaced type pattern. In tribe *Aristideae* (1 genus, 2 species) Aristida adscensionis *Aristida funiculata* exhibit both closely spaced type and widely spaced type sculpturing. In tribe Eragrosteae (one species) *Eragrostis minor* and in tribe *Arundineae* (one species) *Phragmities australis* show medium spaced type ornamentation. In tribe Chlorideae (4 genera, 4 species) closely-spaced type sculpturing was present.

Faegri & Inverson,1964 divided pollen into shape classes spherical, prolate and oblate. In present investigation it was found that in general, pollen are spheriodal, rarely oblate or ellipsoidal. In *Avena ludoviciana, Avena sativa, Chrysopogon aucheri, Dicanthium foveolatum, Oplismenus burmannii, Parapholis strigosa, Paspalidum flavidum, Phleum pratense, Saccharum spontaneum, setaria glauca* and *Setaria pumila, Sorghum halepense* and *vetiveria zizanoides* have oblate pollens while *Alopecurus myosuroides, Bromus catherticus, Heteropogon contourtus, Lolium multiflorum, pennisetum americanum, Phragmities australis* and *Poa annua* have ellipsoid pollen grains.

Operculate and non-operculate pollen grains were also found in all the tribes. However, at the generic level few genera like, *Bromus* (4 species) *Cymbopogon* (2 species), *Paspalum* (2 species) showed exclusively operculate pollen grains, in *Digitaria* (3 species) and *Pennisetum* (2 species) exhibit non-operculate grains only. In other genera both operculate and non-operculate pollen grains were present within the same genus and in some cases are characterstics of species. It can be concluded that operculate and non-operculate pollen types are good characters which are helpful in some cases at specific level with in the Poaceae. It was observed that annulus thickness has much variations in the family and an attempt was made to separate genera on the basis of this character. In stenopalynous family a key based upon pollen morphology is not possible because several important pollen features repeat themselves in different genera and species. However the characters like those of aperture, pore, exine ornamentation, shape and size are fixed and are of basic type in Grameneae the key formulated by using these characters is given at the end. Finally my results (table 7) confirm the observation of Faegri and Iverson (1964) who found that wild grasses and cereals had predominantly granulate sculpturing and support and extend the observations of Qaiser & Siddiqui, (Pers. communication) who divided the grasses into groups on the basis of proximity of granules (scabrae).

The very objective of the present reseach work was pollen collection from more than 60 allergy causing grasses, shrubs and trees, cultivated plants and ornamental flowers representing different families of Islamabad. I was assigned the pollen collection of more than 50 allergy causing and other grasses of Islamabad. With the endeavour of this work collected pollens were used for the preparation of permanent slides for light microscopic and scanning electron microscipic observations. In conclusion, this reserach project has helped in collection, identification and characterization of pollens causing allergy. With the help of this reserach project the specific pollen and plants of Poaceae causing allergy in Islamabad were indentified and pure pollens of allergy causing grasses to build up the pollen bank at National Institute of Health (NIH). This research work has contributed towards the preparation of standarized specific extracts in National Institute of Health (NIH) which would be made available to general public in future. It is hoped that with the help of this research work pollen allergy diseases will be checked and ultimately cured in future.

Key to the Genera of the family Poaceae

1a.	Spikelets 1-many flowered, breaking up at maturity above the ± persistent glumes, or if falling entire then not 2-flowered with the upper floret bisexual and the lower male or sterile, spikelets usually laterally compressed or terete --	2
2a.	Mouth of leaf sheath without auricles, inflorescence a spike with the spikelets sunk in cavities in the rhachis------------------	Parapholis
2b.	Mouth of the leaf sheath with auricles, inflorescence not sunk in the cavities---	3
3a.	Ovary with a fleshy, hairy apical appendage, the styles arising from beneath it---	4
4a.	Inflorescence an open or contracted panicle--------------------	Bromus
4b.	Inflorescence a spike or raceme, spikelets solitary at the nodes of the rhachis, several flowered--------------------------	Brachypodium
3b.	Ovary sometimes hairy at the tip but without a fleshy hairy apical appendage, the styles terminal---------------------------	5
5a.	Spikelets containing 1-fertile floret, with or without 1 or 2 male or sterile florets below it or 1 or more above------------------	6
6a.	Inflorescence of racemes or solitary spikes with a digitate or scattered along the axis--	Cynodon
6b.	Inflorescence a panicle, either open or contracted and spike-like---	7
7a.	Lemmas bearing a 3-branched awn ----------------------------	Aristida
7b.	Lemmas with unbranched awn or awnless---------------------	8
8a.	Lemmas indurated at maturity, if hyaline 2 stout scabrid bristles--	Stipa
8b.	Lemmas hyaline or membranous at maturity, not bilobed -------	9
9a.	Spikelets strictly 1-flowered --	10
10a.	Panicle very dense, cylindrical, spike-like or ovoid--------------	11
11a.	Spikelets falling entire, glumes often connate below, lemmas usually awned, sometimes awnless, the margins often connate below, palea absent--	Alopecurus

11b. Spikelets breaking up above the persistent glumes, the latter free below, lemma awnless, the margins free, palea almost as long as the lemma-- Phleum

10b. Panicle lax, if dense then lobed or interrupted ------------------ Polypogon

9b. Spikelets with more than 1-floret although the 2 lowermost may be reduced to small chaffy scales at the base of the fertile lemma -- 12

12a. Spikelets 3-flowered, the 2 lowest florets male or sterile, fertile, lemma indurated, shining, longer than the others, the latter reduced to small scales ------------------------------------ Phalaris

12b. Spikes 2-several flowered, the lowest florets bisexual, the succeeding similar than the sterile ------------------------------- Avena

5b. Spikelets containing 2 or more fertile florets ------------------ 13

13a. Tall reed-like grass with large plumose panicles -------------- Phragmites

13b. Slender grass without large plumose panicles ----------------- 14

14a. Lemmas 1-3 nerved, if 5-nerved then plant producing cleistogamous spikelets from the lower sheaths -------------- 15

15a. Spikelets in open contracted or spike-like panicles ----------- Eragrostis

15b. Spikelets sessile or very shortly pedicelled loosely to densely imbricate in digitate or racemosely arranged spikes or spike-like racemes, very rarely in solitary spikes ----------- 16

16a. Axis of the spikes terminating with a sharp point, upper glume mucronate or awned, spikes digitate -------------------------- Dactyloctenium

16b. Axis and branches of the inflorescence ending in a spikelet --- 17

17a. Spikelets falling entire at maturity from the axis of straight spikes, the latter numerous and crowded into a long narrow dense panicle, glumes 1-nerved --------------------------------- Desmostachya

17b. Spikelets breaking up at maturity, spikes few to several, persistent --- Eleusine

14b. Lemmas 5-many-nerved, if 3-nerved then lemma with a blunt broadly hyaline tip --- 18

18a. Lateral spikelets without a lower lemmas rounded on the back--- Lolium

18b. All spikelets bearing both lower and upper glumes, inflorescence an open or contracted panicle, lemmas keeled on the back ------ Poa

1b. Spikelets 2-flowered falling entire at maturity with the upper floret bisexual and the lower male or sterile and in the latter case often much reduced, spikelets usually dorsally compressed ----- 19

19a. Spikelets solitary rarely paired with the spikelets all alike, glumes usually membranous, the lower mostly smaller or sometimes suppressed, upper lemma papery to polished and stony usually awnless -- 20

20a. Spikelets not subtended by bristles ------------------------------ 21

21a. Lower glume awned --- Oplismenus

21b. Lower glume at most with a short awn-pointed -------------- 22

22a. Upper lemma coriaceous to crustaceous with narrow inrolled margins, clasping only on the edge of the palea -------------- 23

23a. Lower glume absent --- Paspalum

23b. Lower glume present -- 24

24a. Raceme mostly 4-rowed, the spikelets in clusters of 2 or more spikelets, gibbously plano-convex, cuspidate to awned, upper lemma acute, muticous, upper palea acute with reflexed tip ---- Echinochloa

24b. Racemes mostly 1-2-rowed, the spikelets single or paired, rarely more--- 25

25a. Upper palea acute, its tip reflexed, lower glume turned away form the rhachis -- Paspalidium

25b. Upper palea obtuse, its tip erect not reflexed ----------------- 26

26a. Upper lemma or most obscurely mucronulate spikelets obtuse to acute, lower glume upto half as long as spikelet, turned towards the rhachis -- Brachiaria

26b. Upper lemma obtuse, with a mucro relatively larger, 0.3-1.2 mm long, spikelets usually much exceeding the upper floret cuspidate to acuminate, lower glume turned away from the rhachis ------- Urochloa

22b. Upper lemma cartilaginous, with thin flat margins covering most of the palea or even overlapping above it --------------------------- Digitaria

20b. Spikelets or some of them subtended by 1-many bristles or

	spines --	27
27a.	Bristles persisting on the axis often the spikelets have fallen ---	Setaria
27b.	Bristles or spines falling with the spikelets ----------------------	28
28a.	Involucral bristles free throughout ± filiform -------------------	Pennisetum
28b.	Involucral bristles flattened and connate below, commonly forming a cup --	Cenchrus
19b.	Spikelets typically paired with one sessile and the other pedicelled. Those of each pair usually dissimilar rarely with the spikelet, all alike, glumes as long as spikelets enclosing the florets ± rigid and firmer than the hyaline or membranous lemmas, upper lemmas often with a geniculate awn ---------------------------------------	29
29a.	Spikelets of each pair alike, at least one of them pedicelled ----	30
30a.	Panicle spike like silvery not obviously composed of raceme spike axis tough, both spikelets of a pair pedicelled ------------	Imperata
30b.	Panicle open or contracted if racemose, the component raceme distinct spike axis fragile spikelets pedicelled and sessile in each pair --	Saccharum
29b.	Spikelets of each pair different, sometimes the pedicelled much reduced or rarely suppressed, but then the spikelets all alike ----	31
31a.	Raceme arranged in a panicle with its common axis lager than the lowest raceme, not supported by spathe --------------	32
32a.	Sessile spikelets dorsally compressed --------------------------	Sorghum
32b.	Sessile spikelets laterally compressed, or terete ----------------	33
33a.	Raceme reduced to one sessile and or two additional pairs below	Chrysopogon
33b.	Raceme composed of many pairs or spikelets ------------------	Vetiveria
31b.	Raceme solitary paired or subdigitate often supported by spathe	34
34a.	Awn from the sinus of the two toothed fertile lemma or if lemma awnless then raceme reduced to a three heteromorphs spikelets endosed in a spathe. Leaves more or less aromatic upon crushing---	Cymbopogon
34b.	Awn form the tip of the narrow fertile lemma or if lemma awnless then raceme with an envolucre composed of two homogamous pairs of spikelets. Leaves not aromatic ---------------------------	35

35a. Callus pungent, awn large twisted into a bundle at the tip of raceme -- Heteropogon

35b. Callus obtuse, awn small and not twisted -------------------------- 36

36a. Joints of the pedicelled with a longitudinal furrows ------------- Bothriochloa

36b. Joints of the pedicell without a translucent furrow --------------- Dicanthium

Key to genera and species based on palynological characters of the family Gramineae

1a. Psilate-cloudy psilate

2a. Pore ≤ 2.0μm (diameter)

3a. Annulus 1.5μm wide

4a. Ectoporus, non-operculate, 18-24μm	Echinochloa colonum
4b. Endoporus, operculate, 21-24μm	Desmostachya bipinnata
4c. Ectoporus, operculate, 26-33μm	Parapholis strigosa
4d. Ectoporus, non-operculate, 28-32μm	Dicanthium annulatum

2b. Pore 2.0 or > 2.0μm

3b. Annulus > 1.5μm

5a. Ectoporus, non-operculate, 21-26μm	Cyanodon dactylon
5b. Ectoporus, non-operculate, 22-30μm	Digitaria biformis
5c. Ectoporus, operculate, 23-29μm	Oplismenus burmannii
5d. Ectoporus, non-operculate, 25-32μm	Paspalidium flavidum
5e. Endoporus, non-operculate, 18-24μm	Cymbopogon flexuosus
5f. Ectoporus, non-operculate, 34-37μm	Cenchrus penisctiformis

1.b. Granulate, scabrate or verrucate

6a. Pore 1.5-2.0μm

7a. Annulus 0.5-2.0μm

8a. Endoporus, non-operculate, 20-25μm	Poa nermoralis
8b. Ectoporus, operculate, 20-35μm	Dactyloctenium aegyptium
8c. Endoporus, operculate, 21-26μm	Eragrostis minor
8d. Ectoporus, operculate, 22-27μm	Eleusine indica
8e. Ectoporus, operculate, 22-28μm	Phleum himalaccum
8f. Endoporus, operculate, 22-28μm	Poa infirma
8g. Endoporus, operculate, 22-28μm	Polypogon monspeliensis
8h. Ectoporus, operculate, 24-28μm	Vetiveria zizanoides

8i. Ectoporus, non-operculate, 22-28μm .... Aristida funiculata

8j. Ectoporus, operculate, 25-28μm .... Urochloa panicoides

8k. Endoporus, operculate, 26-29μm .... Phleum pratense

8l. Ectoporus, non-operculate, 26-31μm .... Alopecurus myosuroides

8m. Endoporus, operculate, 27-31μm .... Poa annua

8n. Ectoporus, non-operculate, 27-36μm .... Saccharum spontaneum

8o. Ectoporus, operculate, 27-38μm .... Imperata cylindrica

8p. Ectoporus, operculate, 28-37μm .... Lolium multiflorum

8q. Ectoporus, operculate, 29-36μm .... Digitaria nodosa

8r. Endoporus, non-operculate, 30-36μm .... Digitaria sanguinalis

8s. Ectoporus, non-operculate, 30-36μm .... Pennisetum americanum

8dd. Ectoporus, operculate, 30-37μm .... Cymbopogon schoenanthus

8t. Ectoporus, operculate, 25-32μm .... Paspalum dilatatum

8u. Endoporus, operculate, 31-34μm .... Bromus japonicus

8v. Endoporus, operculate, 32-34μm .... Paspalum distichium

8w. Ectoporus, operculate, 32-36μm .... Bromus pectinatus

8x. Endoporus, operculate, 32-37μm .... Bromus danthoniae

8y. Ectoporus, non-operculate, 32-37μm .... Chrysopogon aucheri

8z. Endoporus, operculate, 33-39μm .... Aristida adscensionis

8aa. Ectoporus, operculate, 35-42μm .... Setaria glauca

8bb. Ectoporus, operculate, 37-42μm .... Phalaris minor

8cc. Ectoporus, non-operculate, 38-44μm ...... Heteropogon contourtus

6b. Pore 2-3μm

7b. Annulus>2.0μm

9a. Ectoporus, non-operculate, 21-26μm .... Brachiaria eruciformis

9b. Endoporus, non-operculate, 25-34μm .... Stipa splendens

9c. Endoporus, operculate, 29-34μm .... Brachypodium distachyon

9d. Ectoporus, operculate, 30-35μm .... Brachiaria distachya

9f. Ectoporus, operculate, 32-36μm .... Bromus catherticus

9g. Endoporus, operculate, 32-39μm .... Dicanthium foveolatum

9h. Ectoporus, non-operculate, 33-36μm ...... Pennisetum lanatum

9i. Ectoporus, operculate, 35-43μm .... Phragmites australis

9j. Ectoporus, operculate, 38-42μm .... Avena ludoviciana

9k. Ectoporus, non-operculate, 39-82μm ...... Sorghum halepense

9l. Endoporus, operculate, 40-49μm .... Setaria pumila

9m. Ectoporus, non-operculate, 47-55μm ..... Avena sativa

Table 8

List of Specimen Examined for Identification of the Taxa Studie

Taxon	Specimen No.	Locality	District	Collected by	Determined by
Alopecurus myosuroides	824 (88809)	Nwansher Chak Shazad	Hazara Islamabad	Muqarrab Shah Mohammad Azam	Tanveer Akhtar Mir Ajab Khan
Aristida adscensionis	1892 (57667) 516 (31236) (15786)	Sahensa Mach University Campus "	Kotli Baluchinstan Islamabad "	Shazad & Nasir Iqbal Dar & M. Arif Manzoor M. Javaid Mohammad Azam	Tanveer Akhtar Tanveer Akhtar Tanveer Akhter Mir Ajab Khan
Aristida funiculata	1336 (72310) 1572 (68845) 78	Balakot Joora Dhoke Habib University Campus	Monshera Muzzaffarabad Rawalpindi Islamabad	Mir Ajab Khan Shahzad Sarfraz Khan & M.Akhtar Mohammad Azam	Tanveer Akhtar Tanveer Akhtar Tanveer Akhtar Mir Ajab Khan
Avena ludoviciana	65 (48873) 200 (88804) 445 (53598)	Panjar Gali Jagir Shah sadarudin Near Foreign Office	Rawalpindi Campballpur D.G. Khan Islamabad	Manzoor & Ashraf Shahzad A. Maqsood A. Saboor Lodhi & Nasir A. Mohammad Azam	Tanveer Akhtar Tanveer Akhtar Tanveer Akhtar Mir Ajab Khan
Avena sativa	591 (04676) 846 (47890) 270 (43087)	C.D.A Nursary Chak No. 8 Kala Shah Kaku Chak Shahzad	Islamabad Sargodha Lahore Islamabad	Arif and Mehmood Mir Ajab K. & M. Ashraf Maqarrab Shah & Ayaz A. Mohammad Azam	Tanveer Akhtar Tanveer Akhtar " Mir Ajab Khan
Bothriochloa pertusa	8430 (122748)	Zürich University Campus	Switzerland Islamabad	K.U. Kramer Mohammad Azam	- Mir Ajab Khan
Brachiaria distachya	32 (63193) 737 (33341) (41471)	Margalla Hills Jagir Kaghan Valley Swat Aligai University Campus	Islamabad Hazara Swat Islamabad	Nasir & Ayaz Shaukat & Nasir Dilawar & Naeem Shah Mohammad Azam	Tanveer Akhtar Tanveer Akhtar " Mir Ajab Khan
Brachiaria eruciformis	519 (61370) 116 (61388) (30894)	Speenmam Manzai Quetta University Campus	N. Waziristan D.I.Khan Quetta Islamabad	Hafeezullah & Ayaz " A.R. Baig Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Brachypodium distachyon	1861 (123266) 372 (122765)	Anavryta State Below khuzareb top Zero Point	Attika Hunza Islamabad	Ph. Ch. L. Leutweinde-Fellendeg M.N. Chaudhry & Mir A. Mohammad Azam	- - Mir Ajab Khan
Bromus catherticus	79 (31397)	Company Bagh Aabpara	Rawalpindi Islamabad	Shahzad & Ashraf Mohammad	- Mir Ajab Khan

Bromus danthoniae	553 (31379) 974 (53705) 360 (53647)	Urrak to Hanna Hazarganja Staff College Quetta Aabara G-6	Quetta Kalat Quetta Islamabad	Baldar & Ashraf Manzoor & Maqsood " Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Bromus japonicus	143 (88863) 824 (48968) 757 (31052)	Bakot Pista Khara Lawrancepur University Campus	Hazara Peshawar Campbellpur Islamabad	Shahzad Iqbal Muqarrub & Ayaz A. M.N. Chaudhry Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Bromus pectinatus	291 (107227) 126 (104457) -	Margalla Hills Aabpara Aabpara	Islamabad " "	Tanveer & Khalid " Mohammad Azam	- Dilawar Mir Ajab Khan
Cenchrus penisctiformis	77 (76586) 2377 (31200) 84 (70381) -	Sector F-6/2 Muzzaffarabad National Park University Campus	Islamabad Muzzaffarabad Rawalpindi Islamabad	Manzoor & Dilawar Jan Mohammad Arif, Afzal & Khan Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Chrysopogon aucheri	27 (33309) 83 (57201) 78 (73615) -	Margalla Hills Chaman Kot Gujar Khan University Campus	Rawalpindi Poonch (A.K) Rawalpindi Islamabad	Ashraf & Maqsood Shahzad, Nasir & Zulfiqar Manzoor & Ayaz Mohammad Azam	- - - Mir Ajab Khan
Cymbopogon flexuosus	(36640) 56 (40085) 424 (36611) -	Islamabad Peshawar Road Muzzaffarabad Staff Colony	Islamabad Rawalpindi Muzzaffarabad Islamabad	M. Ashraf & Sarfaraz Ashraf, Manzoor & Maqsood Ch. Jan Mohammad Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Cymbopogon schoenanthus	(04739) (107244) -	Ayub Park Zero Point University Campus	Rawalpindi Islamabad "	Nasreen Shafi Tanveer, Khalid & Dilawar Mohammad Azam	- - Mir Ajab Khan
Cyanodon dactylon	(102047) 269 (110912) 49 (44297) -	Saidpur Margalla Hills Hajira Near Govt College University Campus	Islamabad Poonch (A.K.) Loralai Islamabad	Ashraf & Maqsood Bashir Ahmed & Javaid Iqbal Dar & Ashraf Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Dactylocteni-um aegyptium	(04554) 32 (40064) 683 (05058) -	Margalla Hills Pind Dadan Khan Nawe Rali Sector G-8	Islamabad Jhelum Swat Islamabad	Faiqah, Rizwan, Afzal, etal M.A. Siddiq, M. Akram Muqarrab, Manzoor, Javaid Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Demostachya bipinnata	108 (45682) 2157 (81365) 312 (110949) -	Yasman Burhan Zero Point Zero Point Sector G-8	Bahawalpur Attock Rawalpindi Islamabad	Mir Ajab Khan & Manzoor Shahzad Iqbal & Nisar Dilawar, Nisar & Khalid Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Dicanthium annulatium	600 (39718) 1458 (107234) 952 (53601) -	Kahotti Near Aabpara Chichian Near France Embassy	Rawalpindi Islamabad Mirpur (A.K.) Islamabad	Shahzad, Arif & Manzoor Khalid & Javaid Shahzad & Arif Mohammad Azam	- - - Mir Ajab Khan

Dicanthium foveolatum	(5737) 22 (94357) -	Dhokri Murree Road Sector G-6/4 Sector G-6/3	Islamabad " "	A. Siddiqui & A. Chaudhry Akram & Maqsood Mohammad Azam	- - Mir Ajab Khan
Digitaria biformis	1425 (36530) 53 (65652) 37 (70341) -	Kotherian Sector H-9 University Campus University Campus	Hazara Islamabad " "	Shaukat & Nisar Nisar & Ayaz " Mohammad Azam	Mrs Tanveer Akhtar " " Mir Ajab Khan
Digitaria nodosa	1158 (49009) 325 (04672) 1172 (31822) -	Kuthwai Miesriot Dam Dodar University Campus	Sargodha Rawalpindi Hazara Islamabad	Mir Ajab Khan Iqbal Dar & Anjum Shaukat & Nisar Mohammad Azam	Mrs Tanveer Akhtar " " Mir Ajab Khan
Digitaria sanguinalis	88 (15905) - -	Muzzaffarabad University Campus University Campus	Muzzaffarabad Islamabad "	Jan Mohammad M. Arif & Nisar Ahmed Mohammad Azam	Tanveer Akhtar " Mir Ajab Khan
Echinochloa colonum	58 (65648) (30953) 4197 (36616) -	Sector H-9 Ayun Muzzaffarabad Sector H-8	Islamabad Chitral Muzzaffarabad Islamabad	Nisar & Ayaz A.R. Baig Jan Mohammad Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Echinochloa crus-galli	20 (65693) 1139 (31815) 125 (39666) -	Rawal Dam Balokaii Chonak Near Super Market	Islamabad Hazara Skardu Islamabad	Arif & Akram Shaukat & Nisar Awalkat S. & Ishrit Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Eleusine indica	610 (104571) 46 (73584) 292 (53612) -	Stream near Aabpara Mallpur Shahbazabad Sector F-6/2	Islamabad " Bannu Islamabad	Nisar, Wali & Dilawar Akram, Dilawar Hafizullah & Dilawar Mohammad Azam	- - - Mir Ajab Khan
Eragrostis minor	36 (15769) 32 (65708) 634 (112077) -	Near Russian Embassy Margalla Hills Lakki University Campus	Islamabad " Bannu Islamabad	Ashraf & Manzoor H. Manzoor & Nisar M. Zubair & Saeed Mohammad Azam	- - - Mir Ajab Khan
Heteropogon contourtus	21 (65788) 334 (15872) 1265 (70351) -	University Campus Muzzaffarabad Kastrilla Station University Campus	Islamabad Muzzaffarabad Quetta Islamabad	Manzoor & Maqsood N. Chaudhry & A. Siddiqui Mansoor & Maqsood Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Imperata cylindrica	1010 (94369) 48 (94491) 120 (31161) -	Loon Bagha to Chitar Margalla Hills Zero Point Near France Embassy	Muzzaffarabad Islamabad " "	Shahzad Iqbal & Nisar Dilawar & Arif Manzoor & Maqsood Mohammad Azam	- - - Mir Ajab Khan
Lolium multiflorum	(37847) 697 (39722) -	Dungian Nursary Gharda Hills Near NIH	Muzzaffarabad " Islamabad	Jan Mohammad Shahzad, Jan M. & Dilawar Mohammad Azam	Tanveer Akhtar " Mir Ajab Khan

Oplismenus burmannii	53 (15826) 137 (102326) -	Murree Sector F-6/2 "	Rawalpin Islamabad "	M. Ashraf & Sarfraz Khan Nisar & Dilawar Mohammad Azam	- Tanveer Akhtar Mir Ajab Khan
Parapholis strigosa					
Paspalidium flavidum	87 (70380) 2 (63185) 123 (84921) -	National park Margalla Hills USA Emabassy University Campus	Rawalpindi Islamabad " "	Arif, Afzal & Akram Nisar & Ayaz Arif & Nisar Abbas Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Paspalum dilatatum	(04833) 7 (94379) -	Company Bagh Sector F-6/3 SBC	Rawalpindi Islamabad "	Mohammad Arif M. Ayaz Abbassi Mohammad Azam	Tanveer Akhtar - Mir Ajab Khan
Paspalum distichium	(04574) 32 (39725) 302 (2337) -	Sector F-7/2 Mughal Gardan National park Sector G-7/2	Islamabad Rawalpindi " Islamabad	Arif & Manzoor Ashraf, Manzoor & Maqsood Arif and Akram Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Pennisetum americanum	65 (65665) (15655) 1302 (72322) -	Dhoke Habib Sector G-6/2 Chattar SBC	Rawalpindi Islamabad Rawalpindi Islamabad	Sarfaraz & M. Akram Rizwana & Fiqah Manzoor & Maqsood Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Pennisetum lanatum	459 (05018) (97062) -	Uthror Changmachan Zero Point	NWFP Skardu Islamabad	Muqarrab Shah & Manzoor Mir Ajab & Nisar Mohammad Azam	Tanveer Akhtar " Mir Ajab Khan
Phalaris minor	797 (04875) 142 (13216) 981 (48922) -	Rawal Dam University Campus Jatlan Zero Point	Islamabad " Mirpur (A.K.) Islamabad	Manzoor & J. Akhtar Manzoor & Maqsood Shahzad & Arif Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Phleum himalaccum	1064 (100353) (49012) -	Dawanian Dadar Sector G-7/2	Muzzaffarabad Hazara Islamabad	Shahzad, Iqbal & Ayaz Muqarrab & Ayaz Mohammad Azam	Tanveer Akhtar " Mir Ajab Khan
Phleum pratense	972 (57690) 33 (31046) -	Rambur Monshera Near Aabpara	Chitral Hazara Islamabad	Muqarrab & Dilawar Shaukat & Nisar Mohammad Azam	Tanveer Akhtar " Mir Ajab Khan
Phragmites australis	(15653) 41 (75350) -	University Campus Air Port University Campus	Islamabad " "	Nisar & Javaid Manzoor & Afzal Mohammad Azam	- - Mir Ajab Khan
Poa annua	273 (104528) 288 (15676) -	Rawal Dam Ayub park Near Aabpara	Islamabad Rawalpindi Islamabad	Nisar, Javaid & Saeed M. Arif & Nisar Mohammad Azam	- - Mir Ajab Khan
Poa infirma	240 (110960) 5 (89320) -	American Embassy National Park University Campus	Islamabad Rawalpindi Islamabad	Nisar, Khalid & Dilawar Ayaz & Wali Mohammad Azam	- - Mir Ajab Khan
Poa nemoralis	-	University Campus	Islamabad	Mohammad Azam	Mir Ajab Khan

Polypogon monspeliensis	28 (309990) 1398 (107252) 253 (04732) -	National Park Margalla Hills Katas Raj University Campus	Rawalpindi Islamabad Jhelum Islamabad	Iqbal & Ashraf, Maqsood Wali & Nisar M.N. Chaudhri Mohammad Azam	Tanveer Akhtar " " Mir Ajab Khan
Saccharum spontaneum	10 (65704) 374 (102356) 368 (74301) -	University Campus Bara Kahu Shawider University Campus	Islamabad " N. Waziristan Islamabad	Maqsood & Manzoor Nisar & Dilawar Hafizullah & Ayaz Mohammad Azam	- - - Mir Ajab Khan
Setaria glauca	23 (63240) 8 (701388) -	University Campus Mughal Gardan University Campus	Islamabad Rawalpindi Islamabad	Manzoor & Arif Maqsood & Dilawar Mohammad Azam	Tanveer Akhtar " Mir Ajab Khan
Setaria pumila	(97103) 792 (94430) 1528 (94456) -	Peshawer More Zero Point Kharaian University Campus	Islamabad " Hazara Islamabad	Maqsood & Dilawar " Chaudhry, Rizwana, Tanveer Mohammad Azam	- - - Mir Ajab Khan
Sorghum halepense	-	University Campus	Islamabad	Mohammad Azam	Mir Ajab Khan
Stipa splendens	-	University Campus	Islamabad	Mohammad Azam	Mir Ajab Khan
Urochloa panicoides	-	"	"	"	"
Vetiveria zizanoides	-	"	"	"	"

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