POLLEN MORPHOLOGY OF COCONUT

(Cocos nucifera Linn.)

THESIS
SUBMITTED TO MAHATMA GANDHI UNIVERSITY
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

By
HANEESA BEEVI, A. MSc, M.Phil

ENVIRONMENTAL RESOURCES RESEARCH CENTRE
PEROORKADA, THIRUVANANTHAPURAM
KERALA-695005

2005

Dedication
In Memorium

"Rise above the muck of the problem and rest in the multitude of possible solutions". This attitude of my husband helped me to complete this work. Dear Salim you are unique unlike anyone else on this earth with your own special ideas and gifts. So I dedicate this thesis to my beloved husband.

Environmental Resources Research Centre
N.C.C. Road, P. B. No. 1230, P.O. Peroorkada, Thiruvananthapuram - 695 005, India
http://www.encentre.org ☎ (O): 0471-2437069, (R) : 2373159
E-mail: errc@encentre.org errc@eth.net

Dr. P.K.K. Nair
DIRECTOR

CERTIFICATE

This is to certify that the thesis entitled of **"Pollen Morphology of Coconut** ***(Cocos nucifera*** **Linn.)"** *is an authentic record of original research work carried out by* **Smt. Haneesa Beevi, A.** *under my supervision and guidance. I further certify that no part of this thesis has previously formed the basis for the award to the candidate for any Degree, Diploma, Associateship, Fellowship or other similar titles of this or any other university or society.*

P.K.K. Nair

E.R.R.C., THIRUVANANTHAPURAM, INDIA

Dr. P.K.K. Nair
Director, Environmental
Resources Research Centre
Peroorkada, Thiruvananthapuram
Kerala – 695 005.

DECLARATION

I hereby declare that this thesis entitled of **"Pollen Morphology of Coconut** *(Cocos nucifera* **Linn.***)" is a bonafide record of original research work done by me and that no part of the thesis has been presented earlier for any degree, diploma on similar title or recognition.*

Kollam
7th July 2005.

HANEESA BEEVI, A.

ACKNOWLEDGEMENT

I would like to express my deep felt gratitude and indebtedness to **Dr. P.K.K. Nair**, *Director, Environmental Resources Research Centre, Thiruvananthapuram, for guidance, encouragement and advice given to me throughout the course of this investigation.*

I wish to express my sincere gratitude to the Director, Central Plantation Crop Research Institute (CPCRI), Kasargode for facilitating collection of materials for the investigation.

I owe debt of thanks to the scientific, technical, field and library staffs of Central Plantation Crop Research Institute (CPCRI), Kasargode, Central Plantation Crop Research Institute (CPCRI) Kayamkulam for their support in the collection and authentication of the materials for the study.

My thanks are also due to **Dr. G. Kulanthavelu**, *Head of the Department of Life Science, Madurai Kamaraj University and* **Dr. Peter Koshy**, *Joint Director, Regional Research Laboratory, Papanamcode, for their help in carrying out S.E.M. work.*

I am indebted to the whole staff of Environmental Resources Research Centre, Thiruvananthapuram and especially to **Dr. P.K.Shaji** *and* **Dr. S.K. Jayalekshmi, Mr. Roy Chacko, Mr. Solomon** *for their advice, suggestions and support in the conduct of laboratory investigation.*

The work was made possible by the award of teacher fellowship under faculty improvement programme. I thank to the Govt of Kerala, U.G.C., authorities of S.N.Trust and S.N. College for Women, Kollam for facilitating the implementation of the F.I.P.

While, I owe my gratitude to my colleagues friends and others. I may mention the names of **Mr. Syam Gopakumar**, *I Year BFA student,* **Mrs. S.K. Bindhu**, *M.G. University,* **Mr. Radhakrishnan**, *Vlakkottu House, Chavara, my son* ***Haroon Al Salim*** *and daughter* ***Saira Salim*** *for the assistant and encouragement given in the various activities associated with this work.*

The service rendered by the staff of Nirmala DTP Centre & Xerox, as also by Hidas Photos are acknowledged with thanks.

I bow before God Almighty, for the choicest blessing.

Mrs. HANEESA BEEVI, A.

PREFATORY NOTE

The pollen grain constitute the haploid male reproductive unit of the flowering plants. They are single celled, with an inner intine and an outer exine wall, the latter of which is both protective and diagnostic of the mother plant it belongs to. The architectural patterns of the exine surface together with other morphological characters of pollen provide direction in considerations of plant taxonomy and evolution, at various taxonomic levels, including biological variants such as ecotypes, genotypes etc. Pollen morphology is now conveniently used for population screening with the aim of identifying improved genetic resources. In the above background the coconut plant (*Cocos nucifera* Linn.), which has been taken for the present study with the aim of characterizing the pollen biodiversity and to fix morphological parameters for use in genetic resource characterization of the coconut plant.

The material for the present study had been procured from the genetic resource collection of the coconut maintained at the Central Plantation Crops Research Institute, Kasargode, Kerala. The pollen material has been processed by the acetolysis method and characterized both by means of Light Microscope (LM) and the Scanning Electron Microscope (SEM). A total number of 44 varieties representing a vast geographical area covering South America, Africa, Pacific Islands, Indonesia, Philippines, Vietnam, Malaysia, Sri Lanka, and India covering Andaman and Nicobar Islands, Lakshadweep and the coastal states of Goa, Kerala, Tamil Nadu, Andhra Pradesh, and Orissa.

The architectural pattern of coconut pollen is unique in the whole group of flowering plants by virtue of the fact that it has a polar cap formed of powdery granules, extending to the other parts of the grain in various forms. A variety of ornamentation patterns have been noticed on the lateral surface, which along with other characters, provided a base for applying pollen morphology in varietal identity, at the same time as providing information, on the impact of diverse coastal ecology of the various countries, each represented by the respective coconut cultivars.

Apart from providing information on genetic resources, pollen morphology has given directions to the possible routes of migration of coconut palm from its original home in South America via the seas, to the various countries by means of the fruits. The results of the present study has added a new dimension to the application of pollen morphology in plant ecology, biogeography and related subjects, apart from substantiating the earlier findings on the application of pollen morphology in plant taxonomy and evolution at the cultivar levels.

CONTENTS

1 – INTRODUCTION

1.1. A HISTORICAL PERSPECTIVE OF PALYNOLOGICAL SCIENCE

That reproductive biology is the key to evolutionary biology is best exemplified in plants which is marked by a "haploid pollen phase" and "the diploid seed phase", the pollen and the seed being the two structural units that fall out of the mother plant during the life cycle. The importance of pollen in the production of fruits and seeds and their improvement has been understood by man in early historical times, as evidenced from the stone carvings of Assyrian period dating back to 717 B.C in Egypt, in which winged human beings have been depicted to pollinate the date palms (*see* Maheshwari, 1950). This was perhaps the first evidence so far known, on the perception of man on the biological process involved in fruit and seed production. Scientific thought and discoveries changed the course of biological science over the years since Assyrian times with the result that new technologies in plant improvement have been evolved but with its fundamental base in the original understanding of man in natural breeding involving pollen and the egg. Man's knowledge of pollen biology made a start only when the compound microscope was discovered by Robert Hooke, in 1756 (*see* Wodehouse, 1935) facilitating the scientific examination of cells and tissues, followed by expansion of knowledge thereafter, even at micro levels, as of today. Since the discovery of the compound microscope there was a continuing interest in the study of pollen as a part of studies in plant morphology and taxonomy, and this was evidenced in the several works by early biologists like von Mohl and Fritsche among others, (*see* Wodehouse, 1935). During the course of their early botanical studies many aspects of vital information have been discovered such as the architectural refinements of pollen surface, presence of intine and exine layers of pollen wall, apertural variations and size and shape differences. The beauty and variety of pollen surface ornamentation pattern encouraged some of the botanists to produce artistic drawings, which conform with the contemporary knowledge in pollen morphology.

For a long time after the end of the 19th century there has been a lull in pollen studies till Wodehouse in 1935 published his book "Pollen grains" which possibly can be considered to be the beginning of contemporary studies in pollen morphology. The above book had its foundation in pollination ecology, but contains a comprehensive idea and resolution of approach in pollen research, categorising the pollen characters into aperture, exine strata, exine ornamentation, pollen size and pollen shape, which today form the fundamental base for studies in pollen characterisation. Apart from structure, Wodehouse explained the importance of structural features in accommodating volume changes (harmomegathy) during pollen transport and transfer mechanisms.

With the publication of the book "Pollen Morphology of Angiosperms" by Erdtman (1952) a strong foundation was laid for using pollen morphology as an index of phylogenetic taxonomy and evolution. In fact, a new beginning in the pollen studies has been ushered which generated valid information on the application of pollen morphology in angiosperm taxonomy. The studies were based on light microscopic observations, but contained very authoritative information on the structure of the pollen wall, terminology for various characters, the methodology for making pollen diagrams, and above all, the technique of acetolysis for preparing pollen for the study of pollen morphology as against that of Wodehouse who studied pollen without chemical treatment. The dissolution of protoplasm by the chemical treatment of acetolysis served to give clarity in the correct understanding of the morphological features and Nair (1970) demonstrated the importance of combining the data on both acetolysed and unacetolysed grains for the purpose of comparative morphology and taxonomy (*see* Faegri and Iversen, 1964).

In the years following 1952, there has been fast advances in optical systems and technologies, consequent to which there has been a fast pace of progress in biological research including pollen. The discovery and continued upstaging of electron microscope (Bradley, 1960) as a tool for scientific research triggered the expansion of the horizon of knowledge in plant biology, of which pollen morphology is a very significant area of strength. There is no denying the fact that data from light microscopic studies are inevitable and thus the present approach to the study of pollen morphology combines the best of the old (LM) and new perceptions (SEM) providing a comprehensive array of information in the study of pollen morphology, and its applications.

During the course of this long period of history of research and management of pollen there has been some efforts made for giving the science an identity by itself, the first of which was the coining of the expression "Pollen Analysis" by Potonie (1916) (*see* Erdtman, 1956) which infact covered only the knowledge from fossil pollen and spores. It was in 1946 that Hyde and Williams (*see* Faegri and Iversen, 1964; Nair, 1965a) coined the term Palynology and that also added only a limited connotation in the sense that the term mainly related to the air borne particulate materials, associated also by pollen morphology. Nair (1970) by way of his various studies brought about a change in the scope of palynological science to cover the entire gamut of structural and functional events in the pollen phase of plant reproductive biology starting with the origin and organization of pollen to the termination of fertilization biology. In advancing this concept it was suggested that the production of reproductive unit has been the focus in evolutionary biology. There is much credibility in thinking that the process of flower development from the formation of sepal to the male pollen suggests the inbuilt protective process in which the security of the haploid pollen has been ensured by the fact that the pollen originated as the last unit in the development process of the flower morphosystem (*see* Brewbaker, 1959)

As mentioned earlier the pollen is the last unit to be organized in the development stage and further, in the pollen unit itself the intine is the last wall to be formed which indicate the pattern of development in strengthening the protection of the haploid genome, before the anther dehisces, freeing the pollen from the mother plant. In the free life stage, the pollen are exposed to a spectrum of unfavourable environmental conditions in which the pollen are protected from destruction and decay by the hard, resistant exine. In the fertilization stage, the pollen germinates on the stigma and pollen tube grows through the style carrying the germ nuclei and reaches the ovule leading to fertilization. Thus, the protective mechanism is a vital factor of value in the process of reproductive biology. There is much validity in contending that palynological science relates to all aspects of the form and function associated also by structure and events serving in the protection of the haploid genome, which in fact constitute the status of palynological science today. The pollen wall, particularly the exine has a unique attribute by virtue of the fact that it combines the function of protection at the same time as possessing characters of value in the diagnosis of the mother plant it belongs to. This combination of protection and diagnosis is unique in the structural features in the cycle of plant biology as a whole, by which the pollen become a genotype as well as a phenotype of vital value (*see* also Rowley, 1959; Rogers and Harris, 1969).

1.2 DIMENSIONS OF PALYNOLOGICAL SCIENCE

It has been indicated in the preceding account on the historical progress of knowledge on pollen-spore biology that the science of palynology today covers the pollen phase in the cycle of plant reproductive biology giving the science a new scope from what Hyde and Williams (1945) conceived, while coining the term Palynology. To explain further, the pollen phase could be resolved into developmental stage, free life stage and fertilization stage in the path of the functional movement of pollen grain from the male to the female leading to fertilization and the formation of fruit and seed (*see* Nair, 1985).

The developmental stage in fact starts with the very initiation of flower bud, followed by the centripetal origin and organization of the floral parts, the sepal, the petal, the androecium and gynoecium in that order following which the reproductive units, the haploid male and the female, are organized within the highly protective structures namely the anther and the ovary respectively. In terms of development of the anther it may be found that the centripetal direction of organization continues in which a strong anther wall is followed inside by a tapetal tissue, subtending the archesporium. The pollen mother cell draws its nutrition from the tapetum and the building material (sporopollenin) of the exine is generated from within pollen cytoplasm as a general rule. However, there is still a controversy about the origin of pollen wall (exine) material. Godwin (1968) observed that the pollen wall is developed in a sporophytic environment drawing its building material and nutrition for the pollen unit from the tapetum. The pollen wall being diagnostic, there is indirect evidence to suggest the genetic interaction from within the pollen in the building of the pollen walls and it has been noticed from TEM that there are microchannels connecting the tapetum within the pollen protoplasm (Rowley, 1959). The exact mechanism of genetic interaction has not get been resolved although it can be safely concluded that a combination of tapetum and pollen protoplasm could be playing a combined role in exine development. While the exine is formed by the above process, the intine is laid as the last wall layer from the pollen protoplasm itself.

During the process of microsporogenesis, the 'pollen cell' divides to produce the generative and the vegetative cells. The vegetative cell degenerates and the pollen with generative nucleus is set free when the anther dehices, thus initiating the free life stage.

There are inbuilt mechanisms for the transport of pollen by various agencies depending upon the floral characters and even pollen characters (see Faegri and Iversen, 1964). Pollination mechanisms are either anemophilous, entomophilous or hydrophilous in each of which pollen structure has a reflection. For example, the pollen surface of entomophilous pollen are sticky, spiny, or rough while in anemophilous ones it is smooth with mild ornamentation; and in the hydrophilous pollen the exine surface has a waxy coating, so as to prevent destruction by water.

The diverse pollination mechanisms carry the pollen by means of air, insect or water to the female counterpart, where it germinates after the fertilizing partner is identified by means of lectin contained in the stigma and pollen. Out of the high number of pollen produced by the anther, only very few are required for pollination and fertilization, and the rest are waste. However, such pollen moves along various directions and become useful materials for new research enquiries and providing more information of value in various areas of human affairs.

The anemophilous pollen finds entry into the respiratory system, causing bronchial allergy in human beings, and therefore the survey of airborne pollen and spores followed by preparation of antigens, their testing on humans and development of therapy are inevitable steps in the diagnosis and treatment of the ailment. On the other hand, the pollen carried by insects, particularly by the honeybees, are taken to the beehives, where it forms a food for the larvae and honeybees together and ultimately coming into honey, providing nutritious elements to the human beings, at the same time as providing information on bee pasture.

The anemophilous, the entomophilous and hydrophilous pollen forms are spread on wet or water surfaces, settle down, get entangled in the mud and become fossils providing information on the vegetational history of the place where the deposition takes place.

Thus, it is clear that the pollen and the spores are of universal occurrence providing a tool for new research pursuits by virtue of the protective and diagnostic value of the exine. The above principles form the foundation for palynological science today.

It is being generally realized that there are social and economic directions. Further new areas are emerging with potential for the application of biotechnology including genetic engineering in plant improvement. There are instances where the pollen of *Typha* and *Cycas* are used as food and the pollen contained in the honey make the product value added by virtue of vitamins and minerals contained in the pollen. The cause of allergy due to pollen has expanded into a moderate pharmaceutical industry with economic application at microlevels of the society. It has been claimed that there are pollen specific characters represented by the genes and its combinations, which led to the emergence of a molecular approach to identify pollen specific genes and to use such knowledge in the genetic transfer of useful characters for plant improvement. For centuries, the pollen was used in breeding programmes and now there is a vast scope for pollen cryopreservation for use in artificial pollination. The use of fossil pollen, in oil exploration and coal stratigraphy is well established (Nair 1965 b). Thus, the science of palynology cover vast and varied areas of research and technology development including agriculture, industry, commerce, and human health, apart from knowledge building in diverse areas like evolutionary biology and plant taxonomy for providing valuable directions in the characterization and classification of microtaxa down to cultivars and for screening plant populations.

1.3 CONCEPTUAL FOUNDATIONS OF POLLEN MORPHOLOGY

During the course of evolution of the plant kingdom, the vegetative haploid tissue has been in the process of reduction throughout the cryptogams, resulting in the origin and organization of the unicellular pollen grains at the level of phanerogams, rather the flowering plants (Nair, 1970). At this level, the reproductive mechanisms have undergone an evolutionary change with the origin of flower and the development of reproductive structures and its functions. In the gymnosperms, a beginning of this process has been in evidence in which pollen grains form the male and the naked ovule formed the female reproductive unit. It is in the gymnosperms that the flower gets resolved into a structure with a diversity of protective mechanisms, with the floral leaves, surrounding the reproductive structure. In the process, the haploid male pollen become mobile and the ovule remained stationary and in such a circumstance, the male needs a high level of protection to safeguard the genome for carrying out the function of fertilization. It is in this context that the pollen grains developed a protective structural system by itself with a resistant indestructible wall, the exine, inside which is the intine. This exine has special attributes not only for protection but also for diagnosis, by virtue of the fact that there is an evident genetic control in the origin and organization of the exine (Godwin, 1968). The diagnostic characteristics of the pollen wall is resolved into five groups of characters namely aperture, exine ornamentation, exine strata, pollen size and pollen shape in the order of their importance in comparative morphology. There has been considerable difference of opinion with regard to the terminology for use in pollen morphology, but a glossary of terms presently used is based on proposals by Nair (1970) together with new terms necessitated in explaining the pollen morphology of coconut.

The wall consists of the exine and intine of which the exine is made up of sporopollenin and the intine is made up of callose. The exine is resolved into endoexine which is homogenous and the ectoexine which is heterogenous, by virtue of its composition formed of radial pin/rod shaped columella, the tip of adjacent ones of which fuse to form a tectum over which is a supratectal layer. It is the tectum or the supratectum, which carries the ornamentation patterns.

The pollen size is measured on the basis of their form, which could be either radial or bilateral. In the case of coconut and a large majority of monocots, the grains are bilateral with three dimensions and for the sake of convenience the length and breadth in lateral view is alone taken in this study.

The shape in monoaperturate grains is variable in various views. Basically a bilateral monocolpate grain like that of coconut is boat shaped in which the colpus remains within the length of distal face or else it continues into the proximal face of the grain. The shape seen in lateral view can vary, although the general pattern is often ellipsoidal or elliptical in nature. In distal view the shape can be ellipsoidal or even rectangular. Between the above two forms there may be other shapes. All the same the shape classes are not of comparative significance, although they are of academic value. Together with the elongate grains, there are also spheroidal grains, almost as a general rule in coconut, and other monocots with monocolpate grains. While taking size measurement of spheroidal grain, the diameter of the whole grain is taken into consideration.

1.4 POLLEN MORPHOLOGY IN PLANT TAXONOMY AND EVOLUTION

It has been mentioned in the account given above that the pollen characters are of diagnostic value and of comparative importance in taxonomy and evolutionary considerations at all taxa levels (*see* Nair, 1991, 2004) and may be even at the level of individuals in plant populations. It was also pointed out that the characters relating to aperture are primary, exine ornamentation secondary and all other characters tertiary in the order of their importance for application in plant taxonomy and evolution and for identification of pollen in its free state. A general analysis of literature in the area is given below.

The book of pollen morphology and plant taxonomy by Erdtman (1952) provide characters for the identification of taxa at the level of families, genera and species. The apertural characters have been the fundamental basis for taxa differentiation. The tricolpate pollen of Ranunculaceae, tricolpate forms in Leguminosae, the pantoporate forms in Malvaceae, Convolvulaceae, Plantaginiaceae and Chenopodiaceae are characteristic and so also the monoporate pollen of the Gramineae. Apart from these generalizations there are specific cases in which the pollen have been an index of taxonomic circumscription. Other special characters serve pollen diagnosis, of which mention may be made of the winged pollen of pinus, and the importance of the ridged pollen of *Ephedra*.

In the taxonomic system of dicotyledons Cronquist (1968), following Thaktajan classified the angiosperm into dicotyledons and monocotyledons of which the dicotyledons have been classified into subclass Magnoliidae and subclass Ranunculidae. The Magnoliidae is characterized by the dominance of monocotyledonous pollen, while the Ranunculidae is totally without monocolpate forms. The monocotyledons are characterized by dominance of monocolpate apertures, but with a mixture of its variants and other forms like triporate and spiraperturate.

In the family Nymphaeaceae (Hutchinson, 1959) the genus *Nelumbium* is characterized by three colpate pollen as against the monocolpate forms in all other genera and therefore, the separation of *Nelumbium* into a new family Nelumbonaceae by Takhtajan (1980) is substantiated. Similarly, the splitting of families of Bentham and Hooker, like Convolvulaceae, Leguminosae and Onagraceae by phylogenetic taxonomists is corroborated by pollen morphology. A striking instance of the pollen difference at the tribe level is seen in Compositae, by virtue of the occurrence of lophate pollen grains in the tribe Vernonieae as against other tribes. Instances of species differentiation, pollen characters like even grain size have been useful (Erdtman, 1952). When the application of pollen morphology at the level of varieties is considered, it has been observed (Nair, 1961) that in the species *Caltha palustris* Linn. the natural variety *alba* is characterized by pantoporate grains as against the tricolpate grain in the variety, *palustris* which suggest the direction for separation of the varieties into two species. At the level of cultivars, the best example is provided by an elaborate study of species and varieties of *Citrus* by Bamzai and Randhawa (1965 b) in which they could find the endocolpium differences as a criterion for varietal separation (*see* Nair, 1970 a). Even at population levels there is an instance in which giant pollen grains have been noticed in a taller ecotype as against small grains in shorter individuals of the species *Rawolfia serpentina* (Nair, 1962). It is therefore, evident that the pollen characters with its genetic manifestations offer a direction to plant taxonomy.

The importance of pollen in evolutionary schemes of the plant kingdom was first formulated by Wodehouse (1935) and later by several authors (Nair, 1965 a; Walker and Doyle, 1975; Muller, 1970; *see* also Chaloner, 1967). In an analysis of apertural evolution (Nair, 1970), it has been noted that the beginning of pollen-spore organization in the plant kingdom has its base in bryophytes in which there are three forms namely trilete, monolete and alete, and such a situation was described as trimorphous with the aperture in proximal position. The trimorphous situation continued to be the pattern in the pteridophytes.

With the advent of the origin of flowering plants (*see* Lawrence, 1951) and the origin and organization of pollen grains, (Godwin, 1968) the proximal position changed into the distal position, but the pollen forms were trimorphous, being monosulcate, inaperturate and trichotomosulcate. This condition continued to the end of gymnosperm evolution. With the origin of the angiosperms and the flower systems as the basis of reproductive biology, the whole pattern of apertural variation changed. Considering the taxonomic system of Cronquist (1968), it may be noted that the trimorphous condition characterized the pre-angiosperms and continued to the subclass Magnolideae of the dicotyledons while the subclass Ranunculideae consist of the tricolpate and its derivatives. In the monocotyledons the monocolpate, trimorphous condition dominated but contained also other structural forms suggesting an identity of its own. On the basis of the above pattern of morphological composition of pollen grains, the triphyletic theory has been propounded by Nair (1970, 1979), by which it has been suggested that the angiosperms originated and evolved along three phylogenetic lines namely the Magnolian stock, the Ranalian stock, and the Monocot stock, with its common root in the Cycadofilicales at which stage the pollen has shown the change from the proximal to the distal position. The principles of morphological evolution (Nair, 1970) can be applied at various taxa levels, (families, genera, species and even at cultivars) which has been demonstrated in several taxa (Nair, 1970; Ravikumar and Nair 1984). Thus, pollen-spore morphology has come to be an inevitable tool in comparative morphology, taxonomy and evolution of plants at the present day (*see* also Eames, 1961; Daghlian, 1981; Nair, 2004).

1.5. POLLEN MORPHOLOGY OF CULTIVATED PLANTS

In the context of the present study of pollen morphology of *Cocos nucifera*, knowledge on the relevance of pollen morphology of cultivated plants (Sampath and Ramanathan, 1951; Nair 1965 b, 1970 a; Srivastava and Nair, 1977); particularly the crops is important. Man's knowledge on the significance of pollen biology is inherent in the stone carvings of Assyrian civilization, depicting artificial pollination of date palms, as early as 716 B.C. The breeding process of plant improvement, has been practiced throughout the history of agriculture, and is being continued even today. However, an understanding of pollen morphology of crop plants and its wild allies is inevitable for evolving new strategies in plant breeding for crop improvement.

Erdtman (1952) recorded pollen abnormalities in several species, which are nothing but variations reflecting genetical changes caused by mutations, recombinations or ecological factors among other reasons. Mourizio (1956) observed correlation between polyploidy and pollen morphology affecting aperture number and pollen size. Similarly, Bronckers (1963) noticed an all round increase of pollen size in autopolyploids as compared to diploids of *Arabidiopsis thaliana,* and similar observations on changes in pollen morphology related to increase in chromosome number have been made by many authors (Kessler and Larson, 1969; Qurios, 1976; Chaturvedi *et al,* 1990). The species *Sisymbrium irio* complex (Khoshoo, 1960) is characterised by triploids, tetraploids, hexaploids, and octaploid forms in which, Nair and Sharma (1966-67) found correlation with the occurrence of increase in colpate number in triploids and tetraploids different from the 3–zonocolpate forms in the diploids. It is significant to point out that minor ecoforms of the tetraploids growing under moist conditions showed the occurrence of 4 – zonocolpate grains as against mixed forms in plants growing under dry sun, suggesting that pollen morphology is a measure of ecology. In the area of biosystematics, Lewis (1965 a and 1965 b) observed an independent origin of tetraploids and hexaploid races in the species *Oldenlandia corymbosa* as a result of parallel geographical migrations. Pollen morphological studies of hybrids and their parents provided new knowledge on the use of pollen as a measure of hybridity (*see* also Gould and Medus, 1953; Chaturvedi *et al*, 1996). Quiros (1976) observed that in the hybrid between *Lycopersicon esculentum* and *Solanum pannelli*, pollen size and spine characters showed differences. The subject of cytopalynology has been reviewed by Nair and Ravikumar (1984) which provide a picture of the practical value of pollen morphology in gaining new information of value in evaluating the population status (Chaturvedi *et at*, 1990; Ravikumar and Nair, 1984).

1.6 SCOPE OF THE PRESENT INVESTIGATION

The fact that the exine is of diagnostic value is at the core of the principles of palynological science with particular emphasis on its application in phylogenetic taxonomy of plants. The most significant finding of interest is the demonstration that exine morphology is a valuable tool in tracing the facts and facets of the evolutionary process at microlevels, which evidently is a reflection of genetic variations in the process of plant evolution. A significant finding in this respect is with regard to the disputed species *Oryza malampuzhensis* with a restricted area of distribution in the Western Ghats of South India in which the pollen grains have been shown to be a true index of the impact of ecological variations in the microlevel evolution (Kuriachan *et al*, 2001-02).

The importance of pollen morphology at cultivar levels is of special significance in the present investigation of coconut cultivars. A foundation for the use of pollen morphology in cultivar classification, evolution and hybridity evaluation has been laid by Nair and his associates from various studies (Nair, 1961, 1979; Ravikumar & Nair, 1985, 1986; Srivastava *et al*, 1977). It has been found that a holistic approach involving both light microscope and S.E.M. studies provide the data of value in comparative morphology in relation to cultivar taxonomy. It is of particular significance to point out that SEM studies have certainly given the most significant information in cultivar differentiation in cases where the light microscope did not provide proper information. This was particularly evident in the case of *Gloriosa* species and varieties in which the information from SEM revealed clear and credible directions of change in exine morphology, which could be used to produce an evolutionary scheme, and which provide information of value in resolving the breeding system of the crop.

The knowledge on the impact of the chemical process of acetolysis on pollen could be used in assessing differences in plants at the various levels including cultivars. The studies by Cranwell (1953); Bamzai and Randawa (1965 a); Nair and Sharma (1963); Nair and Ravikumar (1984); Ravikumar and Nair (1985, 1986) provided enough data on the value of pollen morphology including the effect of acetolysis in cultivar taxonomy. It is in this background that the present study of pollen in coconut varieties assume significance.

An earlier study in the pollen morphology of coconut by Nair and Sharma (1963) took into consideration the data from light microscope studies, which indicated the use of pollen morphology in the cultivar classification of the varieties. However, that study could only establish the value of characters of exine surface ornamentation as seen under light microscope in cultivar characterisation. The present study serves to fill the lacuna of the cultivar studies on the subject at the same time as taking into consideration the modern approaches in using pollen morphology in cultivar classification and evolution. Further, the monumental work by Menon and Pandalai (1958) will have a new discussion of information of value in coconut resources characterization. The present study takes into account not only the few varieties covered in earlier studies but several new ones with a global distribution represented by varied ecosystems. Further, a new scope for the taxonomy and evolution (Takthtajan, 1980) is envisaged (*see* Sovumini, 1968; Thanaikaimoni, 1990) for the evolution of the structural uniqueness of palms (Corner 1966), as reflected in pollen morphology.

2 – MATERIALS AND METHODS

2.1 BACKGROUND INFORMATION

The aspects of the present study of pollen morphology has been focused with a view to assess pollen biodiversity of coconut as applied to coconut biodiversity. The study of pollen morphology cover procurement of polleniferous material, pollen preparation, pollen characterization and analysis, leading to the formation of morphological standards for assessing the index value of pollen authenticating the varietal status, the breeding system, the ecological and environmental dimensions and any other information of use in both academic and applied aspects of coconut biology.

Among the world's approximately 2700 species of Palms (Moore and Uhl, 1982; Corner, 1966) coconut is the most versatile providing edible and industrial oil, protein rich milk and invigorating water and also valuable sources of timber, fibre and matting materials and also a number of products from its fibre and shell (Menon and Pandalai, 1958). The coconut fibre is valued for its elasticity and resistance to mechanical wear and dampness. Byproducts of coir industry such as pith fibre dust are put to a variety of uses as improving the soil texture and conservation of moisture. The coconut is rightly called the tree of heaven 'Kalpa Vriksha' as very few other cultivated plants have such highly diversified utility as the coconut palm.

2.2 BOTANICAL CHARACTERIZATION

The present study is on the pollen morphology of coconut (*Cocos nucifera* Linn.), the botanical characterization of which is presented below.

The coconut belongs to the family of Palms, namely Arecaceae, of the order Monocotyledoneae of Angiospermae. It is a tall stately, unarmed palm growing to a height of 12 to 24 m; the trunk is stout, rarely vertical, but makes a gradual curve, rising from a swollen base surrounded by a mass of adventitious roots spread 2-3 m or more in the soil. The stem is marked by rings of alternating leaf scars which are often not prominent at the base.

Leaves are large, pinatisect, borne as a crown on the trunk; leaflet equidistant, 60 cm – 90 cm long narrow, tapering, linear, lanceolate, coriaceous, flaccid; petioles stout, 90 cm – 150 cm long.

Inflorescence is a spadix. The spadix is 1.2 to 1.8 m long stout, erect, straw or orange coloured, androgynous, simply branched; branches (spike) bearing one or more female flowers at the base and several male flowers above. The spike is contained in two spathes, 60 mm - 90 mm long, oblong, hard and splitting lengthwise. The palm is monoecious with a few female flowers. Male flowers are numerous, small, asymmetric, sweet scented, perianth 6, in two alternate rows. Male flowers with 6 stamens, sabulate filaments, and linear erect, anthers; pistillodes minute; female flowers larger and fewer than the male, about 2 cm - 5 cm long, bracteolate; perianth greatly accrescent, round concave, imbricate.

Fruit is a large, drupe (20 cm - 30 cm long), being trigonous, obovoid, or subglobose. Outer layer of pericarp thick and fibrous, the endocarp hard, horning or strong with three basal pores or marks which are the remains of three carpels or the loci of the ovary, two of which are obliterated; the thin testa cohering the endocarp is lined with white albuminous endosperm enclosing a large cavity partially filled with a sweet fluid (Lawrence, 1951).

2.3 STUDY MATERIAL

The species is recorded to consist of over 100 natural varieties and hybrids spread over the coastal regions of the equatorial tropics with its origin in South America. The coconut is believed to have spread through the sea to the islands and continents covering a wide geographical expanse, producing new varieties and newer variations conforming with the various ecosystems, the reflection of which is noticed mainly in nut characters and other structural features and even pollen morphology as observed in the present study.

The polleniferous material studied had been procured from the Central Plantation Crops Research Institute, Kasargode (C.P.C.R.I.), Kerala, under the Indian Council of Agricultural Research, Govt. of India

(I.C.A.R.; *see* Table I). The collections cover a wide geographical area, represented by several countries such as South America, Africa, Trinidad, Seychelles, British Solomon Islands, Fiji, Guam, Sri Lanka, Indonesia, Philippines, Zanzibar and various ecological sources from India itself, and particularly Kerala. It is felt that the natural varieties have evolved through out crossing, involving natural cross pollination or through ecological adaptations of which field knowledge is lacking. However, the knowledge from pollen morphology might often be a clue to the varietal variations and its causes.

The data on the material contained in the present study are given in table I.

Table I: Details of coconut variety collected (C.P.C.R.I Kasargode, India)

Sl. No	Name of Variety/ Hybrid	Abbreviation	Tree/Field No.	Locality
1.	Andaman Ranguchan	ADRT	29/S-217 D	Andaman & Nicobar Island
2.	Andaman Yellow Dwarf	AYD	29/S 182 D	Andaman & Nicobar Island
3.	Ayiramkacchi	AYRT	IX 250 A	Tamil Nadu
4.	Benaulim	BENT	29/S-190 D	Goa

5.	Blanchesseuse	BLIT	29-N-13 D	Trinidad and Tobago
6.	Borneo Tall	BRT	R.S. 40/6	Indonesia
7.	British Solomon Island	B.S.I.T	28/C-519 C	British Solomon Island
8.	Cameroon Red Dwarf	CRD	29-N 305 D	Ivory Coast
9.	Chandra Leksha	CHD	Near Guest House	Kerala
10.	Chowghat Green Dwarf	CGD	XI SE /4 B	Kerala
11.	Cochin China	CCNT	VIII 186 A	Vietnam
12.	Federated Malay States	FMST	VIII/ 56 A	Malaysia
13.	Fiji Tall	FJT	VIII/117	Fiji Island
14.	Ganga Bondom	GBGD	HSE/29 B	Andhra Pradesh
15.	Gonthembili	GTBT	S.B – 95 A	Sri Lanka
16.	Guam - II	GUT - II	29/S- 200 F	Guam Island
17.	Guam – III	GUT – III	29/S-132 D	Guam Island
18.	Kaithathali	KAIT	XI/5 B	Kerala

19.	Kappadam	KPDT	28/C- 524 C	Kerala
20.	King Coconut	RTB	SB – 89 A	Sri Lanka
21.	Kulasekhara Yellow Dwarf	KYD	29/S-132 D	Tamil Nadu
22.	Laccadive Micro	IMT	39-26 A	Lakshadweep Island
23.	Laccadive Ordinary	LCOT	39-109 A	Lakshadweep Island
24.	Leksha Ganga	LGD	New Block	Kerala
25.	Lifou Tall	LFT	28/C – 467C	Lifou Island
26.	Malayan Green Dwarf	MGD	VIII-51 A	Malaysia
27.	Malayan Tall	MLT	XI – 51 B	Malaysia
28.	Malayan Yellow Dwarf	MYD	27/S-21 B	Malaysia
29.	Markom Valley Tall	MVT	28/C 528 C	Papua New Guinca
30.	Nadora Tall	NDRT	29/S- 174 D	Goa
31.	Niu Leka Dwarf	NLAD	28/C-492 C	Fiji Island

32.	Orissa Tall	SKGT	27-S/956 / B	Orissa
33.	Philippines – Dalig	PDLT	29/S-178D	Philippines
34.	Philippines Laguna	LAGT	28 /C 497 C	Philippines
35.	Philippines Ordinary	PHOT	VII/147 A	Philippines
36.	Saint Vincent	STVT	29/S -189 D	Trinidad and Tobago (W.I)
37.	San Ramon Tall	SNRT	XI – 16 B	Philippines
38.	Seychelles Tall	SYCT	R.S 40/21	Seychelles Island
39.	Sri Lankan Tall	SLT	SB/70	Sri Lanka
40.	Sri Lankan Yellow Dwarf	SLYD	29/S-152 D	Sri Lanka
41.	Strait Settlement Green Tall	SSGT	VIII – 38 A	Malaysia
42.	Verrikobbarri Tall	VKBT	29 /S- 8D	Andhra Pradesh
43.	West Coast Tall	WCT	S.B. 16	Kerala
44.	Zanzibar Tall	ZNT	29/S-148	Zanzibar

2.4 TECHNIQUE OF POLLEN PREPARATION

In making pollen preparations, the acetolysis method of Erdtman (1952) with modifications suggested by Nair (1970) has been followed. The schedule is given below

1. The most mature, undehisced flower buds have been fixed in 70% alcohol contained in vials. The flowers in the vials were transferred to plastic centrifuge tubes and was crushed by a glass rod to release the pollen from mature buds. The dispersion was passed through a copper mesh having 40 divisions per square c.m and the pollen containing alcohol was collected in a glass centrifuge tube, alcohol decanted, about 5 ml of glacial acetic acid added to the sediment and centrifuged.

2. The supernatant liquid decanted and freshly prepared acetolysis mixture consisting of nine parts of acetic anhydride and one part of cone, sulphuric acid was added to pollen sediment in order to maintain starting temperature of 70^0 C.

3. The pollen sediment has been stirred by a glass rod for dispersion in acetolysis mixture. A glass rod was placed in each centrifuge tube for stirring at intervals, and the tubes were transferred to a water bath and heated from 70^0C to 82^0C to boiling point of water and then the flame was put off leaving the tubes in the hot water for thirty minutes till a brown colour was attained, thus ensuring total dissolution of pollen protoplasm.

4. The dispersion was centrifuged and the supernatant mixture was decanted. The pollen sediment was centrifuged with glacial acetic acid followed by decantation of the supernatant acid. The pollen sediment was centrifuged with distilled water two or three times followed by decantation each time.

5. Finally, half of the sediment was stirred in 70% alcohol for SEM photographs and the remaining sediment brought into in 1: 1 glycerine distilled water mixture.

6. After 10-15 minutes the glycerine containing pollen was centrifuged, glycerine decanted and the tube containing the pollen sediment was kept upside down on a filter paper to drain off excess of glycerine.

7. For making slide preparation, a clear glass slide was placed on a table, followed by catching a bit of pollen sediment on a pellet of glycerine jelly carried on a needle from the centrifuge tube, held upside down and transferred to the slide.

8. The slide is warmed on a hot plate to melt the jelly, followed by mounting with a cover glass and sealed by running molten paraffin wax in the vacant space around the glycerine jelly; the excess wax removed by cleaning the slide with xylol. A label with relevant information such as slide number and name of the variety was pasted on the slide.

2.5 POLLEN CHARACTERS AND ANALYSIS

For giving morphological description of pollen, the terminology given by Nair (1970) has been followed. The pollen of *Cocos nucifera* Linn. being a monocot is bilateral having three dimensions $P_x = E_1 \times E_2$. In the present study the size measurement of the longest diameter (E_1) and shortest diameter (P) of the grain seen in lateral view are given. From literature it is also known that the monoaperturate pollen in monocots including the palms consists of both elongate grains with colpate type and spheroidal grains with porate type (Nair and Chaturvedi, 1978). The pore being often larger than half the diameter of grain the term megraporate is used for such grain.

Nair (1970) proposed that the apertual characters are primary, exine ornamentation secondary and other characters tertiary in the order of their phylogenetic importance. Further, within each character group, there are various evolutionary levels of which the apertuaral evolution is of basic importance (Nair, 1965, 1974, 1976,1988).

2.6 PHOTOGRAPHS AND ILLUSTRATIONS

Data on general morphology have been generated from light microscope studies and fine structure of the exine as seen from SEM pictures.

3 – OBSERVATIONS

3.1 DATA INFORMATION AND PRESENTATION

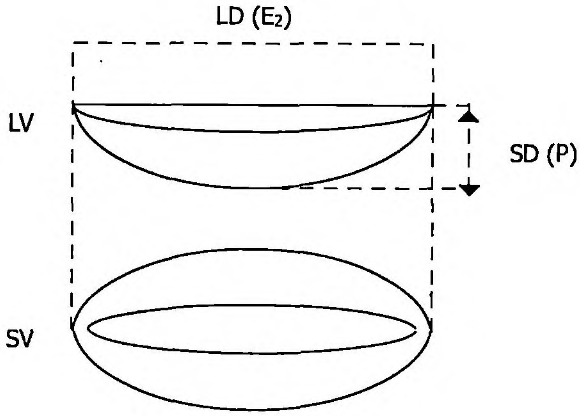
The data on pollen morphology and associated information are presented in the following order. Name of variety, its locality and accession number (tree number obtained from C.P.C.R.I, Kasargode), reference to photographs and illustrations followed by pollen description categorised into Aperture, Exine Ornamentation, Exine Strata, Pollen Size and Shape associated by a note on the distinctive features. Of the above character categories, the exine strata has been found to be of very little comparative importance. The characteristics covered in the various pollen morphological characters are explained below (see Text fig. 1, A –C).

3.1.1. Form

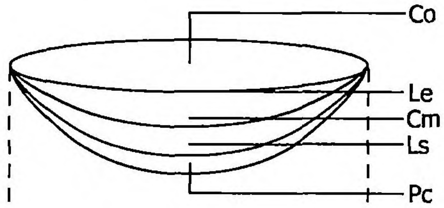
Dimorphism (see Text fig. 1) is common in most varieties, the grains being 1-colpate-elongate and 1-porate-spheroidal. Apart from the above two forms, trichotomocolplate grains with wide aperture or narrow trichotomy also occurs rarely. In order to indicate the comparative composition of the two forms, the expressions high (near to 50%), moderate (nearly 25%), low (below 10%) or nil are used with reference to spheroidal grains in view of the fact that the elongate grains form the dominant type (in above 50% varieties).

Text Figure 1:

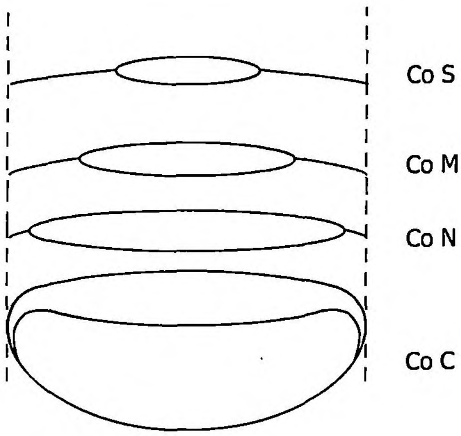
Diagrammatic Representation of Pollen Characteristics



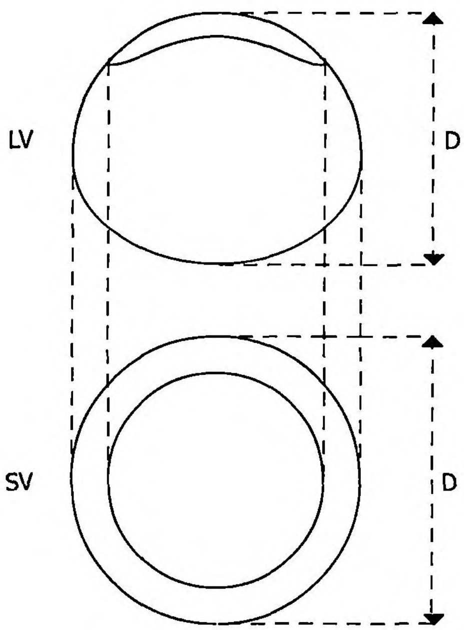
A. Elongate Grain



C. Parts of the Pollen Surface



D. Colpus Types



B. Circular Grain

A. Elongate Grain

LV	- Lateral View
SV	- Surface View
LD (E_2)	- Equitorial Diameter
SD (P)	- Polar Diameter

B. Circular Grain

LV	- Lateral View
SV	- Surface View
D	- Diameter

C. Parts of the Pollen Surface

Co	- Colpus
Le	- Lateral edge
Cm	- Colpus margin
Ls	- Lateral surface
Pc	- Polar cap

D. Colpus Types

Co S	- Colpus Short
Co M	- Colpus Medium
Co N	- Colpus Normal
Co C	- Colpus Curved

3.1.2. Aperture

In terms of NPC (Number, Position and Character), the grains are monocolpate (N) or monoporate (megaporate, pore diameter more than half grain diameter), the position (P) of colpus is distal (as in tetrad) and the characters (C) related to its form, extent, margin and lateral ends, as seen along the longest diameter of the grain (E_I). The colpus is either wide (in the centre) or narrowing; and are short (half the equatorial diameter) or long (reaching lateral ends) or arched, extending, curving and bending down the lateral ends to the polar face (Text fig.1, C); lateral ends are acute or rounded; margin thick or thin, being fortified by the aggregation or agglutination (plated) of powdery granules in various degrees (dense, lax or plated) and which sometimes is restricted to radial patches; in yet others the colpus margin is thin being free from thickening; edge of the colpus margin is either straight (even), slightly wavy, deeply wavy or else corrugate with small protuberances (dense or at random); in some varieties the edge is frilled being formed into folds or into semi circular segments of equal size; in yet others the edge is dissect with conical projections at specified distances on the edge, fitting into diametrically opposite depressions on the other edge. In porate apertures, the pore is generally wide (megaporate) being more than half the diameter of the grain and the edge and margin being either even or uneven, thick or thin.

3.1.3. Exine Ornamentation

In explaining the exine ornamentation the colpate grain in lateral view has been taken as typical and common to all varieties. The ornamentation is resolved into the following components namely Proximal end of grain, Lateral ends of grain, Colpus margin, and Lateral sides (between polar cap and colpus).

The polar cap is formed of the aggregations or agglutination (fusion) of granules which are either dense and thick or else are lax and thin. The cap extends to the equatorial (lateral) ends and down to the colpus margins, or else the granules disperse on the whole grain merging gradually with the lateral sides. Further, the cap is either unitary, trizonate being composed of two dense zones on either sides between which is a lax zone. The granular aggregation may be mildly lax or fully lax. In yet other cases the cap is absent in which case, it is replaced by other formations like the hump, striate toothed ridges, or plated reticulum.

The polar cap formation extends to lateral ends, where it becomes narrow or expands to various degrees. Similarly, the thickening of the colpus margin is in continuity at the lateral ends. In quite many case the powdery granules cover the entire grain and such grains occur together with grains with clear polar cap.

The most common form of ornamentation is the striate pattern in which the ridges (muri) surface is either even or variously ornamented by reticulate, foveolate, fossulate, rugulate or spinulate forms. The characteristic feature is that the above patterns produce a striate appearance being formed in parallel stretches arching in the middle, and connecting the polar end and the colpus margin. The muri of the brochi are generally wide and close to each other and in yet other cases the muri criss crosses to produce a matted pattern. The reticulum when present may have clear brochi in various sizes and shapes or else are smaller. The muri are often discontinuous formed of rounded elevations or elongate ridges capped by spots of granular aggregations; in yet other cases the muri are very close producing streakes of depressions together with circular, fossulate scrobiculate, or pitted depression forms. Similarly, the above patterns may be clearly visible or covered by a veil of powdery granules all over the grain making the ornamentation obscure.

3.1.4 Exine Strata

The exine strata is not of much comparative value and therefore, the thickness of the exine in optical section at the middle of proximal pole in lateral view has been taken. It has been generally seen that the differences are very minor.

3.1.5 Pollen Size

The pollen being dimorphic, the size measurement of the elongate grains and spheroidal grains have been taken, wherever possible (it may be noted that the spheroidal grains are sometimes few or even nil). For taking the measurements, the elongate grains in lateral view has been taken in which the length and breadth are expressed of the equatorial diameter (E_1) and the polar diameter (P) respectively. In spheroidal grains only one diameter is given.

3.1.6. Pollen Shape

In expressing the shape forms, the grains in lateral view has been considered and the shape is expressed as elliptical, ellipsoidal subspheroidal or other shapes of elongate grain. There are also shrunken grains with no specific shape.

3.1.7 Other Data

The comparative data on the elongate and spheroidal grains are expressed as percentages whenever possible, and the expression few or nil (as observed in the present study) is made when percentages have not been taken. Apart from the above, there are also grains which are trilete or quadrilete, but they are extremely few and found only in very few varieties.

3.1.8 Distinctive Characters

Significant characters of diagnostic value of any one variety has been notified and these characters relate to either the aperture or exine ornamentation or both combined.

3.2. GLOSSARY

In expressing the various character groups, the elongate grains seen in lateral view with the colpus at the distal end has been taken as standard. In such a grain, the parts demarcated and terms used are explained below.

3.2.1 Forms

Dimorphic	:	Monocolpate- ellipsoidal and Monoporate–spheroidal occurring together.

3.2.2 Aperture

Aperturate	:	When the grain possess germinal aperture.
Colpate	:	Grain with furrow like aperture, occurring at the distal end.
Porate	:	Grain with circular aperture, which is often more than half the diameter of grain (megaporate), on the distal side.

3.2.3 Colpus Character

Even	:	When straight
Wavy	:	When uneven
Toothed	:	When beset with conical projections on one edge fitting into complementary depressions on opposite edge (profuse; moderate; distant).
Frilled	:	When folded into semicircular (frilled) shapes.
Segmented	:	When fragmented into semicircular segments (frilled)

3.2.4 Colpus Form

Wide	:	Central part expanded
Narrow	:	Central part narrow
Short	:	When the colpus length is half the equatorial diameter
Medium	:	When the colpus length is nearly or as long as the equatorial (longest) diameter.
Arched	:	When the colpus extends to the polar face, arching down the lateral ends.

3.2.5 Colpus Margin

Margin	:	The exine flanking the colpus on either sides of the colpus.
Costate	:	Colpus fortified by uniform, dense or patched aggregation of granules.
Lax	:	Fortified by dispersed granules.
Patched	:	Spot aggregation of granules in radial patches.
Merged	:	Granules merging with the lateral surface of the grain

3.2.6 Colpus Edge

Edge	:	Edge of the margin immediately adjacent to the colpus

3.2.7 Colpus Lateral Ends

Lateral ends	:	Lateral extremities of the colpus
Acusinate	:	When sharp
Acute	:	When angular
Rounded	:	When semi circular

3.2.8 ***Exine Ornamentation:*** Pattern of the exine surface

Granules	:	The basic granular units of exine ornamentation
Polar Cap	:	The cap – like structure on the proximal face, formed of agglutination (shell like) or aggregation (loose) of powdery granules.
Dense	:	When granules are dense and agglutinate
Lax	:	When granules are dispersed
Even	:	When the cap has an even surface
Uneven	:	When cap surface is undulate
Demarcated	:	When the cap is demarcated on the lateral sides by a clear visible line.
Undemarcated	:	When the cap merges into the lateral sides by the thinning aggregations of granules.
Uniform	:	When cap is uniformly dense or lax.
Zonate	:	When polar cap is demarcated into segments of parallel units by way of dense and lax granular aggregations.
Veil	:	The thin spread of granules superimposing the basal ornamentation types.

3.2.9 Surface Pattern Forms

Surface patterns	:	Ornamentation on the lateral surface of the grain, formed by aggregation / dispersion of granules.
Psilate	:	When the surface is plain.
Granulate	:	When the whole surface is spread with minute granules (without modification to form other ornamentation types)
Reticulate	:	When the surface is net-like , the brochi of net being rectangular or in other angular shapes; modifications are the foveolate, fossulate, scrobiculate, or channel like.
Striate	:	Finger print – like formation.
Sinuate	:	Winding line of ridges (lirae) in striate pattern.
Nodular	:	When muri is studded with globular or rounded structures.
Spinulate	:	When muri is studded with short sharp excrescences.
Echinate	:	When excrescences are conical.
Echinulate	:	When excrescences are minutely conical.

Undulate	:	When the muri is uneven
Arched	:	When the pattern is produced in the form of an arch in the middle between polar cap and colpus margin.
Matted/plated	:	When the brochi (muri) are weaved to produce a matted pattern.
Twined	:	When the muri are twined like the thread.
Veiled	:	When the powdery cover is dispersed over the lateral sides.

3.2.10. Exine Strata

Exine strata	:	Thickness at the centre of the optical section on the proximal pole, seen in lateral view (Equatorial diameter).
3.2.11. Pollen Size	:	Expressed as length and breadth of grain in lateral view for elongate grains or expressed as diameter in spheroidal grains.
3.2.12. Pollen Shape	:	Expressed as elliptical, ellipsoidal, subspheroidal depending upon the increase in polar diameter of grains seen in lateral view of colpate grains.

3.3 POLLEN CHARACTERISATION

ANDAMAN RANGHUCHAN

Nativity : Andaman Island **Plate No. 1 - Fig. Nos. 1 – 3**

Form	:	Dimorphic: monocolpate- elongate (95%); monoporate-spheroidal (5%).
Aperture	:	*Colpate form*-colpus elongate (69.3μm × 9.9μm), wide or narrow, reach extreme lateral ends, margin costate with diffuse inner demarcation, edge even. *Porate form* - pore diameter 67μm.
Exine Ornamentation	:	Polar cap marked by dense aggregation of powdery granules extending to lateral ends and to the colpus margin, surface even, inner edge demarcated; lateral sides diffuse to striato-granulate marked by indistinct radial ridges and by spot aggregation of granules small or large spread all over, including muri.
Exine strata	:	3.3 μm thick.
Pollen Size	:	*Elongate*: E-78.09 μm (69μm -83μm), P-46.2μm (43μm -49μm); *circular* 75.9μm (72μm -79μm).

Pollen Shape : Ellipsoidal (60%); Elliptical (35%), Spheroidal (5%).

Distinctive features : Surface diffusely striato-granulate, with spot aggregation of granules, small or large.

ANDAMAN YELLOW DWARF

Nativity : Andaman Island **Plate No. 1 - Fig. Nos. 4 - 6**

Form : Dimorphic: monocolpate - elongate (subspheroidal) (70%); monoporate spheroidal (30 %).

Aperture : *Colpate form*: colpus wide (89μm× 13.92μm), length medium (not reaching lateral ends) acute; margin thin or thick with lax aggregation of granules; edge slightly uneven being wavy with minute projections.

Porate form : pore diameter 24μm.

Exine Ornamentation : Polar cap dense, formed of thick agglutination of granules, inner edge diffuse merging with the lateral surface pattern, like extensions; lateral surface striato–fossulate and netted with adjacent muri crossing over each other or even fused at places; enclosing various depressions; muri dissected, topped by granular aggregations, oriented laterally.

Exine strata	:	4.5 μm thick.
Pollen Size	:	*Elongate*: E–99μm(95-102μm), P52.8μm; *circular*: 66μm (64 -68μm).
Pollen Shape	:	Ellipsoidal (25%)– subspheroidal (45%), Spheroidal (30%).
Distinctive features	:	Pattern straito –fossulate with laterally oriented disrupted muri, topped with granular aggregations and enclosing variously elongated depressions; mildly netted (twined).

AYIRAMKACCHI

Nativity : Andaman Island **Plate No. 1 - Fig. Nos. 7 – 9**

Form	:	Dimorphic : monocolpate -elongate (85%), monoporate - spheroidal (15%).
Aperture	:	*Colpate form* : colpus wide (60μm × 16μm), lateral ends bending down to produce beaks, edge slightly uneven formed into conical elevations; margin costate, inner edge variously demarcated, merging into the lateral surface pattern. *Porate form* - pore diameter 40μm.

Exine Ornamentation	:	Polar cap made of semi-dense or lax aggregation of granules, with central elongate fissures, inner margin undemaracated, with finger like extensions of granular aggregations merging into the lateral surface; lateral surface striate- undulate (wavy) being formed of radial arched, sinuous laterally oriented; discontinuous gradually rising low ridges studded with variously sized elevations formed of spot aggregations of granules; whole surface studded with minute, foveolate, or fossulate depressions; powdery granules spreading over the entire grain surface is characteristic.
Exine strata	:	4.6 µm thick.
Pollen size	:	*Elongate* : E - 70 µm (65µm -74µm) P - 40µm (32µm -44µm): *Circular* : 49.5 µm (44µm -53µm).
Pollen shape	:	*Ellipsoidal*: (10%), subspheroidal (40%), spheroidal, shrunken grain are also seen (50%).
Distinctive Features	:	Colpus edge toothed; striato–undulate lateral surface with arching sinuous ridges; whole surface spread over by granules and variously sized minute depressions.

BENAULIM

Nativity : Goa **Plate No. 2 - Fig. Nos. 10-12**

Form	:	Dimorphic: monocolpate- elongate (70%), monoporate - spheroidal (30%)
Aperture	:	*Colpate form*: colpus wide (52µm–11µm) extending to lateral ends, often produced into beak-like structures; margin uneven (corrugate) with minute triangular (echinulate) projections on one edge together with complementary depression on the opposite edge, margin costate with lax granular aggregation *Porate form* : pore diameter 38 µm.
Exine Ornamentation	:	Polar cap formed of lax aggregation of granules, with low or high humps in conical or rounded shapes; inner margin undemarcated, the powdery granules merging into the lateral surface; lateral surface pattern striate – rugulate, with disrupted straight ridges and mounds oriented towards lateral ends, in parallel formations; a thin veil of granules present over the whole grains surface.
Exine strata	:	4.5 µm thick.

Pollen Size	:	*Elongate*: E-75.9µm (70µm-78µm), P-39.6µm (34µm-43µm): *Circular* : 46.2µm (44µm - 47µm).
Pollen Shape	:	Ellipsoidal: (25%), *Elliptical* (65%), Subspheroidal (10%).
Distinctive Features	:	Colpus margin with minute conical projections on one flap fitting into complimentary depressions on the other. Lateral surface striate-rugulate formed of disrupted straight ridges and mounds, and covered over by a thin veil of granules.

BLANCHESSEUSE

Nativity : Trinidad & Tobago **Plate No. 2 - Fig. Nos. 13-15**

Form	:	Dimorphic: monocolpate-elongate (80%), monoporate- spheroidal (20%).
Aperture	:	*Colpate form*: colpus wide (43µm × 8.25µm) extending from proximal face to the distal arching down laterally; margin thin corrugate, edge slightly wavy.
		Porate form : pore diameter 34 µm.

Exine Ornamentation	:	Polar cap dissected-striate to produce parallel ridges along equatorial diameter separated by clefts (gorges), ridge branched, surface and top corrugate; crest toothed; clefts deep in the middle, and very shallow towards the lateral sides; the entire cap region beset with foveolate depressions; lateral surface corrugate, with ill defined variously sized elevations (granulate, rugulate) and minute depressions and covered over with scattered spot aggregations of granules of various sizes.
Exine strata	:	4.5 µm thick.
Pollen Size	:	*Elongate grain* : E– 66µm (59µm -73µm), P – 39.6µm (29µm -43µm): *Circular* 49.5µm (41µm -55µm).
Pollen Shape	:	Ellipsoidal (80%), Spheroidal (20%)
Distinctive features	:	Colpus edge corrugate; polar cap humped, dissected along equatorial diameter with corrugate ridges and deep gorges in the central region, lateral surface indistinctly corrugate spread over by scattered spot aggregations of granules of various sizes.

BORNEO TALL

Nativity : Indonesia **Plate No. 2 - Fig. Nos. 16-18**

Form	:	Dimorphic: monocolpate-elongate (95%), monoporate - spheroidal (3%).
Aperture	:	*Colpate form*: colpus wide, elongate covering the whole face (E_2) (56μm × 13 μm), margin costate, edge more or less even, ends angular. *Porate form* : pore diameter 30μm.
Exine Ornamentation	:	Polar cap poorly developed represented by a central plate of granular aggregations, gradually spreading and covering the whole grain; lateral surface formed of massive radial, arched ridges, elevations, oriented to lateral ends, and separated by deep gorges; ridges consist of a network of striate micro-ridges formed of small rounded elevations, joining at places enclosing variously sized depressions (fossulate, foveolate, narrow channels). A thin veil of powdery granules, cover the whole surface.
Exine strata	:	3.3 μm thick.

Pollen Size	:	*Elongate*: E- 66µm (59µm -71µm), P -49.5µm (41µm -56µm), *circular*: 46.2 µm (39µm -53µm)
Pollen Shape	:	Ellipsoidal (20%), Subspheroidal (75%), Spheroidal (5%).
Distinctive features	:	Lateral sides with radial massive ridges, formed of micro-striate-foveolate fossulate pattern, the lumina being of various sizes and shapes.

BRITISH SOLOMON ISLAND

Nativity : British Solomon Island Plate No. 3 - Fig. Nos. 19-21

Form	:	Dimorphic: monocolpate-elongate (23%) monoporate-spheroid (77%).
Aperture	:	*Colpate* form - colpus wide (65 µm × 13µm) elongate, confined to the distal face; margin costate, lateral ends acute to rounded, edge even; lateral extremities of grain formed into narrow sharp beaks. *Porate form* : pore diameter (35µm).

Exine ornamentation	:	Polar cap formed of dense aggregation of granules, thinning down to lateral sides; extending to lateral ends and to the colpus margin: polar crest even, the granular aggregation gradually thinning out over the lateral surface (granulate)
Exine strata	:	4.6 µm thick.
Pollen Size	:	*Elongate* –E 86 µm (78 µm- 96 µm), P - 46 µm (42 µm–61µm), *Circular* 65 µm (56 µm – 75 µm).
Pollen Shape	:	Ellipsoidal (5%), Subspheroidal (10%) Spheroidal (70%), Giant pollen (5%).
Distinctive features	:	Colpus wide, : confined to proximal face ; Exine surface psilate with dispersed powdery granules.

CAMEROON RED DWARF

Nativity : Malaysia **Plate No. 3 - Fig. Nos. 22-24**

Form	:	Dimorphic monocolpate - elongate (63%); and monoporate - spheroidal (47 %).
Aperture	:	*Colpate form*: colpus wide (67µm × 13µm); confined to the distal face, margin wavy, slightly costate lateral ends acute or rounded, edge corrugate, wavy. *Porate form :* pore diameter 23 µm.
Exine Ornamentation:		Polar cap poorly developed, but represented by faint striate foveolate ridges, with agglutination of surface elements and with foveolate to scrobiculate depressions spread all over; polar plate extend to the lateral edges and to the colpus margin; lateral surface granulate with the powdery granules spread over like a thin veil with spot aggregation of granules to produce extraneous looking substances in various shapes and sizes spread all over the surface.

Exine Strata	:	3.3 μm thick.
Pollen Size	:	*Elongate*: E–45 μm (42 μm–52 μm), P- 19 μm (16. 5μm–22.5μm); *Circular* 29 μm (24 μm - 36μm).
Pollen Shape	:	Ellipsoidal, subspheridal and also in odd shapes.
Distinctive Features	:	Polar cap not well formed, represented by faintly striate-foveolate-scrobiculate, plated structure. Lateral surface granulate spread over by groups of extraneous aggregated granules in various sizes and shapes.

CHANDRALEKSHA

Nativity : Kerala **Plate No. 3 - Fig. Nos. 25-27**

Form	:	Dimorphic monocolpate-elongate (53%); and monoporate - spheroidal (47 %).
Aperture	:	*Colpate form*: colpus elongate, wide (70μm × 12 μm); reach lateral extremities; ends acute; margin costate, costae being formed of round thickenings all along the length, edge even.

Porate form : pore diameter 33 µm

Exine Ornamentation: : Polar cap formed of lax aggregation of granules, demarcated but defused by the granular spread over the exine surface; lateral surface echinulate with low conical projections becoming striate at places.

Exine Strata : 4.3 µm thick.

Pollen Size : *Elongate*: E – 86 µm (78 µm –96µm), P- 44 µm (425µm –515µm); *Circular* -60 µm (54 µm –36 µm)

Pollen Shape : Ellipsoidal (15%), subspheroidal (63%), spheroidal (22%)

Distinctive Features : Lax polar cap. lateral surface echinulate.

CHOWAGHAT GREEN DWARF

Nativity : Kerala **Plate No. 4 - Fig. Nos. 28-30**

Form	:	Dimorphic: monocolpate -elongate (90%), monoporate - spheroidal (10%).
Aperture	:	*Colpate form* : colpus wide, (60μm × 12μm) elongate, curving down at lateral ends to distal pole, ends acute, margin costate, edge even. *Porate form* : pore diameter 33 μm.
Exine Ornamentation	:	Polar cap narrow formed of dense aggregation of granules resolved into rounded or variously sized islands towards the lateral surface; producing a faint striate pattern, with rounded beads, arranged end to end and covered over by a thin veil of powdery granules.
Exine Strata	:	4.29 μm thick.
Pollen Size	:	*Elongate* : E- 71.28 μm (63μm -76 μm), P- 39.6μm (32μm - 46 μm); *Circular* - 51 μm (40μm -57μm).
Pollen Shape	:	Various; ellipsoidal (10%) and subspheroidal (85%), spheroidal -(10%)
Distinctive features	:	Radially arched faint striate pattern formed of variously sized rounded beads of granular aggregations.

COCHIN CHINA

Nativity : Vietnam **Plate No. 4 - Fig. Nos. 31-33**

Form		Dimorphic: Monocolpate - elongate 85% and porate - spheroidal 15%.
Aperture		*Colpate form*: colpus wide (42.9μm × 6.6μm); confined to distal face. Lateral ends acute, margin frilled formed as a result of raised spots spaced almost equally, edge uneven (frilled). *Porate form*: pore diameter 30.5 μm.
Exine Ornamentation	:	Pole humped; polar cap undifferentiated, marked by aggregation of granules spreading down the lateral sides and to the whole surface; lateral surface striato-areolate with disrupted muri formed of rounded aggregations of granules placed end to end or dispersed; random occurrence of puncta seen.
Exine Strata	:	3.3 μm thick.
Pollen Size	:	*Elongate* : E 62.7μm (56μm -67 μm), P- 36.3μm (28μm –39μm): *Circular*-49.5μm (32μm –54μm).

Pollen Shape	:	Dominantly ellipsoidal
Distinctive features	:	Colpus edge frilled due to spot elevations or undulations. Polar cap humped, formed of thin aggregation of granules spreading to lateral surface, striate – granulate.

FEDERATED MALAY STATES

Nativity : Malay State **Plate No. 4 – Fig. Nos. 34-36**

Form	:	Dimorphic: monocolpate-elongate (40%), monoporate- spheroidal (60%).
Aperture	:	*Colpate form*: colpus narrow to wide (66μm × 10.89μm), extended to lateral ends ending in lateral beaks in some grains; margin variously costate, with varying extent of lateral extensions in disrupted zones, edge even. *Porate form* : pore diameter 28.7μm
Exine ornamentation	:	Polar cap marked by dense aggregation of granules, gradually thinning towards lateral sides, and dispersed over the whole grain (in some grains), formed into radial wide arches of granular aggregation; general surface finely granulate.
Exine strata	:	4 μm thick.

Pollen Size : *Elongate*: E– 75.9μm (67 μm –81 μm),
P- 46.2μm (38 μm –41 μm):
Circular- 50.5μm (39 μm –61 μm).

Pollen Shape : Elliptical (5%), ellipsoidal (45%), spheroidal (60%).

Distinctive characters : Powdery aggregation of granules all over the surface in most grains: general surface finely granulate.

FIJI TALL

Nativity : Fiji Islands **Plate No. 5 - Fig. Nos. 37-39**

Form : Dimorphic. monocolpate -elongate (30%), monoporate - spheroidal (70%).

Aperture : *Colpate form* : colpus (80μm × 12.9 μm) wide, confined to polar face, margin costate formed of tubercular aggregation of granules, edge even.

Porate form : pore diameter 45 μm.

Exine ornamentation : Polar cap slightly formed of a narrow well demarcated aggregation of powdery granules extended to the colpus margin, lateral surface spread over by a powdery veil over reticulate-matted general surface.

Exine Strata	:	4 µ m thick.
Pollen Size	:	*Elongate* grain: E–99µm (81µm -107µm), P-49.5 µm (41µm-57µm); *Circular* –44µm (39µm - 48µm)
Pollen Shape	:	Ellipsoidal (10%), Subspheroidal (30%)
Distinction features	:	Thinner margin : exine surface reticulate matted, covered over by a veil of fine granules.

GANGA BONDOM

Nativity : Andhra Pradesh **Plate No. 5 - Fig. Nos. 40-42**

Form	:	Dimorphic: monocolpote - elongate (70%) monoporate - spheroidal (30%).
Aperture	:	*Colpate form* : Colpus (79.2µm × 6.6µm) wide, confined to proximal face, obliterated at one lateral end in an odd grain by the marginal fusion formed of tubercular aggregation of granules; margin thick, edge slightly even. *Porate form* : pore diameter 37µm.

Exine Ornamentation	:	Polar cap thick formed of agglutination of powdery granules extended laterally into tubercular elevations formed of aggregation of granules, lateral surface with radial, striate-tuberculate aggregation of granules enclosing streaks of depressions of various sizes and shapes.
Exine strata	:	4.5μm thick.
Pollen Size	:	*Elongate*: E-825μm (71μm-89μm), P-36.3μm (29μm -32μm); *Circular* -49.5μm (39μm -51μm).
Pollen Shape	:	Ellipsoidal (60%), Spheroidal (4.36%)
Distinctive Features	:	Surface striate-tuberculate-foveolate-(cloudy).

GONTHEMBILI

Nativity : Sri Lanka **Plate No. 5 - Fig. Nos. 43-45**

Form	:	Dimorphic. monocolpate -elongate (98%) monoporate - spheroidal (2%)
Aperture	:	*Colpate form*: colpus wide (82µm×12µm), extending to the lateral ends, either confined to proximal face or slightly arching; margin slightly costate; edge even. *Porate form* : pore diameter 40 µm.
Exine ornamentation	:	Polar cap formed of dense aggregation of granules demarcated laterally, extending to lateral ends and to the colpus margin, lateral surface matted-foveolate -reticulate with wide muri enclosing foveolate to slightly fossulate depressions.
Exine strata	:	4.5 µm thick.
Pollen Size	:	*Elongate* : 92.4 µm (84 - 99µm), P- 46.2µm (38µm -51µm); *Circular* - 56 µm (44µm-59 µm)
Pollen Shape	:	Ellipsoidal (40%) and spheroidal (60%).
Distinctive features	:	Matted Foveolate–reticulate ornamentation.

GUAM – II

Nativity : Guam Island **Plate No. 6 - Fig. Nos. 46-48**

Form : Dimorphic: monocolpate -elongate (95%), monoporate - spheroidal (4%).

Aperture : *Colpate form*: colpus wide (62μm×13μm), arched extending to lateral ends; margin costate fortified by radial low ridges, edge even, operculate; operculum significant (seen in some grains).

Porate form : pore diameter 30 μm.

Exine Ornamentation : Polar cap formed of agglutination of powdery granules, arching down the lateral sides, like a semicircular plate almost touching the colpus margin; arch surface, segmented into parallel ridges of various diamensions and low or deep streak-like or fosulate depressions, with the outer margin extended into finger like elongations (frilled) joining the colpus margin. Whole surface covered by a veil of granules.

Exine strata : 3.3μm thick.

Pollen Size : *Elongate*: 72.6μm (65μm-81μm); P- 42.9μm (35 μm–46 μm); *circular*: 39.6 μm (31μm - 46μm).

Pollen Shape : Ellipsoidal (91.5%), circular (3.5%), triangular (5%).

Distinctive characters: Operculate colpus; arching polar cap, extending laterally down to near the colpus margin.

GUAM – III

Nativity : Guam Islands **Plate No. 6 - Fig. Nos. 49-51**

Form : Dimorphic: monocolpate - elongate (98%), monoporate - spheroidal (2%).

Aperture : *Colpate form* :colpus wide (42.9μm × 9μm), either short or extending to lateral ends; margin costate, slightly arching or very short in some grains, edge even.

Porate form : pore diameter 28 μm.

Exine ornamentation :	:	Polar cap formed of dense aggregation of powdery granules, somewhat delimited and extending to lateral ends, lateral surface striate with radial ridges criss-crossing at places, enclosing lumina of various sizes and shapes; muri beaded, being formed of agglutination of granules capped by spots of white powdery granule.
Exine strata	:	3.3µm thick.
Pollen Size	:	*Elongate*: E–67.09µm (59µm-73µm), P– 35.19µm (28 µm- 43 µm); *Circular* :26-32µm.
Pollen Shape	:	Elliptical (25%), ellipsoidal (50%), other shapes (25%)
Distinctive characters	:	Striate with radially elongate beaded criss-cross ridges.

KAITHATHALI

Nativity : Kerala **Plate No. 6 - Fig. Nos. 52-54**

Form : Dimorphic: monocolpate-elongate (75%), monoporate- spheroidal(25%)

Aperture : *Colpate form*: colpus wide, (55µm× 9.9µm) arched laterally, some times shaped variously, margin slightly costate, edge even.

Porate form : pore diameter – 33 µm

Exine Ornamentation: Polar cap depressed as seen in some grains, narrow formed of dense powdery granules, under laid by matted striate surface oriented along equatorial diameter, general surface striate, with sinuous arched lirae and variously sized stirae (depressions); powdery granules spread over the whole grain.

Exine strata : 4.5 µm thick.

Pollen Size : *Elongate* : E-65 µm (61 µm - 73µm), P-38µm (31 µm - 43µm); *Circular* -42 µm (35µm - 47µm).

Pollen Shape : Ellipsoidal (35%), spheroidal (25%) and odd shape (15%).

Distinctive Features : Surface striate; ridges sinuous, lirae of various sizes; powdery granules spread over the whole surface.

KAPPADAM

Nativity : Kerala **Plate No. 7 - Fig. Nos. 55-57**

Form	:	Dimorphic: monocolpate- elongate (98%) monoporate-spheriodal (2%).
Aperture	:	*Colpate form*: colpus wide (86μm × 12μm), width constant along the whole length, confined to distal face, lateral ends acute or slightly rounded, margin costate (or not thick) being disrupted due to the uneven spot aggregation of granules, edge almost even but with sparse' conical projections, on one edge fitting into complimentary depressions on the other edge. *Porate form* : pore diameter 45 μm.
Exine ornamentation	:	Polar cap formed of dense agglutination of powdery granules, demarcated laterally, reaching the lateral ends and becoming thinner along the colpus margin; lateral surface reticulate matted with muri topped by lax aggregation of granules and poorly defined low depressions (lumina); of various sizes and shapes.

Exine strata	:	4.6 μm thick.
Pollen Size	:	*Elongate*: E - 97μm (91 μm- 105μm), P-45 μm (39 μm - 52μm); *Circular* - 55 μm (42 μm – 62 μm).
Pollen Shape	:	Ellipsoidal (35%), subspheroidal (65%)
Distinctive features	:	Lateral surface matted reticulate with muri, overtopped by lax aggregation of granules; and lumina of various sizes and shapes.

KING COCONUT

Nativity : Kerala **Plate No. 7 - Fig. Nos. 58-60**

Form	:	Monomorphic; monocolpate - elongate
Aperture	:	*Colpate form* : colpus wide (51μm × 9μm), confined to proximal face, margin slightly costate, edge even.
Exine ornamentation	:	Polar cap formed of thick agglutination of powdery granules, surface uneven, being with elevations and depressions and formed of indistinctly defined striate-matted pattern oriented equatorially, lateral surface radially

striate –foveolate with wide uneven ridges, being formed of disrupted elevations of granular aggregations; ridges either matted or adnate or even fused producing low depressions of various sizes and shapes.

Exine Strata	:	4.6 µm thick.
Pollen Size	:	*Elongate* : E- 6 5µm (57 µm - 69µm), P – 35 µm (29µm- 42µm).
Pollen Shape	:	Mostly elongate, ellipsoidal (25%), subsperoidal (75%).
Distinctive features	:	Polar cap surface uneven; lateral surface striate matted fossulate surface with lax, wide uneven muri, often coalescent.

KULASEKHARA YELLOW DWARF

Nativity : Tamil Nadu **Plate No. 7 - Fig. Nos. 61-63**

Form	:	Dimorphic: monocolpate -elongate (30%), monoporate - spheroidal (70%).
Aperture	:	*Colpate form* : colpus narrow or wide (30µm × 8µm), extending end to end on distal face, margin costate, edge even.

Porate form : pore diameter 25 μm.

Exine ornamentation	:	Polar cap formed of shell like (plate) agglutination of granules, laterally demarcated extending to lateral extremities and to the colpus margin and beset with low foveolate depressions; lateral surface and margin minutely echinulate, conical spins being formed into a radial configuration, and even dispersed. General surface covered by a veil of granular spread.
Exine strata	:	4.5 μm thick.
Pollen Size	:	*Elongate*: E - 39.6μm (24μm - 47μm), P - 23μm (18 μm-26μm); *Circular*-33μm (25μm - 38μm).
Pollen Shape	:	Ellipsoidal (50%), Subspheroidal (25%); spheroidal (25%).
Distinctive features	:	Lateral surface echinate.

LACCADIVE MICRO

Nativity : Lakshadweep **Plate No. 8 - Fig. Nos. 64-66**

Form	:	Dimorphic: monocolpate -elongate (10%) monoporate -spheroidal (90%).
Aperture	:	*Colpate form*: colpus wide (9.2μm × 5.3μm), confined to distal face, lateral ends rounded; margin undulate (frilled) with discontinuous thickening formed by spot agglutination of radially oriented powdery granules. *Porate form* : pore diameter 22 μm.
Exine Ornamentations	:	Polar cap, characterized by dense aggregation of granules, undemarcated being extended into lateral sides by finger like formations; lateral surface indistinctly rugulate-striate, with spot aggregations producing nodules of various sizes. Whole surface spread over by powdery granules.
Exine strata	:	3.3 μm thick.
Pollen Size	:	*Elongate*: E –30 μm (22 μm 32 μm), P – 13 μm (11 μm-15μm); *Circular* - 25μm (21 μm – 28 μm).
Pollen Shape	:	Ellipsoidal.
Distinctive features	:	Colpus margin undulate (frilled); lateral surface indistinctly rugulate – striate.

LACCADIVE ORDINARY

Nativity : Lakshadweep **Plate No. 8 - Fig. Nos. 69-69**

Form	:	Dimorphic: monocolpate -elongate (2%), monoporate -spheroidal (98%).
Aperture	:	*Colpate form* : colpus (12.7µm x6.6 µm) wide, arching down to the proximal face. *Porate form* : pore diameter 28µm.
Exine Ornamentation	:	Polar cap is not delimited, but a low hump is present; lateral surface granulate covered by powdery granules as a veil beneath which could be seen as minute depressions (punctate) spread all over.
Exine Strata	:	3.3 µm thick.
Pollen Size	:	*Elongate* : E–36.3µm (27µm - 42µm) P- 16.5µm (13 µm 19µm); *Circular* –1.25µm (32µm – 47µm).
Pollen Shape	:	Ellipsoidal.
Distinctive features	:	No polar cap; Low polar hump, lateral surface minutely punctate.

LEKSHA GANGA

Nativity : Kerala **Plate No. 8 - Fig. Nos. 70-72**

Form	:	Dimorphic: monocolpate -elongate (95%), monoporate -spheroidal (5%) in some grain.
Aperture	:	*Colpate form*: colpus narrow short or long (59 µm × 7.2 µm), margin slightly costate, edge even; some grains trichotomocolpate.
		Porate form : pore diameter 31µm.
Exine Ornamentation	:	Polar cap formed of lax aggregation of granules, demarcated; lateral sides marked by variously sized low elevations, covered by a thin veil of dispersed powdery granules, associated into cloudy spots; general surface psilate.
Exine strata	:	3.3 µm thick.
Pollen Size	:	*Elongate*: E -63 µm (66 µm - 71 µm) P -36 µm (31 µm -39 µm); *Circular* - 41 µm (35 µm - 47µm).
Pollen Shape	:	Ellipsoidal (25%), subspheroidal (70%) spheroidal (5%).
Distinctive features	:	Lateral surface with low variously sized mounds, psilate covered by powdery granules with spots of white cloudy aggregations.

LIFOU TALL

Nativity : Lakshadweep **Plate No. 9- Fig. Nos. 73-75**

Form	:	Dimorphic: monocolpate-elongate (80%), monoporate-spheroidal (20%).
Aperture	:	*Colpate form*: colpus wide (33µm× 9.9µm), extending to lateral ends of distal face, margin costate, edge even. *Porate form* : pore diameter 41 µm
Exine Ornamentation	:	Polar cap formed of a thick agglutination of powdery granules, extending to the lateral ends, lateral limit undemarcated with the surface uneven having equatorially oriented elongate or circular or variously shaped depressions; lateral sides with low mounds made up of tuberculate-reticulate pattern with wide muri, twining and enclosing depressions (elongate, fossulate or foveolate); aggregation of white granules tops the muri surface.
Exine Strata	:	4.6 µm thick.
Pollen Size	:	*Elongate*: E -66µm (57 µm- 73µm); P -39.6µm (29µm- 46µm); *Circular*: 49.5µm (38 µm-57µm).

Pollen Shape	:	Ellipsoidal (80%), Spheroidal (20%).
Distinctive features	:	Lateral sides with low variously sized mounds made up of tuburculate – reticulate pattern.

MALAYAN GREEN DWARF

Nativity : Malaysia **Plate No. 9 - Fig. Nos. 76-78**

Form	:	Dimorphic: monocolpate-elongate (30%), monoporate - spheriodal (70%); shrunken grain common.
Aperture	:	*Colpate form*: colpus wide (49.5μm × 13.2μm), confined to ¾ equatorial diameter, margin costate, edge uneven with minute echinulate projections, all along the length. *Porate form* : pore diameter 42μm.
Exine Ornamentation	:	Polar cap formed of a lax association of powdery granules, becoming denser at places, and continuing to the lateral ends and to the colpus margin and spreading like a veil over the equatorial surface; lateral surface striate-matted reticulate obliquely oriented; muri surface undulate with nodules or elongate elevations, toped by granular aggregations.

Striae wide or narrow being fossulate or foveolate; muri totally fused towards colpi margin. Granular aggregations cover whole grain.

Exine Strata	:	6.6 μm thick..
Pollen Size	:	*Elongate* : E-62.7μm (53 μm-65μm); P- 26.4μm (21μm-31μm); *Circular*: 49.5μ m (41μm- 57μm).
Pollen Shape	:	Elliptical (20%) and ellipsoidal (80%).
Distinctive features	:	Lateral surface striate – matted –reticulate with muri bearing variously sized elevations; striate ridges obliquely oriented.

MALAYAN TALL

Nativity : Malaysia **Plate No. 9 - Fig. Nos. 79-81**

Form	:	Dimorphic:monocolpate-eleongate (63%), monoporate - spheroidal (37%).
Aperture	:	*Coplate form* : colpus (59μm × 11 μm) wide confined to proximal face, extending to lateral ends, margin slightly costate, edge slightly even with conical projections on one margin, together with complementary depressions on

the opposite edge, providing provision for tight closing of the colpus.

Porate form : pore diameter 37 µm.

Exine Ornamentation	:	Polar cap formed of thick agglutination of powdery granules, demarcated, extending as a narrow strip to lateral ends, and to the colpus margin; lateral sides faintly developed, striate corrugate with dissected low muri often twining and enclosing elongate depressions.
Exine Strata	:	4.6 µm thick.
Pollen Size		*Elongate* : E 70µm (65 µm -77µm); P - 48 µm, (35 µm -53 µm); *Circular* -40 µm (38 µm - 47µm).
Pollen Shape	:	Ellipsoidal (15%), subspheroidal (62%), spheroidal (37%).
Distinctive features	:	Colpus margin with conical projections fitted into the opposite complimentary depressions; lateral surface faintly striate- corrugate with disserted muri, twining at places.

MALAYAN YELLOW DWARF

Nativity : Malaysia **Plate No. 10 - Fig. Nos. 82-84**

Form	:	Dimorphic: monocolpate-elongate (85%), monoporate - spheroidal (15%).
Aperture	:	*Colpate form* : colpus faint, narrow (60μm × 10 μm), confined to proximal side, extending to lateral ends, margin dissected, costate being disrupted due to spot thickening, edge wavy. *Porate form* : pore diameter 38 μm.
Exine Ornamentation	:	Polar cap narrow, formed of lax aggregation of powdery granules, laterally, demarcated; lateral surface granulate, granule becoming aggregated at places to produce rounded structures.
Exine strata	:	3.3 μm thick.
Pollen Size	:	*Elongate* : E - 77 μm (69 μm - 85μm), P 42μm (32 μm - 47μm); *Circular*: 47 μm (42 μm - 57μm).
Pollen Shape	:	Ellipsoidal (30%), Subspheroidal, (24%) Spheroidal (14%), Giant pollen (24%), Shrunken (22%).
Distinctive features	:	Colpus faint, with disrupted marginal thickening; lateral surface granulate with granules aggregated to produce rounded elevations.

MARKOM TALL

Nativity : Papua New Guinea Island   Plate No. 10 - Fig. Nos. 85-87

Form	:	Dimorphic: monocolpate - elongate (25%), monoporate - spheriodal (75%).
Aperture	:	*Colpate form*: colpus wide (42.9µm×13.2µm), confined to proximal face, extending to sub terminal lateral ends, margin costate, edge even. *Porate form* : pore diameter 31µm.
Exine Ornamentation	:	Polar cap formed of dense aggregation of powdery granules, laterally undemarcated merging into the lateral surface; lateral surface striate, with closely placed wide twined equatorially oriented muri, enclosing narrow channels, foveolate or elongate depressions.
Exine strata	:	4. 6 µm thick.
Pollen Size	:	*Elongate*: E -59.4µm (41µm-63µm); P- 26.4µm (21µm-32µm); *Circular* : 46.2µm (40 µm - 55µm).

Pollen Shape : Ellipsoidal(5%), subspheroidal (20%), spheroidal.

Distinctive features : Polar cap formed of dense granules. Lateral surface striate; muri closely placed, twined, and elongated along equatorial axis.

NADORA TALL

Nativity : Goa **Plate No. 10 - Fig. Nos. 88-90**

Form : Dimorphic: monocolpate-elongate (10%), monoporate-spheroidal (90%); some grains trichotomocolpate - triangular.

Aperture : *Colpate form* :colpus (70 μm × 10 μm) wide, arching down to polar face; margin mildly costate; edge even. Some grains trichotomocolpate.

Porate form : pore diameter 30 μm.

Exine Ornamentation : Polar cap formed of lax aggregation of granules, undemarcated, extending to the lateral ends, and to the colpus margin lateral surface striate - reticulate, with sinuate nodular ridges, separated by wide lumen (striate); ridges cross over adjacent ones at places.

Exine Strata	:	3.3 µm thick.
Pollen Size	:	*Elongate* : E - 82 µm (78 µm- 86µm); P - 37 µm (29 µm -45 µm); *Circular* : 48µm (43 µm - 55µm).
Pollen Shape	:	Subspheroidal (7%), spheroidal (93).
Distinctive features:		Lateral surface striate, with narrow sinuate ridges (lirae) carrying rounded nodules and wide lumen (striae), crossing over each other at places.

NIU LEKHA DWARF

Nativity : Fiji Island **Plate No. 11 - Fig. Nos. 91-93**

Form	:	Dimorphic: monocolpate-elongate (77%); monoporate - spheroidal (23%).
Aperture	:	*Colpate form* : colpus wide (71 µm × 10µm), confined to proximal face; extending to the lateral ends; margin costate, edge even. *Porate form* : pore diameter 35 µm.
Exine Ornamentation	:	Polar cap formed of agglutination of granules, laterally demarcated; lateral surface with variously sized, corrugate (megatuberculate) rounded mounds covered by pitted depression, and spot aggregations of granules.
Exine Strata	:	4.6µm thick.

Pollen Size : *Elongate* : E - 85μm (78 μm- 88 μm); P-36 μm (33 μm -39μm); *Circular* : 41μm (37 μm – 44 μm).

Pollen Shape : Ellipsoidal (17%), Subspheroidal (60%), Spheroidal (23%).

Distinctive features : Exine surface with variously sized corrugate rounded mounds (megatuberculate), with pitted depressions, and spot aggregation of granules.

ORISSA TALL

Nativity : Orissa **Plate No. 11 - Fig. Nos. 94-96**

Form : Dimorphic: monocolpate - elongate (80%), monoporate - spheroidal (20%).

Aperture : *Colpate form* : colpus wide (59.4μm × 13.2 μm), margin mildly costate, edge corrugate with rounded or variously sized structures along the whole edge; in some edge is even sparsely or slightly wavy.

Porate form : pore diameter 48μm.

Exine Ornamentation:	:	Polar cap formed of lax aggregation of granules, underlain by striate matted pattern oriented equatorially, undemarcated; lateral surface ground pattern matted reticulate, muri, oriented equatorially, lumina wide of various sizes and shapes.
Exine strata	:	4.6μm thick.
Pollen Size	:	*Elongate*: E -89.1μm (79μm -97μm); P-49.5μm (41μm-58μm); *Circular*: 59.4μm (40 μm - 65μm).
Pollen Shape	:	Elliptical 5%, Subspheroidal 75%, Spheroidal 20%.
Distinctive features	:	Lateral surface matted reticulate oriented equatorially; polar cap undefined, represented by lax aggregation of granules.

PHILIPPINES DALIG

Nativity : Philippines **Plate No. 11 - Fig. Nos. 97-99**

Form	:	Dimorphic: monocolpate-elongate (98%), monoporate-spheroidal (2%).
Aperture	:	*Colpate form* : colpus wide (80μm× 12 μm), arching down to proximal face, margin mildly costate, edge corrugate. *Porate form* : pore diameter 31μm.
Exine Ornamentation	:	Polar cap formed of lax powdery aggregation of granules, not delimited providing a disrupted cloudy appearance; with variously sized elevated formations; lateral surface diffuse (striate-reticulate) with punctate depressions covered by a powdery veil of granules.
Exine Strata	:	3.9μm thick.
Pollen Size	:	*Elongate*: E- 92.4μm (86 μm-105 μm); P- 39.6μm (31 μm - 47μm); *Circular* 38 μm (36 μm-43 μm).
Pollen Shape	:	Ellipsoidal -(60%), subspheroidal-(40%)
Distinctive Characters	:	Lax polar cap with a cloudy appearance covered over by disrupted elevated formations. Lateral surface pattern poorly diffuse.

PHILIPPINES LAGUNA

Nativity : Philippines **Plate No. 12 - Fig. Nos. 100-102**

Form : Dimorphic to polymorphic; monocolpate - elongate (30%); monoporate-spheroidal (60%); polymorphic (10%).

Aperture : *Colpate form*: colpus (38 µm ×12µm) wide, touching the lateral ends confined to distal face; margin mildly costate being wider in middle and narrower at the lateral ends, edge uneven.

Porate form : polar diameter 39 µm.

Exine Ornamentation: Polar cap not clearly formed with patches of granular aggregations extending to the lateral ends and to the colpus margin; lateral surface rugulate- striate–foveolate, rugulae being formed of granular aggregations and in various sizes and shapes. The whole grain is covered by the powdery granules / aggregations.

Exine striate : 4.5 µm thick.

Pollen Size : *Elongate*: E – 90µm (84 µm- 102µm); P- 46.2µm; (37 µm-53µm); *Circular* : 58.08µm (49 µm - 6 7µm).

Pollen Shape	:	Various, elliptical (25%), ellipsoidal (35%), subspheroidal (30%) and in other varied shapes (10%); spheroidal in monoporate forms.
Distinctive character	:	Lateral surface regulate striate –foveolate, rugulae being formed of aggregations of granules.

PHILIPPINES ORDINARY

Nativity : Philippines **Plate No. 12 - Fig. Nos. 103-105**

Form	:	Dimorphic: monocolpate - elongate (70%), monoporate - spheroidal (30%).
Aperture	:	*Colpate form* :colpus narrow (5µm × 9 µm), one edge fitted into the other opposite at places, by way of conical elevations fitting into corresponding depressions; even the edges fuse at places, margin costate, with a wavy inner outline, spreading out into variously sized, aggregation of granules. *Porate form* : pore diameter 55µm.

Exine Ornamentation	:	Polar cap formed of a dense aggregation of powdery granules, undemarcated, gradually spreading loose over the general surface; lateral surface striate with low, highly undulate, muri laterally oriented, muri covered by nodular aggregation of granules.
Exine strata	:	3.3 µm thick.
Pollen Size	:	*Elongate* : E-78.09µm (71 -µm 87µm); P-62µm (53µm - 69µm); *Circular*: 75.9µm (67 µm - 81µm).
Pollen Shape	:	Ellipsoidal (25%), subspheroidal (45%), spheroidal (30%).
Distinctive features	:	Colpi edges fitted into each other and even fused at places. Lateral surface striate, laterally oriented, ridge – highly folded.

SAINT VINCENT

Nativity : Trinidad and Tobago Plate No. 12 - Fig. Nos. 106-108

Form	:	Dimorphic: monocolpate -elongate (45%), monoporate - spheroidal (54%); triiete form (1%).
Aperture	:	*Colpate form* : colpus wide (53 μm × 12 μm), elongate, nearly touching the lateral ends, margin thick, edge mildly uneven. *Porate form* : pore diameter 41 μm.
Exine Ornamentation:	:	Polar cap formed of close aggregation of granules extending to lateral ends and to colpus margin, demarcated; lateral surface pattern ill defined (faintly) granulate granular aggregations cover the whole surface.
Exine Strata	:	3.3μm thick.
Pollen Size	:	*Elongate*: E - 64μm (57 μm - 68 μm), P - 30.4μm (23 μm - 34μm); *Circular* : 52 μm (47 μm- 56μm)
Pollen Shape	:	Ellipsoidal 5%, Subspheroidal 40%, Spheroidal 55%.
Distinctive features	:	Lateral surface pattern ill defined, but with minute granular aggregations spread over the surface.

SAN RAMON TALL

Nativity : Philippines **Plate No. 13 - Fig. Nos. 109-111**

Form	:	Dimorphic: monocolpate -elongate (10%), monoporate - speroidal (90%).
Aperture	:	*Colpate form* : colpus (45µm × 12 µm) wide, confined to proximal face extending to lateral ends producing beaks or no beaks, margin costate, edge even; circular large pore is spheroidal grains. *Porate form* : pore diameter 37µm.
Exine Ornamentation	:	Polar cap formed of agglutinated granules demarcated (lax towards lateral ends); lateral surface echinulate formed into striate formations, general surface granulate; spot aggregation of granules often present at excrescence region.
Exine Strata	:	4 µm thick.
Pollen Size	:	*Elongate* : E-57 µm (51µm - 65µm), P -25µm (23 µm - 28 µm); *Circular*: 46.5µm (41 µm - 52µm).
Pollen Shape	:	Ellipsoidal (15%), Subspheroidal (65%), Spheroidal (20%).
Distinctive features	:	Lateral surface echinulate, in striate formations – general surface granulate.

SEYCHELLES TALL

Nativity : Seychelles **Plate No. 13 - Fig. Nos. 112-114**

Form	:	Dimorphic: dominantly -monocolpate, elongate (99%); monoporate – spheroidal (1%).
Aperture	:	*Colpate form* : colpus wide (82 µm × 13 µm), arching down at lateral extremities, margin costate, edge even, becoming beaked at lateral ends. *Porate form* : pore diameter 35 µm.
Exine Ornamentation	:	Polar cap zonate being demarcated into 3 zones with dense aggregation of powdery granules, or either side of a middle zone of lax granules; lateral surface radially striato-matted (twined) with wide adnate muri twining with each other enclosing depressions of various sizes and shapes. Foveolate, reticulate; radially extended
Exine Strata	:	3.3 µm thick.
Pollen Size	:	*Elongate* : E – 92 µm (85 µm – 97 µm), P - 33µm (28 µm– 36 µm); *Circular*: 42 µm (37 µm – 45 µm).

Pollen Shape : Mostly ellipsoidal (90%), subspheroidal (10%).

Distinctive features : Polar cap zonate being alternately thick, and thin; lateral surface striate matted with radially oriented, muri.

SRI LANKAN TALL

Nativity : Sri Lanka **Plate No. 13 - Fig. Nos. 115-117**

Form : Dimorphic: monocolpate-elongate (99.5%), some grain tricholomocolpate (5%).

Aperture : *Colpate form* : colpus wide (49.5μm × 13.2μm), short confined to proximal face, margin slightly wavy, edge costate, with lateral extensions, noticed in some grains.

Porate form : pore diameter 21 μm.

Exine Ornamentation : Polar cap formed of a dense aggregation of powdery granules extending to the whole surface and to the colpus margin in most grains; in yet others lateral surface psilate-faintly rugulate, covered over by a thin veil of dispersed granules formed into minute spots of various sizes and shapes.

Exine strata	:	3.3 µm thick.
Pollen Size	:	*Elongate* : E - 66 µm (61 µm - 70µm), P - 29 µm (24 µm - 34 µm), *Circular* : 30 µm (26 µm - 33µm).
Pollen Shape	:	Ellipsoidal (50 %), subspheroidal (25%) spheroidal (25%).
Distinctive features	:	Colpus short confined to distal face. Whole surface covered by white powdery granules; lateral surface psilate (faintly rugulate) with a veil of dispersed granules.

SRI LANKAN YELLOW DWARF

Nativity : Sri Lanka **Plate No. 14 - Fig. Nos. 118-120**

Form	:	Monomorphic: colpate-elongate.
Aperture	:	*Colpate form* : colpus wide (42 µm × 10 µm), elongate, lateral ends acute margin costate, edges segmented with semicircular segments being also slightly thicker at the junction of segments.

Exine Ornamentation	:	Polar cap absent; polar region cleft into two equatorial halves, the upper line of each half of being uneven, with high or low elevations; surface including creft striate foveolate – fossulate, ridges in lateral surface, formed of dissected elevations (rounded or in other shapes) with spot aggregation of granules and covered over by a thin veil of dispersed granules; lateral surface developed into radial variously sized mega islands.
Exine Strata	:	3.3 μm thick.
Pollen Size	:	46 μm (42 μm-59 μm); P 26 μm (23μm-29μm).
Pollen Shape	:	Ellipsoidal (25%), subspheroidal (75%).
Distinctive features	:	Segmented colpus edges; absence of polar cap; Polar regions cleft; Surface striate-foveolate, lateral sides formed into low mega islands and with striate –rugulate pattern.

STRAIT SETTLEMENT GREEN TALL

Nativity : Malaysia **Plate No. 14 - Fig. Nos. 121-123**

Form	:	Dimorphic: monocolpate-elongate (85%), monoporate-spheroidal (15%).
Aperture	:	*Colpate form* : colpus wide (55μm × 10 μm), slightly arched at lateral ends, extended into beak, margin costate, edge even. *Porate form* : pore diameter 41 μm.
Exine Ornamentation	:	Polar cap is slightly formed of lax aggregation of granules, not delimited; lateral surface striate-reticulate, matted oriented along equatorial axis; muri, wide close, enclosing depressions (striae) like channels or in fossulate / circular patterns; whole surface covered by the spread of powdery granules, in varying concentrations.
Exine Strata	:	3.3μm thick.
Pollen Size	:	*Elongate* : E -71 μm (68 μm -74 μm),P 31 μm (24 μm -39 μm); *Circular* 30 μm (28 μm - 33 μm).
Pollen Shape	:	Ellipsoidal (25%), Subspheroidal (60%), Spheroidal (15%)
Distinctive features	:	Lateral surface striate-reticulate – matted, extended equatorially.

VERRICOBARRI

Nativity : Andhra Pradesh **Plate No. 14 - Fig. Nos. 124-126**

Form	:	Dimorphic: monocolpate -elongate (95%), monoporate - spheroidal (5%).
Aperture	:	*Colpate form* : colpus wide (52.8μm × 9.9μm), with a mild, lateral arching; margin mildly costate, edge even.
Exine Ornamentation	:	Polar cap formed of dense aggregation of powdery granules, delimited, extending to lateral ends and to the colpus margin; lateral sides, striato-reticulate- scrobiculate. muri low, wide enclosing faint lumina; muri surface scrobiculate; white powdery nodular spot aggregation spread over the surface.
Exine Strata	:	4.1 μm thick.
Pollen Size	:	*Elongate*: E-62.7μm (53 μm-67 μm), P-36.3μm (29 μm – 42 μm).
Pollen Shape	:	Ellipsoidal (25%), Subspheroidal (75%).
Distinctive features	:	Striato – reticulate – scrobiculate exine surface with spot aggregations of powdery granules on low striate ridges.

WEST COAST TALL

Nativity : Kerala **Plate No. 14 - Fig. Nos. 127-129**

Form	:	Dimorphic: monocolpate - elongate (95%), monoporate - spheroidal (5%).
Aperture	:	*Colpate form* : colpus wide (70µm × 6.6 µm), margin mildly costate, edge even, bend at lateral ends. *Porate form* – pore diameter – 44 µm.
Exine Ornamentation	:	Polar cap formed of dense aggregations of powdery granules; lateral sides cloudy with islands of granular aggregations; lateral surface diffusely ridged; with radial megaridges having foveolate or fossulate patterns.
Exine Strata	:	4.6µm thick.
Size	:	*Elongate* : E- 72.6µm (65 µm – 77 µm, P – 42.9µm) (36 µm – 45 µm); *Circular*: 56.1µm (49 µm - 59µm).
Shape	:	Elliptical (25%) to Ellipsoidal (75%).
Distinctive Features	:	Lateral sides cloudy produced into faint hillock like formations; lateral sides with megaridges having striate-foveolate -fossulate patterns.

ZANZIBAR TALL

Nativity : Zanzibar **Plate No. 15 - Fig. Nos. 130-132**

Form	:	Dimorphic: monocolpate-elongate (15%), monoporate -spheroidal (15%).
Aperture	:	*Colpate form*: colpus wide (37μm × 12μm), margin costate, edge mildly wavy. *Porate form* : pore diameter 44 μm.
Exine Ornamentation	:	Polar cap region humped, topped by lax aggregation of powdery granules, sparse in some grains, and demarcated in some others; lateral surface striate, often twined or matted enclosing foveolate depressions, muri formed of nodular formations; sprinkled over by white powdery granules; strait or arched; some other grains with well demarcated cap.
Exine Strata	:	4.95μm thick.
Pollen Size	:	*Elongate*: E-67.98μm (61μm - 75μm), P-34.98μm (28 μm - 35 μm); *Circular* : 56.1μm (49 μm- 61μm).
Pollne Shape	:	Ellipsoidal (25%), Subspheroidal (60%), Spheroidal (15%).
Distinctive features	:	Surface striate nodulate, with twined - matted striate, foveolate at places.

4 – DISCUSSIONS

4.1 BACKGROUND INFORMATION

In the evolutionary biology of plants, the reproductive machinery has been the focus of protection and organized structural system in view of the fact that the success in reproduction is vital for the continuation of life associated also with adaptation to ecological and geographical variations in the evolutionary process. In such an event, the haploid (reproductive) and diploid (vegetative) components of the reproductive machinery has been undergoing natural variations in conformity with the requirements in evolutionary situations through time and space. In this context, the haploid has always been vulnerable to the impacts of environmental stress and strain and therefore, required its own protective mechanisms, apart from the additional structure offered by the diploid plant body. Thus, the reproductive haploid unit constituted of spores and pollen grains have been bestowed with the unique protective cover, which is indestructible under any adverse environmental situations. At the same time as providing protection, the wall structure is also diagnostic because of the fact that the pollen-spore unit can be considered to be the gene pool of variations during the life cycle of the plant. This twin feature of protection and diagnosis makes the wall a unique structure in plant morphology. The generations of knowledge on spores and pollen over the last several centuries, particularly in the second half of last century, indicates that the spores and pollen are 'single celled' units enveloped in a wall composed of an outer (exine/exosporium in spores) and intine (endosporium in spores). It is the exine which is endowed with the protective and diagnostic characteristics and therefore, of use in the study of plant relationships. Considering the evolutionary progress of the plants, it is known that there has been a progressive reduction of the vegetative gametophyte associated also by a progressive increase in the sporophytic vegetative body, consequent to the changes in habitat of the plants which originated and evolved during the course of geological time (Nair, 1970).

The evolutionary trend has been to produce an independent gametophyte, and which has become a reality in the flowering plants, with the origin and evolution of flower morphosystem, as a concrete mechanism in the reproductive process. In fact, the spores in cryptogams are structurally and functionally different from pollen in flowering plants. However, the wall of spores and of pollen have the common direction of protection of germplasm and of having diagnostic characteristics. Contemporary taxonomists takes due note of the value of pollen morphology in establishing plant relationships (Nair, 2004).

The voluminous literature on pollen morphology, beginning with Wodehouse (1935) followed by Erdtman (1952) has established beyond doubt the relevance of pollen morphology in plant taxonomy and evolution. By virtue of the diagnostic value of the pollen unit, the application of pollen morphology in various areas of scientific research is well established, and today the structure of exine can be understood at micro levels, thanks to the technology offered by scanning electron microscope, with the result that the pollen has become a practical tool in establishing genetic variations and recombinations at even population levels, apart from its demonstrated value in authenticating and circumscribing cultivars (Nair and Sharma, 1967; Nair and Ravikumar, 1989; Ravikumar and Nair, 1986) and natural varieties (Nair 1961). It is this current level of advancement in our knowledge in pollen morphology that formed the background of the present study on the pollen morphology of cultivars of an important plantation crop namely coconut (*Cocos nucifera* Linn.) which is tropical in distribution.

The coconut palm belonging to the family Arecaceae is considered to have originated in the Amazones of South America and distributed through its fruits to the Pacific Islands and to the main lands of Africa, India and South and South East Asia, through the seas. It is mainly of coastal occurrence thriving well on sodic soils, but over the years it has been introduced and cultivated in lateritic and other soil systems, where also it adapted remarkably well. In the process of such a wide range of geographical, edaphic and ecological conditions, the plant seems to have undergone variations and modifications as evidenced in the structure and production of fruits (Menon and Pandalai, 1952). The economics of most of the countries inhabited by coconut is reflective of the influence of the palm on the people. Thus, the material studied has considerable scientific and economic relevance.

In view of the fact that the pollen unit could be reflective of genetic variations undergone by the coconut plant during the course of its distribution and establishment (Nair, 1963), the present research programme relate to a palynological evaluation of coconut biodiversity as reflected in pollen morphology. The study is envisaged to provide new knowledge on the nature and direction of changes undergone by the plants and to develop pollen standards for screening coconut population of even single varieties as known at present, for resolving them into more micro ecological associations. In order to cover the genetic resources over a wide geographical range, the pollen collections were made from The Plantation Crop Research Institute, Kasargode, Kerala which maintains a live collection representing West Africa, Zanzibar Seychelles, Latin America, Philippines, Indonesia, Vietnam, Malaysia, Guam, Fiji, Solomon Islands, India and Sri Lanka.

4.2 POLLEN MORPHOLOGY OF COCONUT

The pollen grains of coconut as in most of the palms is monocolpate, bilateral and with granulate to reticulate ornamentation of the exine. The present investigation combining both light microscope and scanning electron microscope has provided much information.

In studies on pollen morphology, five groups of characters namely aperture, exine ornamentation, exine strata, pollen size and pollen shape, are taken into consideration. In coconut pollen, the aperture is basically monocolpate, but a certain percentage of the grains have circular large pores (megaporate) and thus the pollen are dimorphic being monocolpate–elongate and monoporate- spheroidal. The colpus itself has several features, which could be of comparative value among which are the length, the edge and the margin of the colpus. With regard to exine ornamentation, the scanning electron microscope has revealed a configuration which is far different from known information as understood from earlier light microscope studies (Nair and Sharma 1963).

Basically, the pollen surface has a polar cap (proximal face), extending to the lateral ends of the grain and proceeding to the colpus margins (on the distal face). Between the polar cap and colpus margin the exine (lateral face) ornamentation is generally striate reticulate extending radially and arching between the cap and margin. The exine strata is not of considerable comparative interest. The pollen size in bilateral grains is known to have three dimensions namely the longer parallel to colpus (E_1) and shorter perpendicular to the colpus at the centre (E_2) and polar diameter (P). For practical reasons, the P and E_1 alone have been considered in the present study and further, the diameter of circular grains has also been provided, which could either be polar or equatorial. In expressing the shape, colpate grain lying in lateral view has been taken as standard and the shape varies from elliptical to semicircular. Considering all the characters together, the colpus and the exine ornamentation are of primary interest, to which the size characters could also be associated.

4.3 MORPHOLOGICAL ANALYSIS

A comparative analysis of the pollen morphology of varieties of *Cocos nucifera* Linn. studied is presented below.

4.3.1 Pollen Form

In form, the pollen grains of coconut are dimorphic, being monocolpate-elongate (boat–shaped) monoporate circular (spheroidal) as seen in lateral view. Rarely, trichotomocolpate–circular grains are also noticed in extremely small percentage (1% in St.Vincent and 0.5% in Sri Lankan Tall).

The monocolpate elongate form is the most dominant (in more than 50% varieties studied). A few varieties are monomorphic being monocolpate–elongate alone (King Coconut, Sri Lankan Yellow Dwarf) while the monoporate-circular form is of the order of 98% in Laccadive ordinary and 90% in Laccadive micro, Nadora and San Ramon Tall).

Dimorphism combining monocolpate–elongate type and the monoporate-circular type is the commonest feature in a large majority of the varieties studied. Based on the percentage of the monocolpate form as the standard, the varieties may be grouped into 5 categories namely 1-15% (monocolpate–elongate) in 4 varieties, 16-25% in 2 varieties, 26– 50 % in 6 varieties, 51-75% in 6 varieties and 76-99% in 19 varieties. For comparative purposes, the monocolpate -elongate form may be considered the basic type, on the merit of its dominance.

Dimorphism has been noticed by Sharma (1967) in the pollen of monocotyledonous taxa, and the basic nature of the monocolpate–elongate has been recorded in an analysis of the two forms, the monocolpate and the monoporate (Nair and Sharma; 1962). The occurrence of triradiate (circular) form could be a minor variation, occurring only in a few varieties in negligible percentages.

4.3.2 Apertural System

The apertural system consist of the aperture (colpus or pore) its margin including edge, and the inner demarcation of the marginal area and any other features. The colpate form has been considered the standard for analyzing the apertural system, consisting of the furrow (colpus) region, the furrow margin is resolved into the edges, the area behind the edge fortified by the aggregation granules all along (costate) or at spots, and the line of demarcation of the costae on the lateral sides. The colpus in most varieties is wide in the middle narrowing down towards the lateral extremities (eg: Fiji Tall). The colpus is being flat (straight) mildly or sharply curved, both of which can be seen in the variety (West Coast Tall). The variation from the above situation, is the arching of the colpus at the lateral ends, in various degrees leading to its extension to the proximal face (Ayiramkacchi; Gonthembili; Guam II; Laccadive Ordinary). Often the formation of a beak-like structure is associated with the lateral bending and the curving of the colpus (Ayiramkacchi; Benaulim, British Solomon Island). However, the above special features are not characteristic features of pollen in any one variety, but are found along with normal forms.

The colpus edges are mostly even (West Coast Tall), wavy (Blanchesseuse, Cameroon Red), frilled (Borneo Tall; Cochin China, Laccadive Micro), segmented (Sri Lankan Yellow Dwarf). In yet others, the edges are echinulate (Benaulim, Malayan Green Dwarf), with minute triangular projections, all along the edges or echinate (Ayiramkacchi, Kappadam, Malayan Tall) in which there are conical projections on one edge, complemented by depressions on the opposite side to fit in the projection. In a rare case, the edges fuse at places (Philippines Ordinary) producing narrow disrupted colpus (Federated Malayan States), a closed colpus (Andaman Ranguchan), and the feature of the colpus edge is characteristic of some of the varieties.

The margin is fortified by the aggregation or agglutination of powdery granules in most varieties (Benaulim, West Coast Tall) and rarely the aggregation is absent (Blanchesseuse, Cochin China) or scarcely present (Cameroon Red Dwarf). In yet others, spot aggregation is noticed (Laccadive Micro; Sri Lankan Yellow Dwarf). The inner line of the marginal thickening is delimited or else merged with the pattern on the lateral surface of the grain.

A rare case of the apertural system bearing the operculum has been noticed in Guam II, which may be considered as a characteristic feature of the variety.

4.3.3. Exine Surface Ornamentation

While the exine surface ornamentation is a directive feature of value in resolving the genetic resources of coconut, the components of surface pattern may be demarcated into two main zones namely the polar cap, formed in the proximal pole, the architecture of the lateral surface between the proximal and the distal poles associated by lateral extremities of equatorial (long) diameter, in a grain seen in lateral view. The finer components of the exine surface is constituted of minute granules, which sometimes are not even discernible, and the various patterns of the polar cap and the lateral surface, are produced by granular aggregations (dense or lax) or agglutinations (fused) to produce visible structural differences. Sometimes the powdery granules envelop the whole surface of the grain (Cochin China).

4.3.3.1 Polar Cap

Very rarely the polar cap is absent (Laccadive Ordinary) but marked by other unique characteristics, being humped (Blanchesseuse Cochin China; Zanzibar Tall) and the feature is supplemented by a dissected cap region to form ridges with toothed crest and oriented along the long equatorial diameter (Blanchesseuse). Sometimes, the polar cap is poorly developed (Borneo Tall; Cameroon Red Dwarf), or made up of lax granules in varying grades (Laksha Ganga) leading to dense aggregations (Andaman Ranguchan). In 'Borneo Tall' the powdery granular aggregations is confined to the center of polar region. Normally, the polar cap extend to the lateral sides (San Ramon Tall) along varying widths, demarcated along the long equatorial diameter or merging with lateral surface ornamentations. Rarely, the polar cap have depressions (King coconut, Lifou Tall; Philippines Dalig or cleft (Sri Lankan Yellow dwarf). In an odd case, the lateral extension arches almost touching the colpus on the distal side (Guam II).

4.3.3.2 Lateral surface

Normally, the general surface bearing the ornamentation is flat (plain). However, the general surface, is resolved into broad radial arched ridges along polar diameter, (Borneo Tall) with the ridges broader towards the polar cap, and narrowing towards the colpus, and oriented obliquely towards one end. In yet another variety (Niu Lekha Dwarf), the surface configuration is marked by rounded hillock like elevations of various sizes and shapes, although covered over by a thin veil of granules. The above situation could be considered characteristic of the some varieties providing a link character in evolutionary morphology.

Considering all other varieties mentioned together, the lateral surface is psilate (Laksha Ganga) covered over by a veil of powdery granules, granulate (British Solomon Island; Cameroon Red, Malayan Yellow Dwarf). The surface is echinate (Kulasekhara Yellow Dwarf).

The striate pattern formation is the most dominant configuration, with the striations being radial, meandering, and often arched with the curve of the arch orientated towards one end of the grain. Wavy meandering ridges with low lumina (between adjacent ridges) spread over by diffuse powdery granules is seen in Ayiramkacchi; striate, diffuse, with granular, crowded aggregations in Chowghat Green dwarf. The other type of formations are striate tuberculate (Ganga Bondom), striate-rugulate (Benaulim; Laccadive Micro; Philippines Laguna, Sri Lankan Tall), striate fossulate (Guam II), regulate striate (Sri Lankan Yellow Dwarf) and the striate-reticulate in most varieties, which by itself exhibit a great degree of diversity. In all striate types, the ridges (lirae) is made up of granular aggregations of various sizes and shapes, placed end-to-end, carrying excrescences, whenever present. Further, powdery granular spot formations cap the ridges and the cavae (striae) between adjacent ridges are either wide Guam III

(Zanzibar Tall) or narrow, and often the adjacent ridges cross over each other fusing at the nodular points enclosing thereby lumina of various sizes and shapes. (Kaithathali, Nadora Tall). In the typical reticulate types (Kappadam, Malayan Green Dwarf, Markom Yellow Tall; Seychelles), the ridges (muri) are wide and agglutinated, with the lumina being formed by the close adnation or fusion of adjacent muri, enclosing lumina of various sizes and shapes, leading to foveolate, fossulate or cavate (channel) depressions and even all the types occur together in the same variety. Further, the muri are formed into a plated (matted) pattern, and which are normally radial in orientation, except for the rare equatorial orientation (along longer axis) in some varieties Markom Tall; Orrisa Tall). These variations are almost typical for each variety, except for some common features like the spread of powdery granules in various forms, suggests the ecological-genetical impact on the varietal resources, distributed over a wide range of coastal habitats.

4.3.3.3 Other Characters

The exine strata, size and shape are not of comparative value, but could be taken as tertiary characters for purposes of varietal characterization.

4.4 POLLEN MORPHOLOGY AND VARIETAL CIRCUMSCRIPTION

The varietal circumscription and rating is based on a array of varietal characteristics, and product evaluation (Menon and Pandalai, 1958). However, pollen morphology has not been used as one of the characters in varietal characterization. But in the present day studies in plant taxonomy, pollen morphology is considered abundantly (Nair, 2004), in the background of the studies made by Erdtman (1952) and a host of others. With the introduction of SEM as a tool in the application of pollen morphology in plant taxonomy, it is now possible to resolve the natural varieties and cultivars (Ravikumar and Nair, 1986) and to gain new knowledge on morphological evolution allowing a proper insight into the breeding systems. Nair and Sharma, (1963) indicated the differences in the surface morphology of *Cocos nucifera* Linn. on the basis of light microscopic studies, and the present study has given a totally new picture of fine morphology of the exine surface, providing new direction for cultivar typification.

The apertural and exine ornamentation characteristics may be considered to be of conservative value in the comparative morphology of pollen for use in taxonomy and evaluation (Nair; 1970). Considering the various cultivars presently studied, single or combination of characters of diagnostic value has been noticed even to the minutest level, typical cases of which are presented below.

Colpus faintly developed	:	Malayan Yellow Dwarf
Colpus narrow	:	Federation of Malay State
Colpus narrow and disrupted (by fusion of edges)	:	Philippines Ordinary
Colpus operculate and polar cap arched	:	Guam II
Colpus edge profusely toothed (echinulate)	:	Cameroon Red Dwarf
Colpus edge scarcely toothed	:	Kappadam
Colpus edge distantly toothed	:	Malayan Tall
Colpus edge frilled	:	Laccadive Micro
Colpus edge segmented	:	Sri Lankan Yellow Dwarf
Exine lateral surface formed into massive ridges	:	Borneo Tall
Exine lateral surface formed Into rounded hillock structures	:	Niu Leka Dwarf

Among other typical characteristics of value in cultivar authentication, the following typical cases may be noticed.

Polar cap absent	:	Laccadive Ordinary
Polar region humped	:	Cochin China
Polar region cleft	:	Sri Lankan Yellow Dwarf
Polar region dissected striate	:	Blamchesseuse
Polar cap lax	:	Laksha Ganga
Polar cap zonate	:	Seychelles
Lateral surface regulate-striate (regulae straight)	:	Benaulim
Lateral surface echinulate	:	San Ramon Tall
Lateral surface echinate	:	Kulasekhara Yellow Dwarf
Whole grain granulate	:	Cochin China
Surface striato-reticulate	:	Zanzibar Tall

Apart from the other typical morphological situation, there are differences with grades of differences in the density of the polar cap, their demarcation laterally, the striations and their meandering, and each variety is typical in its own combination of characteristics. When a limited number of varieties in a certain ecosystem in taken into research consideration and even for population screening, the pollen characteristics, particularly, of the aperture and the exine ornamentation could be applied with advantage.

4.5 MORPHOLOGICAL EVOLUTION

In an analysis of the species and cultivars of *Gloriosa*, Ravikumar and Nair (1986) conceived the possible line of morphological evolution, starting with the granulate primitive form to the matted advanced form, through several intermediary forms. Taking all the various varieties of coconut together, there is no significant pattern of evolutionary change in apertural characteristics except perhaps for the change from the normal (primary) flat orientation of the colpus (Gonthembili) reaching the lateral ends, to a stage of arching (Ayiramkacchi, West Coast Tall) leading to bending down (West Coast Tall) and curving to the polar surface (Guam II). Similarly, even the colpus edge could be a character of value, the basic form being even and straight from which new characters namely profusely toothed (Benaulim) or scarcely toothed (Kappadam), distantly toothed (Malayan Tall), frilled (Laccadive Micro) and segmented (Sri Lankan Yellow dwarf) characters could have developed. The operculate form in Guam II could be of special importance in evolutionary considerations.

While taking the exine surface architecture, the polar region and the lateral surface are the two components for consideration. The polar cap may be absent (Blanchesseuse) or lax (Laksha Ganga), or well formed (Saint Vincent). The formation of a polar cap, is a morphological event in the organization of the pollen-spore unit in the plant kingdom as a whole, and in the flowering plants in particular. Hence, the feature may be considered a special component in evolutionary morphology. When the polar cap is absent, the polar region is substituted by other structural features like the formation of hump (Cochin China) or dissected ridges (Blanchesseuse) or other special features which serve to fortify the polar region.

Regarding the ornamentation of the lateral surface or even the whole grain, occurrence of powdery granules, spread over the grain as dense aggregations (as in polar cap), spot specific structures, or as a veil may be noted as a new feature. Further, the powdery granules is evidently a supratectal structure, below which is the tectate surface bearing the ornamentation patterns. The very fact that these granular aggregations or agglutinations are characteristic in various varieties, is a feature which is evidently genetically controlled.

In designing a scheme of morphological evolution, the general surface (superatectum) features could be the base to which, other special features may be associated. In such a scheme, the psilate surface (Blanchesseuse, Cameroon Red Dwarf) could be the basal form from which the granulate (Cochin China, Malayan Yellow Dwarf) on the projection stock, and a variety of other forms in the depression stock with the common features, varying widely: striato-granulate, striato-rugulate, striato-echinulate, striato-reticulate, striato-scrobiculate. The grades of striate forms are such that there is a range of intermediary types starting with widely separated ridges (muri) to close ridges (adnate or even fused) and crossing over each other. Special surface configurations like the undulate-striate (Ayiramkacchi), massive ridge (Borneo Tall) or rounded hillock–like mounds are of special significance, which all could form a line of evolution by itself.

Taking into consideration the available information, there seems to be three lines of morphological evolution starting from the basal psilate form. The three lines are constituted of (i) granulate–echinulate-echinate line, (ii) widely–closely striate diverse depression forms (iii) mega–tuberculate line. However, the above lines of evolution do not show any definitive direction for resolving the varieties studied along the path of evolutionary lineage, but comparative morphology of pollen may be used to advantage in resolving biodiversity at regional levels and to establish links between geographically scattered or isolated varieties.

4.6 STRUCTURAL FEATURES OF FUNCTIONAL RELEVANCE

The very fact that the exine is made up of sporopollenin, which is resistant to destruction, is known to be a measure for the protection of genome, in order to ensure reproductive success and production of seed (Nair 1970, 2004). But the special features of pollen exine, allow not only the protection but also the diagnosis of the mother plant the pollen belongs to (Erdtman 1952). Wodehouse (1935) also indicated that the morphological features of the aperture are associated with the harmomegathic function associated with the opening and closing of the aperture to be specific.

In the pollen of *Cocos nucifera* Linn., the grains are monocolpate/ monoporate and bilateral with new structural characteristics, like the polar cap hump, the dominantly striate pattern of the lateral surface which together are apparently meant to fortify the exine. The coconut palm is coastal in natural occurrence, being subject to marine stress and strain, and the pollen needs to float in the air. There is as yet no study on the floatation pattern of coconut pollen, but the occurrence of the polar cap, which is sometimes replaced by other characteristics like hump, and the occurrence of powdery granules spread of the entire granules, give the impression of special protective mechanisms, as well as a mechanism for pollen floatation in a special manner, possibly with the aperture directed towards the upper side, the heaviness of the polar cap aiding such a situation. The very fact that the polar cap is sometime scarce or lax, indicates the special adaptation to produce favourable environmental conditions. Similarly, the special characteristics of the colpus margin and edge for locking the colpus and also for easy opening, could be adaptations associated with facilitating harmomegathic function. The whole subject deserves new research attention including experimental verification.

4.7 POLLEN MORPHOLOGY AND GEOGRAPHICAL DISTRIBUTION

The coconut varieties studied cover a wide range of geographical distribution; which may be resolved into the following zones, and associated pollen characters.

I. Latin America (Trinidad – Tobago): Primary Region

Var. Blanchesseuse	-	Polar cap absent;polar region dissected; lateral surface diffusely granulate
Var. St. Vincent	-	Polar cap formed; lateral surface ill defined.

II. Africa

Var. Seychelles Tall	-	Zonate polar cap; matted striate surfac
Var. Zanzibar Tall	-	Polar cap humped; striate nodulate with wide lumina; twined; matted

III. Pacific Islands

Var. Fiji Tall	-	Polar cap slightly formed; reticulated matted
Var. Niu Leka Dwarf	-	Megatuberculate, foveolate

Var.Lifou Tall (Lifou Island)	-	Polar cap agglutinate-surface with lowly developed mounds (tuberculate) covered with, foveolate – fossulate depression.
British Solomon Island	-	Polar cap present; lateral side psilate, but covered with powdery granules.
Guam II	-	Polar cap arched; colpus operculate
Guam III	-	Polar cap normal, striate nodulate, criss crossed.

IV. South East Asia

Kerala

Var. Chandra Laksha	-	Polar cap normal; surface echinulate
Var. Chowghat Green Dwarf	-	Polar cap narrow, surface striate with disrupted lirae.
Var. Kaithathali	-	Polar cap narrow; striate, lirae disrupted with variously sized nodules
Var. King Coconut	-	Polar cap agglutinate; striate reticulate –matted
Var. Laksha Ganga	-	Polar cap lax. Psilate – cloudy lateral surface
Var. West Coast Tall	-	Polar cap diffused- surface cloudy with round aggregation of powdery granules

Goa

Var. Benaulim	-	Polar cap lax; surface striate rugulate – rugula straight
Var. Nadora Tall	-	Polar cap lax. Striate narrow nodulate ridges wide lumina, looked

Orissa

Var. Orissa Tall	-	Polar cap undefined, matted reticulate – equatorially oriented.
Var. Verrikobbarri Tall	-	Polar cap normal- surface striate – scrobiculate

Andhra Pradesh

Var. Ganga Bondom	-	Polar cap agglutinate, tuberculate foveolate – cloudy

Tamil Nadu

Var. Kulasekhara Yellow Dwarf		Polar cap normal, surface echinate

4.7. Islands

i. Andaman and Nicobar Island

Var. Andaman Ranguchan		Polar cap formed of aggregation of granules; striate – granulate – nodulate
Var. Andaman Yellow Dwarf	-	Polar cap normal, lateral sides striate-fossulate

ii. Lakshadweep Island

Var. Laccadive Micro	-	Polar cap aggregation–colpus margin frilled, lateral surface granulate.
Var. Laccadive Ordinary	-	No polar cap but humped,lateral surface minutely granulate – punctate

iii. Sri Lanka

Var. Gonthembili	-	Polar cap normal- foveolate matted
Var Sri Lankan Tall	-	Polar cap normal – surface psilate
Var. Sri Lankan Yellow dwarf	-	Polar cap absent, colpus edges, cleft, segmented, surface formed of rounded low elevations foveolate

iv. Malaysia

Var. Cameroon Red Dwarf	-	Polar cap not well formed but fortified faintly by striate – foveolate ridges; surface psilate
Var. Federated Malay State	-	Polar cap and general surface covered by powdery granules – general surface granulate
Var. Malayan Green Dwarf	-	Polar cap normal striate - nodulate – arched
Var. Malayan Tall	-	Polar cap agglutinate–surface striate – reticualte – twined

Var. Malayan Yellow Dwarf	-	Polar cap lax – surface granulate
Var. Strait Settlement Green Tall	-	Polar cap lax. Surface striate - reticulate matted

V. Indonesia

Var. Borneo Tall	-	Polar cap poor – lateral sides striate - mega ridged

vi. Vietnam

Var. Cochin China	-	Polar cap humped- surface striate granulate

vii. Philippines

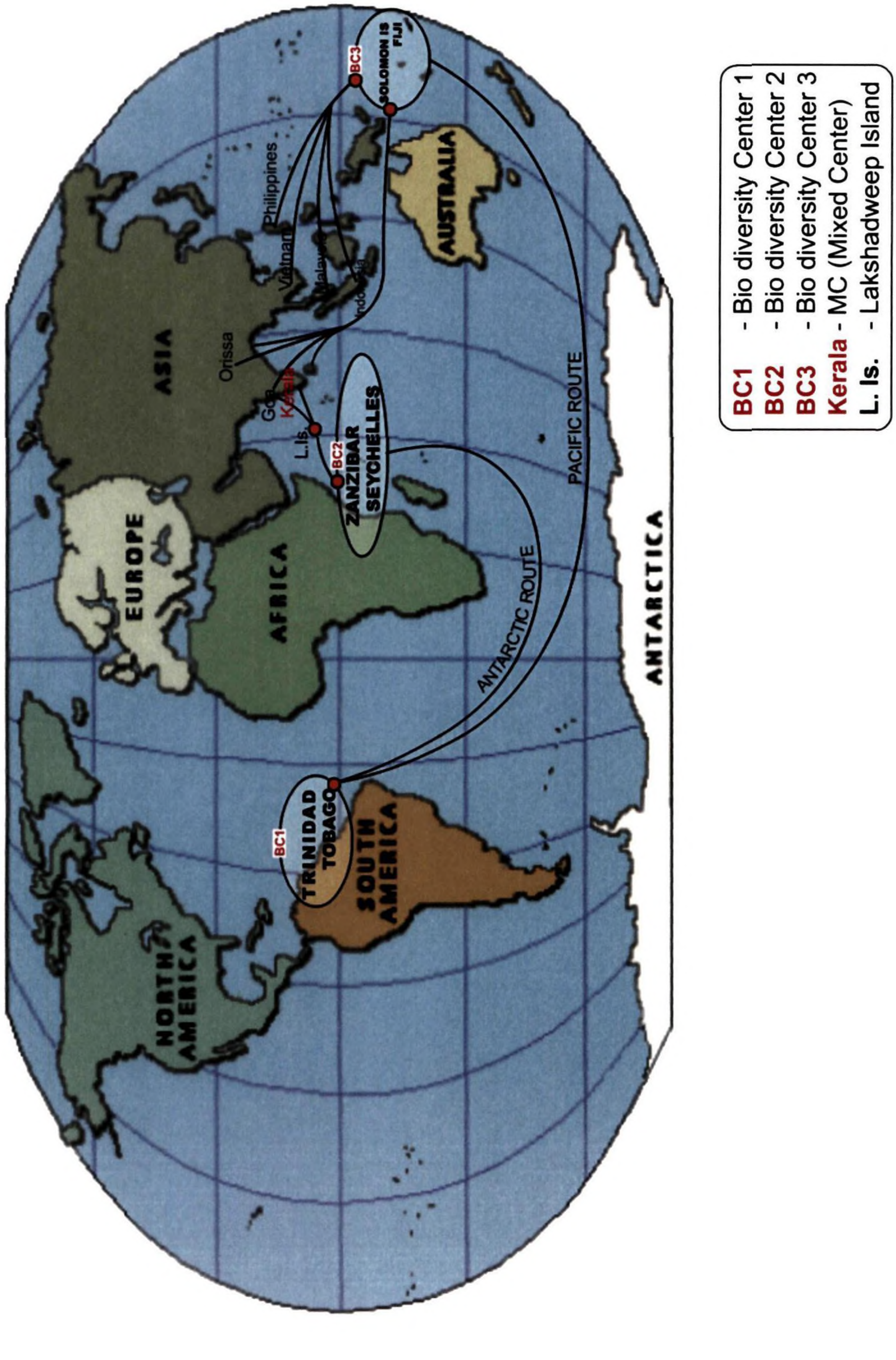
Var. Philippines Dalig	-	Polar cap lax; lateral surface cloudy
Var. Philippines Laguna	-	Polar cap slight; surface striate-foveolate
Var. Philippines Ordinary	-	Polar cap normal – surface – striate-noduate – arched
Var. San Ramon Tall	-	Polar cap agglutinate - surface striate – echinate

On the basis of the known route of distribution of coconut via the sea (Menon and Pandalai, 1958), the varieties studied may be grouped into four major ecological zones namely Latin America (centre of origin is considered to be South America), Pacific Islands, Africa and South East Asia together consisting of both islands and coasts of mainland. Pollen morphology does not totally provide a direction to the route of distribution and the changes acquired through ecological/environmental impact, but it reflects the characteristic features of the genetic resources in various regional situations. The polar cap is the most distinctive feature of coconut pollen, the absence of which is substituted by appropriate mechanism of fortification. In the Latin American species itself, the two forms are noticed, the cap being well formed in St. Vincent and dissected in Blanchesseuse. Thus, the beginning for morphological diversity has been laid in the original home itself of coconut. It may further be noted in the above two varieties the lateral surface is psilate–faintly granulate, with spread of powdery granules all over grain surface.

The African region is represented by Seychelles Tall and Zanzibar Tall, in the former of which the zonate polar cap is characteristic and the replacement of the polar cap by humped polar region is the characteristics of Zanzibar. The striate lateral surface is common to both but with variations, being open striate in Seychelles and matted striate in Zanzibar. The process of diversification as a result of naturalization in a new habitat is evident in this region.

Text Figure 2:

Centers of bio diversity and distributional pattern of coconut genetic resources, based on pollen architecture



The third natural region is possibly the Pacific Islands represented by Fiji, British Solomon Islands, Lifou Tall and Guam, which could be the centre of noticeable changes, reflected in pollen morphology. Polar cap of various gradations of aggregation of powdery granules leading to agglutinate (plated) form is found; both psilate (British Solomon Islands) striate–nodulate and criss-crossed (Guam III) or reticulate matted (Fiji Tall) may be noted. New surface configurations in the form of low mounds (Lifou Tall) also occur. To top it all is the arched polar cap and the operculate colpus in Guam II. The degree of dimorphism also showed variations, the monocolpate form being 98% (British Solomon islands) with corresponding higher percentage of 70% (Fiji Tall) down to only 20% (Lifou Tall). It may be therefore be safely argued that the Pacific Island region has been the home of major diversification.

In South East Asia comprising India, Sri Lanka, Malaysia, Indonesia, Philippines and Vietnam, are apparently new centres of natural introduction/naturalisation of coconut. In India itself, there are Island groups like Lakshadweep, and Andaman and Nicobar and also the main land coast represented by Kerala, Goa, Orissa, Andhra Pradesh and Tamil Nadu.

Among the Lakshdweep varieties, no polar cap of powdery granules present in Laccadive Ordinary, but a low humped polar region is visible. Laccadive Micro is characterized by the frilled colpus margin, but both varieties are fundamentally granulate. The absence of powdery polar cap, replaced by hump in Zanzibar (African zone) is repeated in the Laccadive Ordinary, which may be considered as a link between the two geographical regions. Among the Andaman and Nicobar group, a new character of note is the undulate-striate configuration of exine surface in Ayiramkacchi. Among the mainland varieties, the noticeable new characteristic (Kerala) exine pattern are echinate in Chandra Laksha and Kulasekhara Yellow Dwarf (Tamil Nadu), striate-rugulate with straight rugulae in Benaulim (Goa), tuberculate foveolate in Ganga Bondom (Andhra Pradesh), and striate-scrobiculate pattern in Orissa Tall, (Orissa). Other varieties taken together, provide a wide variety of gradations in polar cap, surface ornamentation ranging from granulate, striate-reticulate matted. The occurence of a toothed colpus in Ayiramkacchi (Kerala) in significant. Among the Sri Lankan varieties cleft polar end, low rounded mounds on exine surface associated also by segmented colpus edges in Sri Lankan Yellow Dwarf, are significant new characters, while in other varieties, a combination of various forms occur.

Among the Malaysian varieties, Cameroon Red Dwarf is devoid of a polar cap, but there is a faint presence of dissected - foveolate plate, similar to such a basic character noticed in Blanchesseuse (South America). The colpus edge is variously toothed being profuse, (Cameroon Red Dwarf), moderate and minute (Malayan Green Dwarf) and distant (Malayan Tall), otherwise the repetition of various other characters, from granulate matted surface pattern, and polar cap formation are like those of other regions.

Taking all other countries together, Indonesia, Vietnam, and Philippines, the configuration of exine surface, striate -segmented mega ridge in Borneo Tall is significant. Similarly, the polar hump in Cochin China (Vietnam), cloudy lateral surface formed by tuberculate aggregation of powdery granules (Philippines Dalig), striate-foveolate pattern in Philippines laguna and striate echinate pattern in San Ramon Tall (Philippines) are significant.

The data generated suggests that pollen morphology could be used as a measure for cultivar characterization and identity in regional biodiversity and assessment of evolutionary/varietal status. The data provide indications on the geographical routes along which the distribution and naturalisation of the coconut genetic resources took place. In such a process, the appearance of new characteristics, and also link characteristics could be the guiding principles.

The original home, the South America (Latin America) could have been the starting point, and among the two varieties representing this region the polar cap is present in Saint Vincent, but characterized by the dissected polar cap region in Blanchesseuse. The lateral surface is psilate, covered over by a veil of widely spread powdered granules in both varieties. The polar cap is common in a majority of varieties on the various geographical regime of coconut, and similarly the powdery granules is a common feature.

A new character that appeared in the African varieties is the zonate polar cap in Seychelles Tall, and the humped polar region in Zanzibar Tall. Further, striate nodulate surface with mild arching and criss-crossing is seen in Zanzibar Tall and striate - reticulate matted in Seychelles. Thus, there is a totally new development of structural features, meriting the consideration of a line dispersion from the primary centre to Africa.

Considering the Pacific region, it is evidently a high degree of biodiversity, producing even new surface configurations in the form of rounded mounds (Lifou Tall), and operculate colpus (Guam II). Thus, the pacific region may be considered a target centre of naturalization through variations and natural selection.

The South East Asian region is wide with varying ecosystem diversity. The nearest centre to the African zone is the western coast of India, with the Lakshadweep Island and the Western Coasts of Kerala and Goa. In Laccadive Ordinary, the presence of polar hump is a linking character with Zanzibar Tall (African region) and in Laccadive Micro, the colpus margin is frilled both of which could be considered as new characteristics. Similarly, the surface configuration is undulate striate in Ayiramkacchi (Kerala) and new surface characters such as echinate (Chandra Laksha), striate-rugulate (Benaulim, Goa), tuberculate foveolate (Ganga Bondom, Andhra Pradesh), striate-scorobiculate (Orissa Tall) and echinate (Kulasekhara

Yellow Dwarf, Tamil Nadu) provide a picture of diversity and new character development. The toothed colpus edge is another new character (Ayiramkacchi, Kerala).

Among the Sri Lanka varieties, the occurrence of segmented frilled colpus margin (Sri Lankan Yellow Dwarf) is a unique character. Further, the occurrence of low mounds on exine surface in the above variety is indicative of a link with a similar character in Lifou Tall (Pacific region) which may suggest a line of migration of coconut from the pacific region.

Among the other varieties in the South Asian Region, the presence of a faint dissected polar cap in Cameroon Red (Malaysia) is indicative of a similar situation in the South American variety Blanchesseuse, which may be considered as suggestive of the reappearance of the character. Further, there are an array of new characters that have developed among which are the striate-segmented ridges in Borneo Tall (Indonesia), polar hump in Cochin China (Vietnam), tuberculate aggregation of granules, striate foveolate patterns in Philippines Laguna and striate-echinate pattern in San Ramon Tall in Philippines. The above new characteristics are coupled with grades of toothed colpus edge, in Malaysian varieties. Here again, there is indication of major or minor biodiversity, suggesting various lines of migration and ecological stabilization.

Considering the above facts, it is felt that the migration of coconut from its primitive home has been along two primary routes namely the African route and the Pacific route, each of which provided the base for further migration to the Western Indian Coast from African Centre via Lakshadweep (humped pollen being link character connecting South America, Africa and Lakshadweep) and the other countries of South East Asia including East Coast of India from the Pacific centre with the rounded low or higher hillocks being a link character between Lifou Tall, Niu Leka Dwarf and Sri Lankan Yellow Dwarf and the occurrence of the character in King Coconut of Kerala suggests the influence of the African and Pacific links in the Kerala region. In each of the territory centre, parallel or related lines of diversification apparently occurred. These tentative suggestions need to be substantiated with data from other disciplines, which needs new research probes taking into consideration the direction provided by pollen morphology, the pollen being a partner in reproductive biology. There is every reason to think that the phenotype reflected in the exine is an expression of the genotype of the pollen resources and the plant it belongs to. The user of pollen morphology in geographical distribution of plant genetic resources has been observed earlier (Nair and Sharma, 1962) in *Argemone mexicana* and by Lewis (1964, 1965a, 1965b) in Rubiaceae and the present findings provide substantial new evidence.

SUMMARY

SUMMARY

BACKGROUND INFORMATION : The pollen grains being the male partner in the reproductive biology of the flowering plants, it has a vital role to play in the production of fruits and seeds for sustaining the food needs of man the importance of pollen in plant improvement has been understood by man as early as 700 B.C., as evident from the stone carvings of Assyrian period showing winged human beings pollinating the date palm. Scientific knowledge building on pollen biology began with the discovery of the compound microscope by Robert Hooke in 1756 and since then botanical pursuits covered in pollen studies to result in the understanding of the relevance of pollen in plant biology. A very definite scientific beginning to the study of pollen structure was made with the publication of the book "Pollen grains" by Wodehouse (1935), followed by another publication "Pollen Morphology of Angiosperms" by Erdtman (1952).

During the last 50 years, fast progress has been made in the knowledge of pollen architecture aided by the advances made in optical technologies, particularly the TEM and SEM. It is now clearly established that pollen morphology is of application in plant taxonomy and evolution at various taxa levels down to natural varieties and even cultivars.

The structural features are attributed to the exine and the dual characteristic of protection and diagnosis is unique to pollen units. Genetical changes due to various factors are reflected in pollen morphology, which has given a new dimension of application of morphology in the biology of plants. This is particularly important in view of the fact that pollen morphology serves to resolve the breeding system of crop plants and its wild allies giving new directions for plant improvement practices. It is in this background that the study of pollen morphology of coconut cultivars has been taken up for the present investigation.

MATERIALS AND METHOD: The pollen materials consisting of male flowers has been procured from the CPCRI, Kasargode, Kerala, India, where a sizable germplasm collection of the crop from various parts of the world is maintained. In the present study, 44 cultivars representing South America, Africa, Pacific Islands and South East Asia covered by India, Sri Lanka, Malaysia, Indonesia and Vietnam are considered.

Pollen preparations have been made by the acetolysis method of Erdtman (1952) modified by Nair (1970). Data generation of pollen morphology has been made from Light Microscope (LM) and Scanning Electron Microscope (SEM) studies and morphological analysis based on proposals by Erdtman (1952) and Nair (1970), associated also by new terms and expressions has been necessitated by the present investigation.

OBSERVATIONS: In order to characterise pollen morphology of each variety, the general procedure has been to resolve all the characters into five groups namely Aperture, Exine Ornamentation, Exine Strata, Pollen Size and Shape, in the order of the importance in comparative morphology.

A special feature in coconut pollen is the occurrence of dimorphism with monocolpate–elongate and monoporate–spheroidal pollen types, the percentage of each of which vary with the varieties warranting also been taken into consideration. For reasons of comparative analysis of the pollen morphology, the monocolpate pollen has been considered as the standard form for descriptions. In the monocolpate form, the aperture position is distal and into form and structure varies in the varieties. In order to explain the exine ornamentation, the grain in lateral view has been taken and such a grain has been resolved into (i) Distal point (colpus end) (ii) Proximal point (diametrically opposite to colpus end) (iii) the lateral extremities of colpus (iv) lateral surface (area between the distal face and proximal face). In recording pollen size, the longest diameter of colpate grain in lateral view is considered; and in the case of spheroidal grains the diameter is provided.

COMPARATIVE MORPHOLOGY: The aperture is dominantly monocolpate, with the difference that in some varieties, the megaporate–spheroidal types are present very rarely or in larger percentages. In the monocolpate form, the aperture is furrow-like, with the furrow being wide or narrow, and the colpus margin is fortified by thickenings and very rarely without it. While the edge of the colpus margin is generally even, some varieties have novel characteristics, being sometimes frilled, (var. Borneo) or even segmented (Var. Sri Lankan Yellow dwarf). Among the varieties studied Guam II alone is characterized by the presence of an operculum.

The exine ornamentation as presented by SEM is the most unique feature of coconut pollen. The proximal end of the grain is bestowed with a cap-like structure, formed of dense or lax aggregation or agglutination of powdery granules (described as polar cap). In some varieties, the polar cap is missing, but replaced by other unique characteristics, like the hump (eg. Zanzibar) or thick-segmented ridges (Blanchesseuse). The nature and extent of the polar cap varies with the varieties and in general, the polar cap formation extends to the lateral ends and to the margin of the colpus as a continuous formation.

The lateral surface is variously ornamented being psilate, echinulate, echinate and striate, the striae being in a variety of forms varying with varieties, in the nature of the muri, the width between adjacent ridges, the fusion and orientation of the ridges leading to a twined, or matted pattern, reflective of the various varieties.

The exine strata is not of any comparative value and so also the pollen size and shape, although the pollen size can be of subsidiary value in varietal characterization.

POLLEN MORPHOLOGY AND CULTIVAR EVALUATION: The apertural and exine ornamentation characteristics may be considered to be of considerable value in cultivar evaluation. In such an event single or combination of characters has been noticed to be relevant even at the micro taxa levels, (eg. Colpus edge), as evident from the following instances.

Colpus faintly developed	:	Malayan Yellow Dwarf
Colpus narrow	:	Federated Malay States
Colpus narrow and disrupted (by diffuse fusion of edges)	:	Philippines Ordinary
Colpus operculate and polar cap arched	:	Guam II
Colpus edge profusely toothed (echinulate)	:	Cameroon Red Dwarf
Colpus edges scarcely toothed	:	Kappadam

Colpus edge distantly toothed	:	Malayan Tall
Colpus edge frilled	:	Laccadive Micro
Colpus edge segmented	:	Sri Lankan Yellow Dwarf
Exine lateral surface formed into massive ridges	:	Borneo Tall
Exine lateral surface formed into rounded hillock structures	:	Niu Leka Dwarf

Among other typical characteristics of value in cultivar authentication, the following informations may be provided.

Polar cap absent	:	Laccadive Ordinary
Polar region humped	:	Cochin China
Polar region cleft	:	Sri lankan Yellow Dwarf
Polar region dissected, striate	:	Blanchesseuse
Polar cap lax	:	Laksha Ganga

Polar cap zonate	:	Seychelles Tall
Lateral surface rugulate- (striate rugulate; rugulae straight)		Benaulim
Lateral surface echinulate	:	San Ramon Tall
Lateral surface reticulate	:	Kulasekhara Yellow Dwarf
Whole grain granulate	:	Cochin China
Surface striato – reticulate	:	Zanzibar Tall

EVOLUTIONARY AND ECOLOGICAL CONSIDERATIONS: The polar cap and pattern of lateral surface could possibly be considered in designing the status of morphological evolution in coconut pollen. The varieties with polar cap are the most common but there are a few varieties without the cap, but with other structural features. This gives the direction that there are two lines of diversification one with cap and another without cap. While it is very complex to make a generalization on morphological evolution of all the varieties taken together; it could be possible to develop some standards for coconut diversification on the basis of pollen morphology, considering that the psilate form could be more primitive and that matted form is the most advanced. Considering the various geographical zones, the diversity is perceptible with the varieties within any one geographical zone and very special features such as segmentation of the colpus edge, the formation of operculum, or else the variations in exine topography could be the result of local ecological impacts. On the basis of comparative characterization, and commonalities of characteristics the varieties studied could be considered to have been dispersed along two possible lines of movement of the coconut fruits from its original home in South America, namely Africa–West of India route and the Pacific islands South Asia route including east of India. In certain varieties locational specificity, as an evidence of ecological adaptation, is of significance.

The pollen data provide ample evidence to substantiate cultivar characterization made on the basis of nut characteristics. The pollen data have provided a new parameter in defining the route of migration and changes that occurred during the course of naturalization of the crop, along a wide expanse of the coastal belt covering South America, Africa, Pacific Islands, and South East Asia. Therefore, the information from pollen morphology could be beneficially utilized in gaining new knowledge on coconut biodiversity and dispersal.

REFERENCES

REFERENCES

Bamzai, R. D. and Randhawa, G.S. 1965a. Palynological studies in subtropical fruit trees. Mango (*Mangifera indica* L.) grapes (*Vitis* spp.) and phalsa (*Grewia asiatica* L.). *Palynol. Bull.* **1**: 36 – 43.

Bamzai, R. D. and Randhawa, G. S 1965b. Palynological studies in *Citrus*. *J. Palynol.* **1** : 111-121.

Bradley, D. E. 1960. The electron microscopy of pollen and spore surfaces. *Grana Palynologica* **2** (2) : 3–8.

Brewbaker, J. L. 1959. Biology of the angiosperm pollen grain. *Indian J. Genet. Pl. Breeding* **19** (2): 121- 131.

Bronckers, F.J. 1963.Variation poliniques dams une serried autopolyploids Thalians (L.) *Meynor Pollen. el Sponres*. **5**: 233-238.

Chaloner, W.G., 1967. Spores and land plant evolution. *Rev. Palaeobot. Palynol.* **1**: 83- 93.

Chaturvedi, M., Yunus, D. and Nair, P.K.K 1990. Cytopalynological studies of *Arachis*. *Grana* **29**: 109-117.

Chaturvedi, M., Yunus, D. and Nair, P.K.K. (1996) Cytopalynological studies of *Drachis (Legani)* and wild species and their hybrids. *Grana* **29.** 109-117.

Corner, E. J. H. 1966. *The natural history of palms*. London.

Cranwell, L.M.1953. New-Zealand pollen studies. The Monocotyledons. *Bull. Auckland Inst. Mus.*, No.3.

Cronquist, A. 1968. *The evolution and classification of flowering plants*. Nelson, London.

Daghlina, J, 1981. A review of fossil record of monocotyledone Proof. Rev **47**: 517-555.

Dahil, A. O. and Rowly, J. R 1956. The cytology of *calths*. Proc. Mission Acad. Sec. 24.

Eames, A. J. 1961. The morphological basis for a Palaeozoic origin of the angiosperm. *Recent Adv. bot. Res.* 722 – 726.

Erdtman, G. 1952. *Pollen morphology and plant taxonomy of Angisoperms*. Stockholm.

Faegri, K. 1937. Some fundamental problems of taxonomy and phylogenetics. *Bot. Rev.* **3**: 400 – 423.

Faegri, K. and Iversen, J. 1964. *Textbook of pollen analysis*. Copenhagen.

Godwin, H. 1968. The origin of the exine. *New Phytologist* **67**: 667– 676.

Gould, A. and Medus, J. 1953 A cytotaxonomic study in the genus Ardropogon. *Amer. J. Bot.* **40**: 297 – 306.

Hutchinson, J.1959. *The families of flowering plants*. Clarendon Press. Oxford.

Hyde, H.A and Williams, D.A. 1945. Palynology. *Nature*: 155; 265.

Kessler, L.G. and Larsen, D.A. 1969. Effects of Polyploidy on pollen grain diameter and other exomorphic exine features in *Tridax coronifolia. Pollen et spores.* **11**: 203-221.

Khosher, T.N 1960. Biosystematics of sysymbrium irio complex IX. Genome analyss V. *Indian bot. Soc.* **39 (2)** : 217 –226.

Kuriachan, Philomena, Joseph, Latha, and Sunnichan, V. G. 2001-2002. Polymorphism in pollen characters of *Oryza malampuzhensis.* Krishna Chandra. *J.Palynol.* **37-38** :123-131

Lawrence, G. H. M 1951. *Taxonomy of Vascular Plants*. London.

Lewis, W.H. 1964. *Oldenlandia corymbosa* (Rubiaceae). *Grana Palynol.* **5(3)** : 330 – 341.

Lewis, W.H. 1965a. Cytopalynology of African Hedyotideae *Ann. Misouri bot. Garden.* **52:** 182-211.

Lewis, W.H. 1965b. Pollen morphology and evolution in *Hedyotis* subgenus Edrisia (Rubiaceae). *Amer. J. bot.* **52 (3)**: 257–264.

Maheshwari,P.1950. An introduction to embryology of angiosperms, McGraw Hill Book Co. Inc., New York.

Menon, K.P.V. and Pandalai, K.M.1958. *The coconut palm. A monograph.* Indian Central Coconut Committee, Cochin.

Moore J, H.E and Uhl, W.W 1982, Major trends of evolution in palms. *Bot. Rev.* **48 (1)** : 1 –89.

Mourizio, A. 1956. Pollengestaltu bee einigen polyploiden kultur pflanzen. *Grana Palynol* **1 (2)** : 59-69.

Muller, J. 1970. Palynological evidence on early differentiation of angiosperms. *Biol. Rev.* **45** : 417 – 450.

Nair, P.K.K. 1961. Pollen grains of Indian specimens of *Caltha palustris L. Grana Palynol.* **2**: 98 – 100.

Nair, P.K.K., 1962. Pollen grains of Indian plants. II. *Bull. Nati. bot. Garden.* No. 60.

Nair, P.K.K., 1965 a. Trends in the morphological evolution of pollen and spores. *J. Indian bot. Soc.* **44**: 468 – 478.

Nair P.K.K, 1965 b. Significance of pollen morphology in the study of cultivated plants. *Indian Agriculturist* **9**: 53 – 58.

Nair, P.K.K. 1970 a. Crop playnology and its significance in agricultural research. *J. Palynol.* **6**: 25 - 30

Nair, P.K.K, 1970 b. *Pollen morphology of angiosperms*–A *Historical phylogeneitc Study.* Scholar publishing House, Lucknow, Vikas Publishing House, Delhi.

Nair, P.K.K. 1979. The palynological basis for the triphyletic theory of angiosperms. *Grana.* **18**: 141 – 144.

Nair, P.K.K. 1985. *Essential of palynology.* Today & Tomorrow's Printers and Publishers, New Delhi.

Nair, P.K.K. 1991. Pollen morphology, plant taxonomy and evolution, *Rheedea,* **1 (1 & 2)**: 78 - 83

Nair, P.K.K. 2004. Plant taxonomy. *Curr. Sci.* **86 (5, 10)** : 665 – 667.

Nair, P.K.K. and Chaturvedi, M.1978. An analysis of pollen morphotype in some Indian monocotyledons. *J. Palynol.* **14 (1):** 101-107.

Nair, P.K.K. and Ravi Kumar,C. 1984. Aspects & prospects of cytopalynology with special reference to pollen morphology. *Advances in Pollen – Spore – Research* **XII**: 1 – 20.

Nair, P.K.K and Sharma, M. 1962. Pollen morphology with reference to the geographical distribution of *Argemone mexicana. Lloydia.* **25(2)**: 123-129.

Nair, P.K.K. and Sharma, M. 1963. Pollen grains of *Cocos nucifera* L. *Grana Palynol.* **4**: 373 – 379.

Nair, P.K.K. and Sharma, M. 1966–67. Cytopalynological observations on the *Sisymbrium irio* complex. *J. Palynol* **2 & 3**: 33- 40.

Qiros. C.F. 1975. Exine pattern of a hybrid between (*Lycopersicom exculentom* and *Solanum pennellii*). Herrd. **66** : 45-47.

Ravikumar, C and Nair, P.K.K. 1985. Gloriosa–A cytopalynological study. *New Botanist.* **12**: 1- 68.

Ravikumar, C and Nair,P.K.K. 1986. Pollen morphology of *Amaryllis* Linn.*J. Palynol* **22** : 69-102.

Rowley, J. R 1959. The fine structure of the pollen wall in the Commelinaceae. *Grana Palynol.* **2 (1):** 3 – 31.

Sampaty. S. and Ramananthan, K. 1951. Pollen grain, size in Oryza. *J. Indian bot. Soc.* **30**: 40 – 48.

Sharma, M. 1967. Pollen morphology of Indian monocotyledons. *J. Palynol. Spl.* Vol.: 1– 97.

Sowumni, M. A. 1968. Pollen morphology of the palmae and its bearing in taxonomy. *Rev. Palaeobot. Palynol.* **13** : 1-80.

Srivastava, V. Pal, M and Nair, P.K.K. 1977. A study of the pollen grains of *Amaranthus spinosus* Linn. and A dubius Mart. Ex Thellung and their hybrids. *Rev. Palaeobot. and Palynol.* **23**: 287 – 291.

Takhtajan, A. 1980. Outline of the classification of flowering plants. *Bot. Rev. 46*: 225 – 359.

Thanikaimoni, G. 1970. Pollen morphology, classification and phylogeny of Palmae. *Adansonia* **10(3)**: 347– 365.

Walker, J.W and Doyle, J.A. 1975. The basis of Angiosperm phylogeny-Palynology. *Ann. Missouri bot. Gard.* **62** : 664-723.

Wodehouse, R. P. 1935. *Pollen grains* Mc. Graw Hill Book Co., New York.

LEGENDS TO PLATES I – XV

FIGURES 1-132

(PHOTOMICROGRAPHS BY SEM)

PLATE 1

FIGURES1 - 9

Fig 1-3: ***Andaman Ranguchan***

1. Pollen in group (X 240)
2. Single grain lateral view (X 900)
3. Pollen surface (X 3600); Note: Striate laterally oriented granular aggregations; faint low round mounds of granular modules.

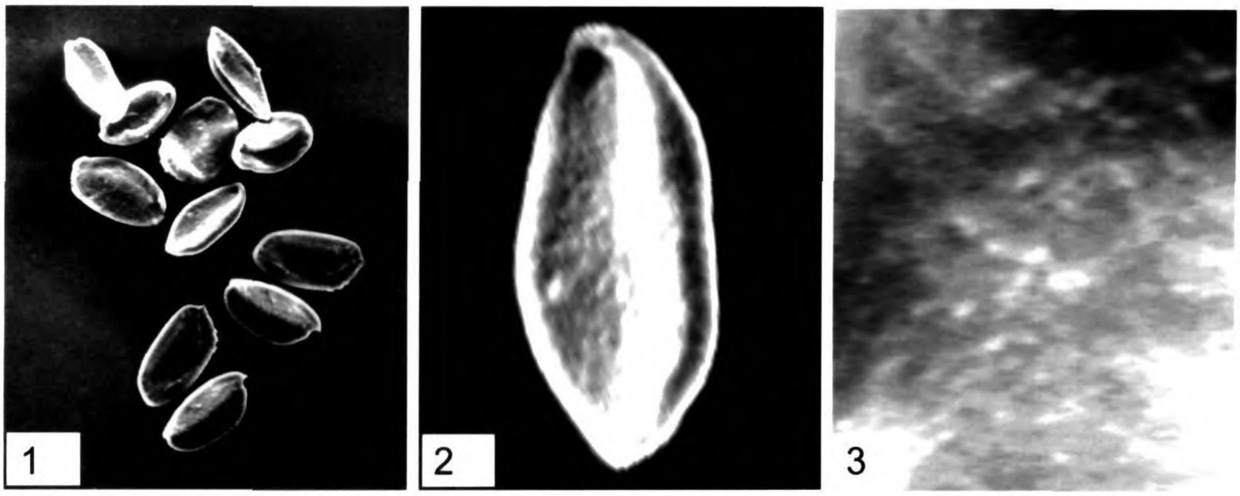
Figs. 4-6: ***Andaman Yellow Dwarf***

4. Pollen in group (X 300)
5. Single grain, surface view (X 850)
6. Pollen surface, Lateral view (X 4000); Note : Laterally oriented striate surface with disrupted lumina, and ridges covered by granular aggregations; note also large depression at one end; plate like polar cap.

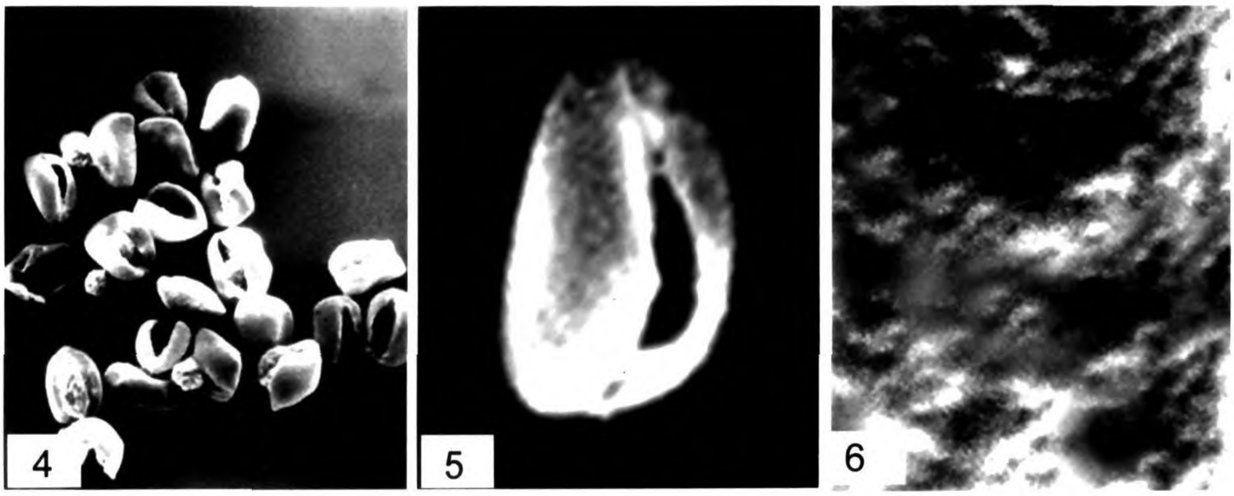
Figs 7-9: ***Ayiramkacchi***

7. Pollen in group (X 300)
8. Single grain, lateral view (X 900)
9. Exine surface (X 4000); Note: Sinuate arched ridges; punctate depressions all over the surface; conical projections on the colpus edges; elongate depression at one end; beaked lateral end.

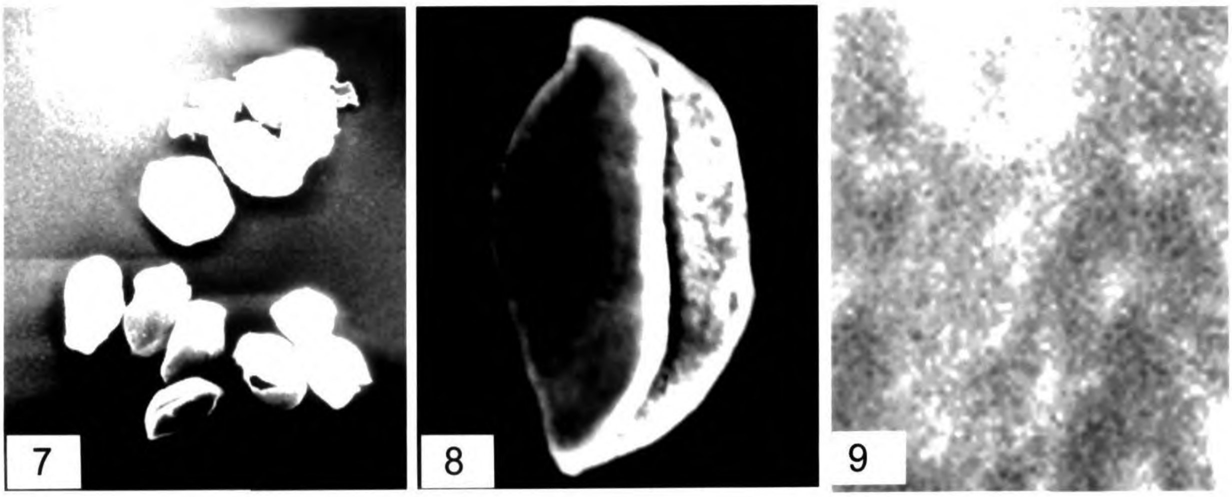
PLATE-I



Andaman Rangucham



Andaman Yellow Dwarf



Ayiramkacchi

PLATE II

FIGURES10 - 18

Figs. 10-12: ***Benaulim***

10. Pollen in group (X 240)

11. Single grain surface view (X 900; see wide colpus)

12. Lateral surface (X 4000); Note: Striate rugulate pattern with disrupted, straight ridges, oriented laterally; corrugate colpus margin.

Figs. 13-15. ***Blanchesseuse***

13. Pollen in group (X 240)

14. Single grain, obliquity lateral view (X 950)

15. Lateral surface (X 2400); Note: Surface; oriented equatorially; spot association of granules in various shapes and sizes; (elongate colpus margin).

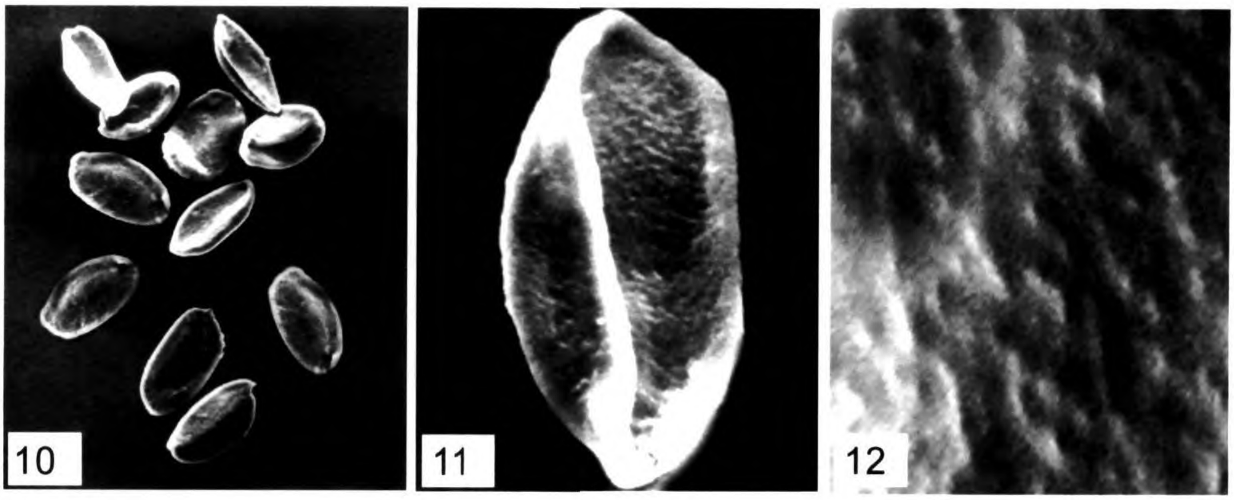
Figs. 16-18: ***Borneo Tall***

16. Pollen in group (X 240).

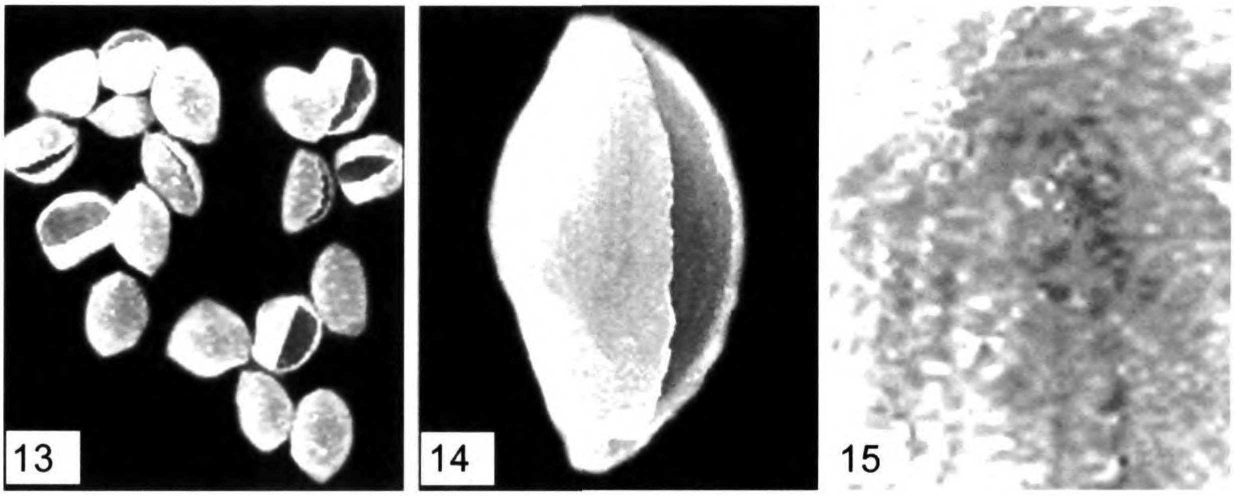
17. Single grain (X 900) surface view, see wide colpus.

18. Lateral surface (X 3600); Note: Massive, striate ridges, made up of nodular association of granules, oriented towards one end; spot presence of polar cap; overspread by granules.

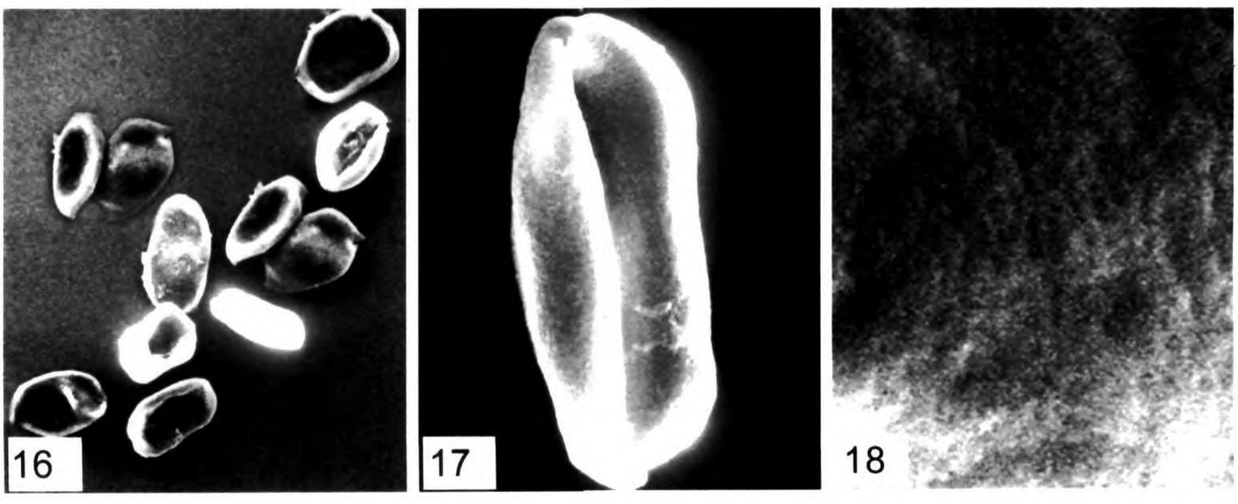
PLATE-II



Benaulim



Blanchesseuse



Borneo Tall

PLATE III

FIGURES 19 - 27

Figs. 19-21: ***British Solomon Islands***

19. Pollen in group (X 240)

20. Single grain (X 900) surface view; see wide colpus

21. (Lateral surface (X 2400); Note: Dense agglutination of granules in polar plate, cloudy lateral end with central depression.

Figs. 22-24: ***Cameroon Red Dwarf***

22. Pollen in group (X 240) see various shapes

23. Single grain (X 900)

24. Lateral surface (X 3600); Note : Polar cap absent, but plated and foveolate; spread of granular strips in various shapes and sizes; corrugate colpus margin with short spinula projection.

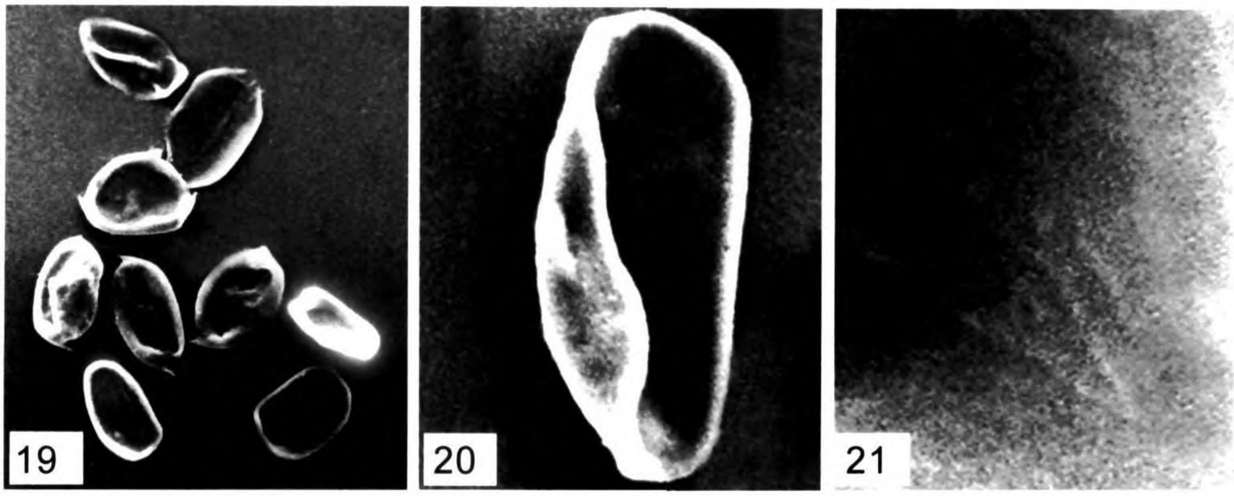
Figs. 25-27: ***Chandra Leksha***

25. Pollen in group (X 240); see, various pollen shapes

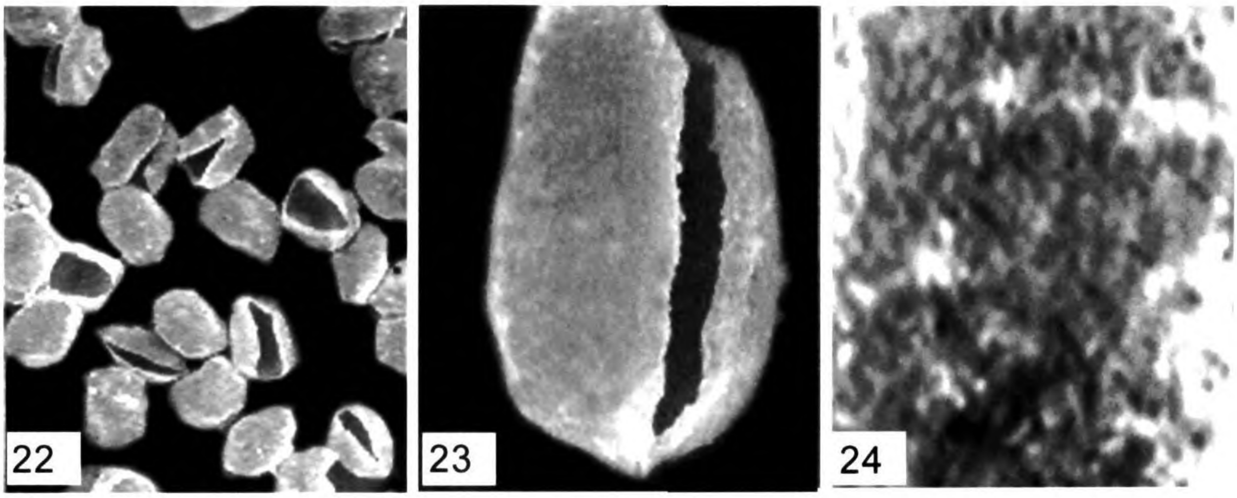
26. Single grain (X 800); see thick, rounded colpus margin

27. Lateral surface; (4000) Note: Polar cap merging into lateral sides as a veil of granules; low elevations in conical or elongate shape and even equatorially oriented striae.

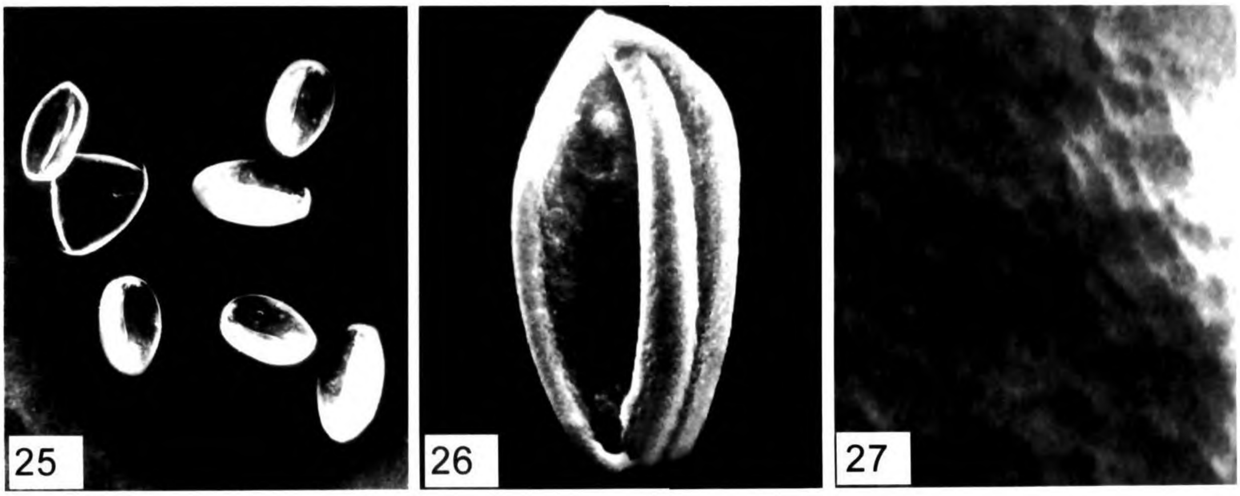
PLATE-III



British Solomon Island



Cameroon Red Dwarf



Chandra Leksha

PLATE IV

FIGURES28 - 36

Figs. 28-30: ***Chowghat Green Dwarf***

28. Pollen group; see dominance of colpate elongate form (X 300).

29. Single grain (X 700); see wide colpus;

30. Lateral surface (X 4000); Note: dense polar cap, merging and spreading as a veil on lateral surface; striate–arched pattern, with the ridge (lirae) formed of discontinuous granular nodules.

Figs. 31-33: ***Cochin China***

31. Pollen group (X 240); see circular and semicircular grains.

32. Single grain (X 900) see frilled colpus margin.

33. Lateral surface (X 2400); Note: Polar cap absent, replaced striate–lateral side radially striate-nodulate, turned, foveolate, fossulate pattern modulate patern with equatorial orientation.

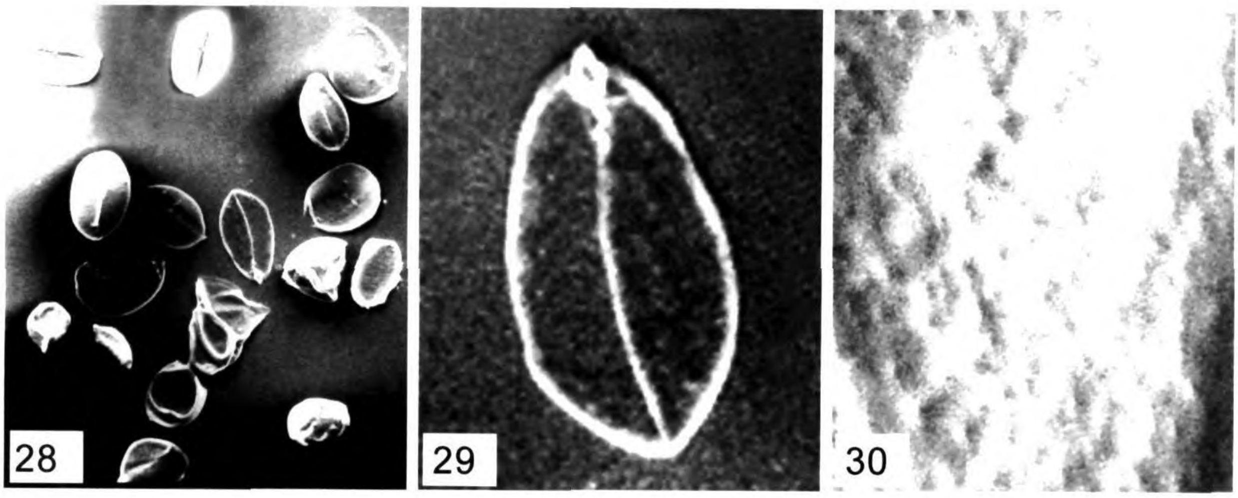
Figs. 34-36: ***Federated Malay States***

34. Pollen group (X 300); see beaks at lateral ends of one pollen.

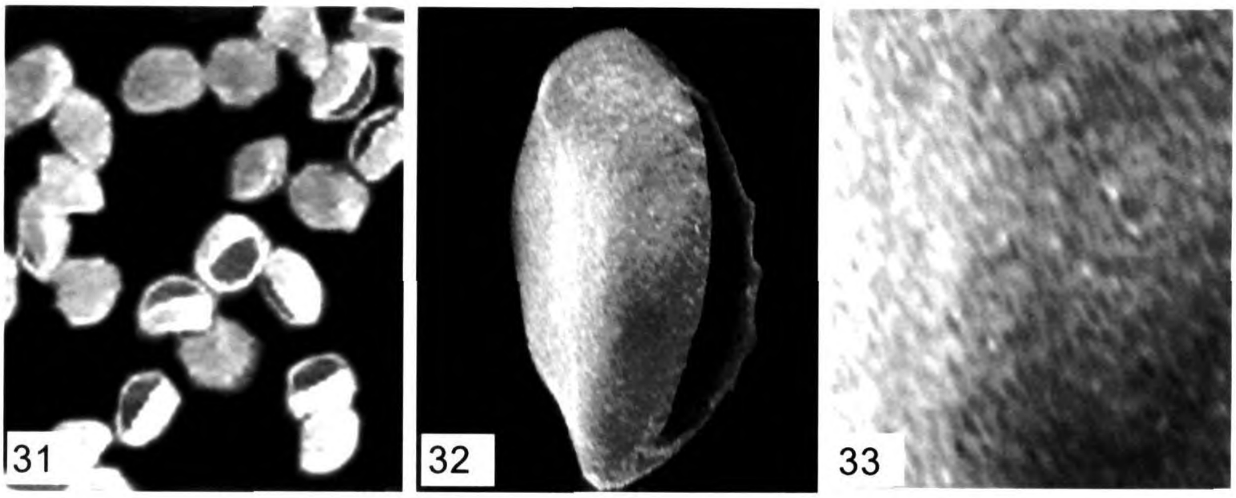
35. Single grain (X 900) with narrow colpus; fused at places.

36. Surface (X 4000); Note: Striation of granular association and spot formation of granular groups.

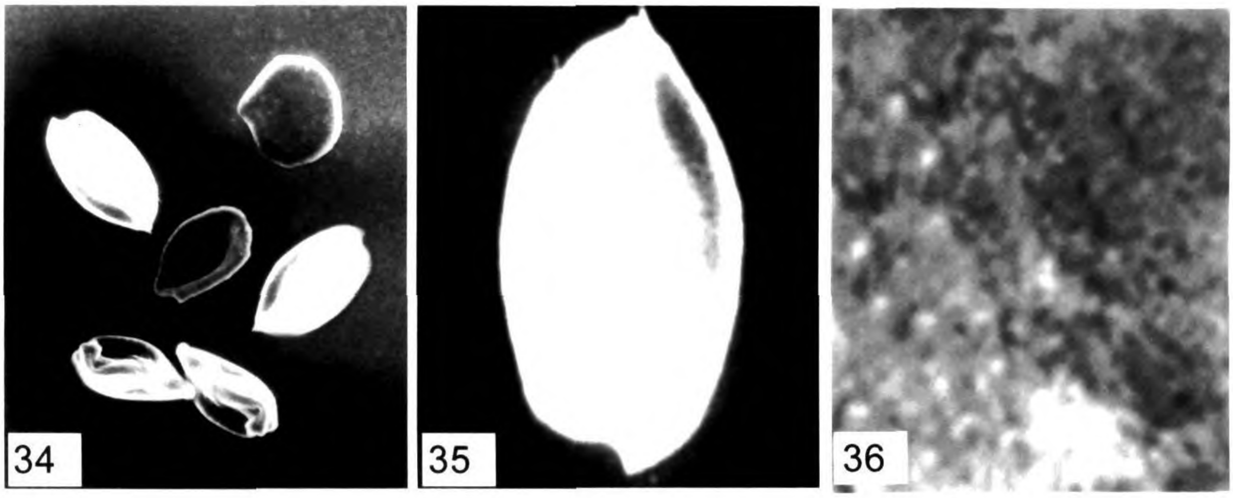
PLATE-IV



Chowghat Green Dwarf



Cochin China



Federated Malay State

PLATE V

FIGURES 37 - 45

Figs. 37-39: ***Fiji Tall***

37. Pollen group (X 300).

38. Single grain (X 900)

39. Surface (X 2400); Note: Lax polar cap and colpus margin; circular mouds formed of nodular granular aggregations.

Figs 40-42: ***Ganga Bondom***

40. Pollen group (X 240).

41. Single grain (X 900); see total fusion of colpus region at one end; leaving partial colpus

42. Surface (X 4000); Note: Tubercular aggregation of granules, and wide depressions on surface.

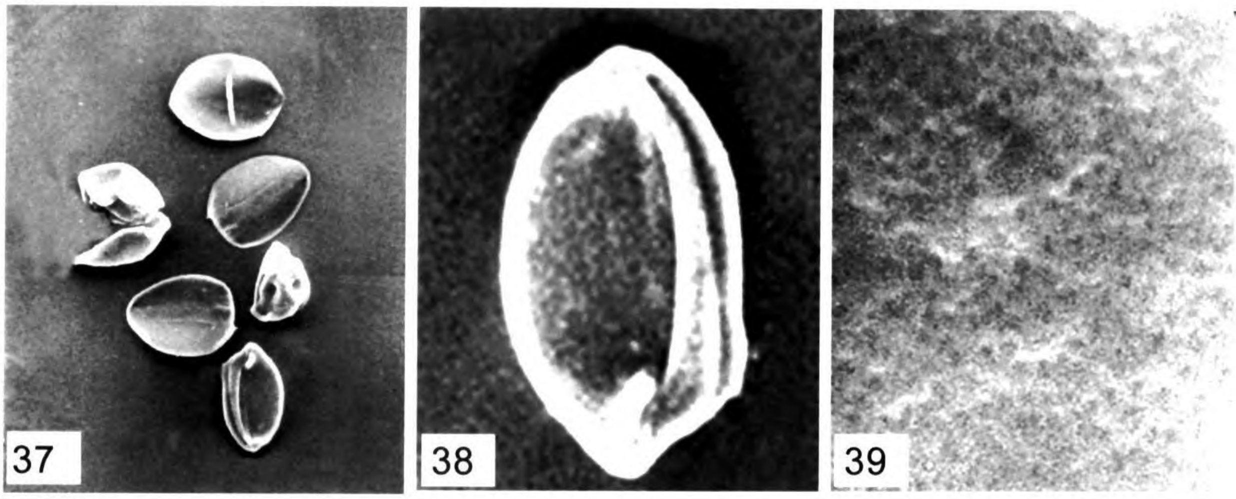
Figs. 43-45: ***Gonthembili***

43. Pollen group (X 300); see dominance of elongate grains.

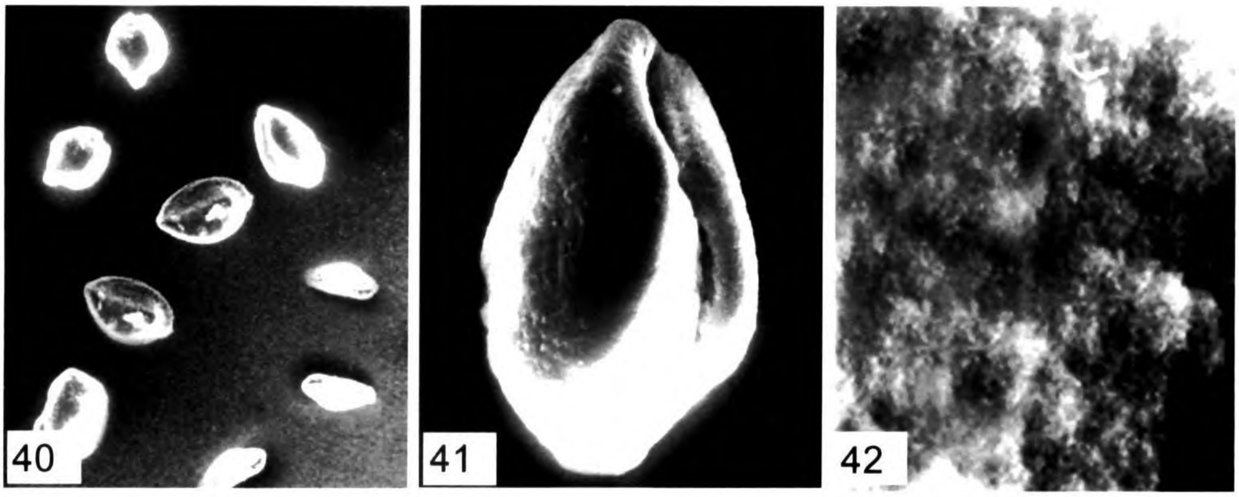
44. Single grain (X 900).

45. Surface (X 2400); Note: Lax polar cap; spread of granules as a veil; foveolate surface.

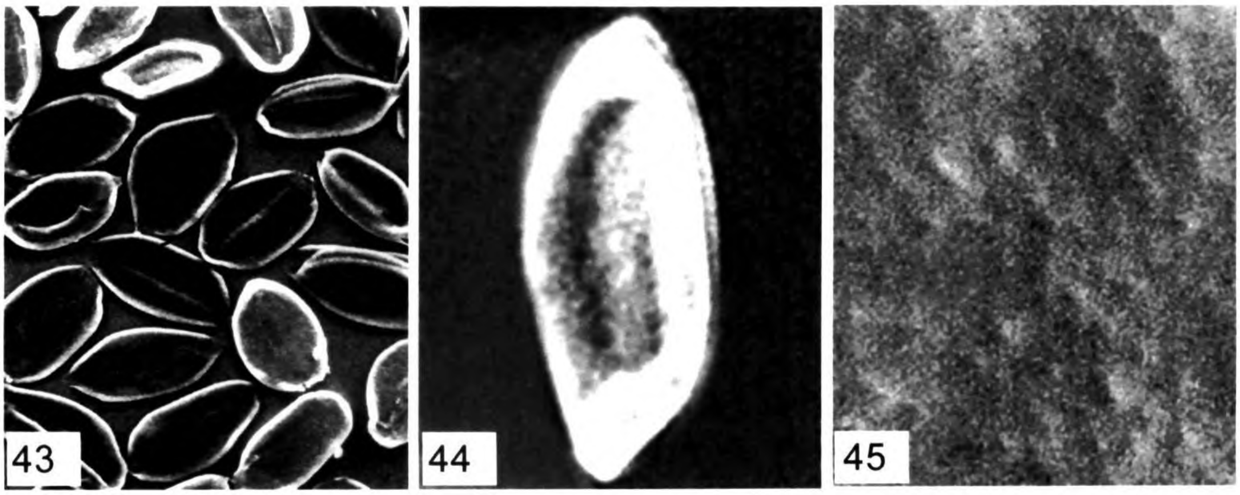
PLATE-V



Fiji Tall



Ganga Bondom



Gonthembili

PLATE VI

FIGURES 46- 54

Figs. 46-48: ***Guam II***

45. Pollen group (X 180); see Triangular (trichotomocolpate grain).

47. Single grain (X 950); see operculum.

48. Surface (X 4000); Note: Arched and equatorially dissected polar cap; operculum with rounded structures.

Figs. 49-51: ***Guam III***

49. Pollen group (X 240)

50. Single grain (X 700); see wide colpus.

51. Surface pattern (X 2400); muri (lirae) being made of granula connected granular modules.

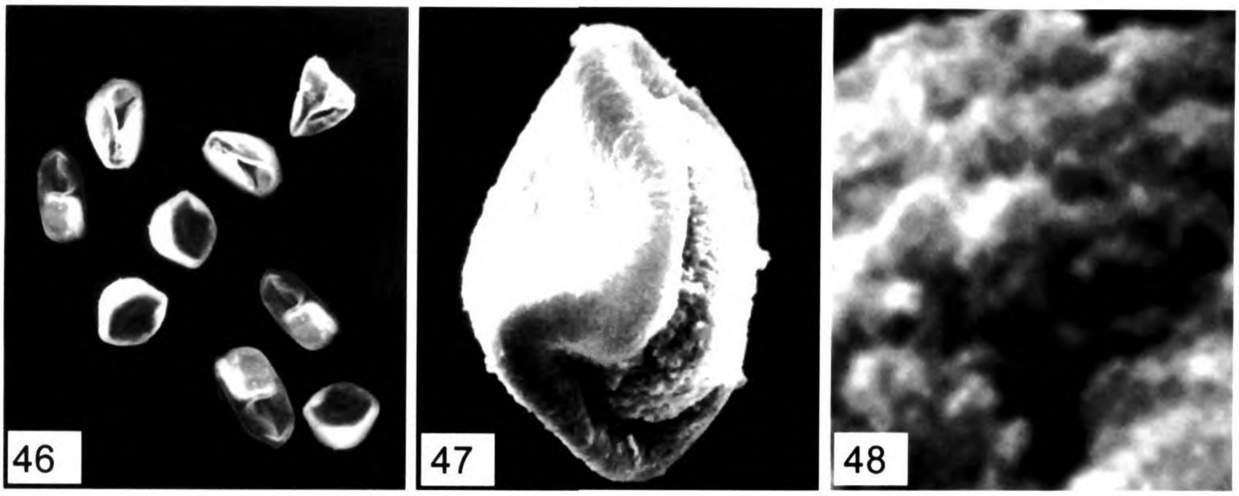
Figs. 52-54: ***Kaithathali***

52. Pollen group (X 300); see surface wholly covered with granules.

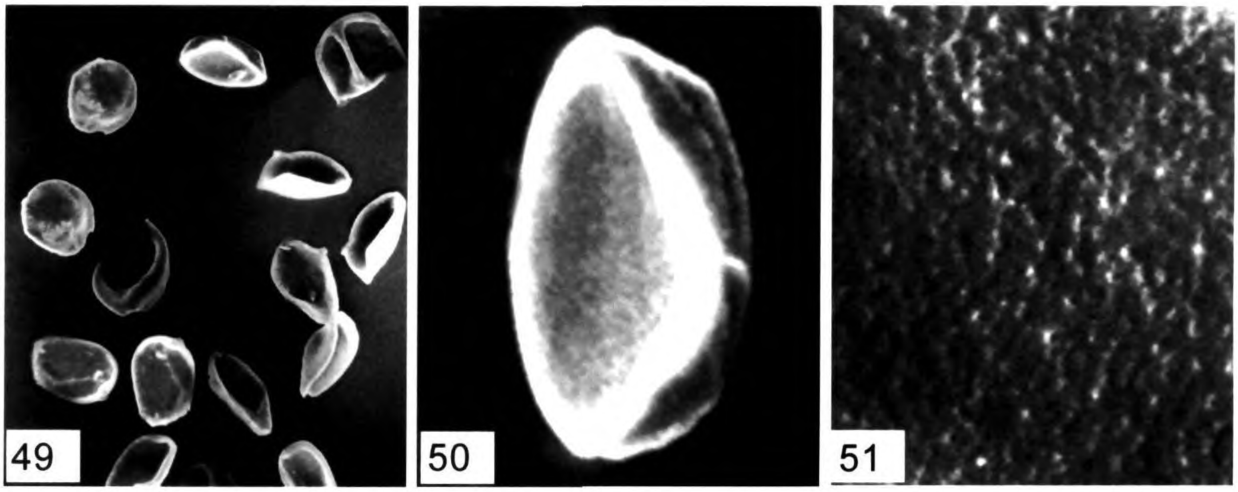
53. Single grain (X 750); see lax colpus margin.

54. Surface (X 3600); Note: Polar cap absent, depressed polar surface; with striate, rugulate pattern, lateral surface radially striate with closely placed ridges (Lirae).

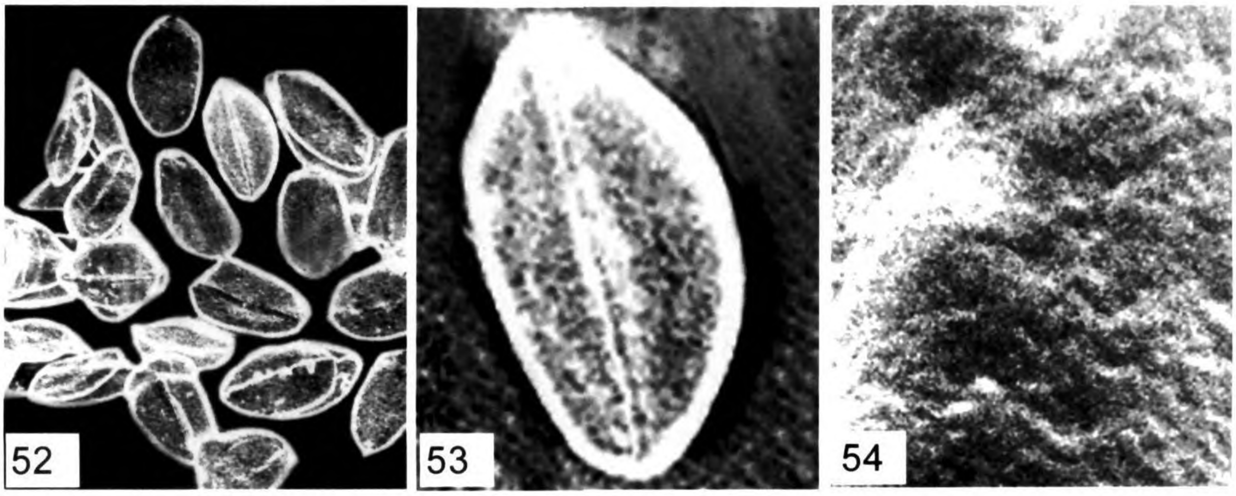
PLATE-VI



Guam II



Guam III



Kaithathali

PLATE VII

FIGURES 55- 63

Figs. 55-57: ***Kappadam***

55. Pollen group (X 240); see dominance of colpate elongate pollen.

56. Single grain (X 900)

57. Surface (X 2400). Note: Colpus margin with disrupted costae, and colpus edge with triangular projection, and complementary, depression.

Figs.58-60: ***King Coconut***

58. Pollen group (X 240).

58. Single grain (X 900); see wide colpus.

60. Surface (X 2400). Note: Polar cap with a large depression, and striate pattern, lateral surface depressed.

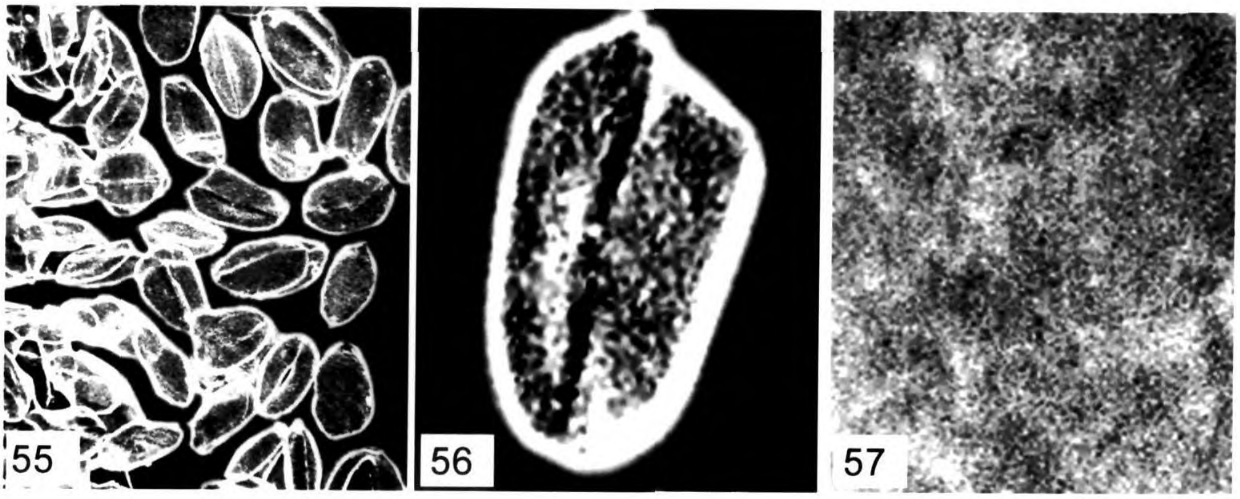
Figs.61-63 : ***Kulasekhara Yellow Dwarf***

61. Pollen group (X 180).

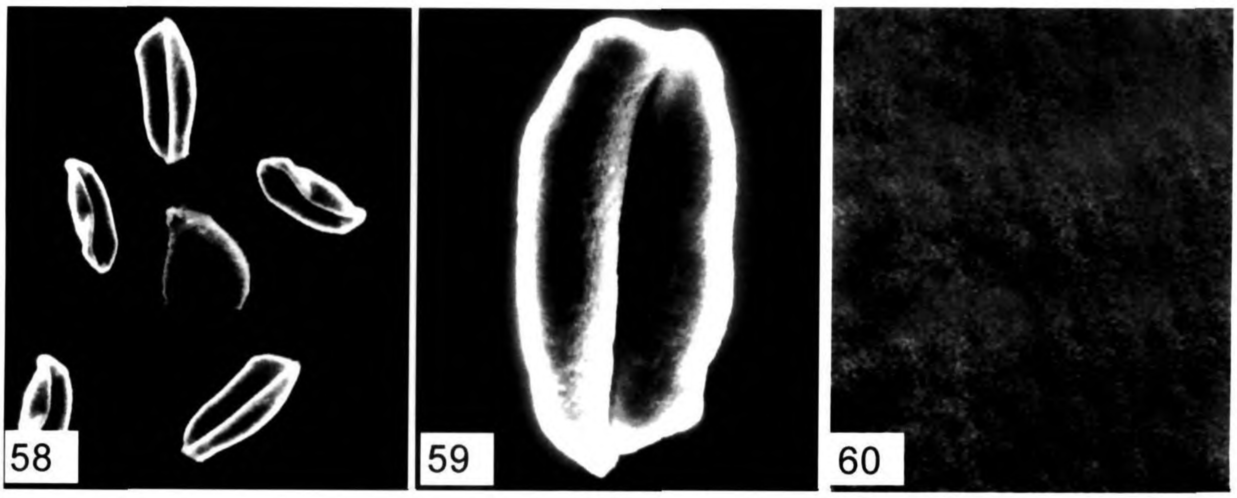
62. Single grain (X 900).

63. Surface (X 2400); Note: Echinate, lateral surface.

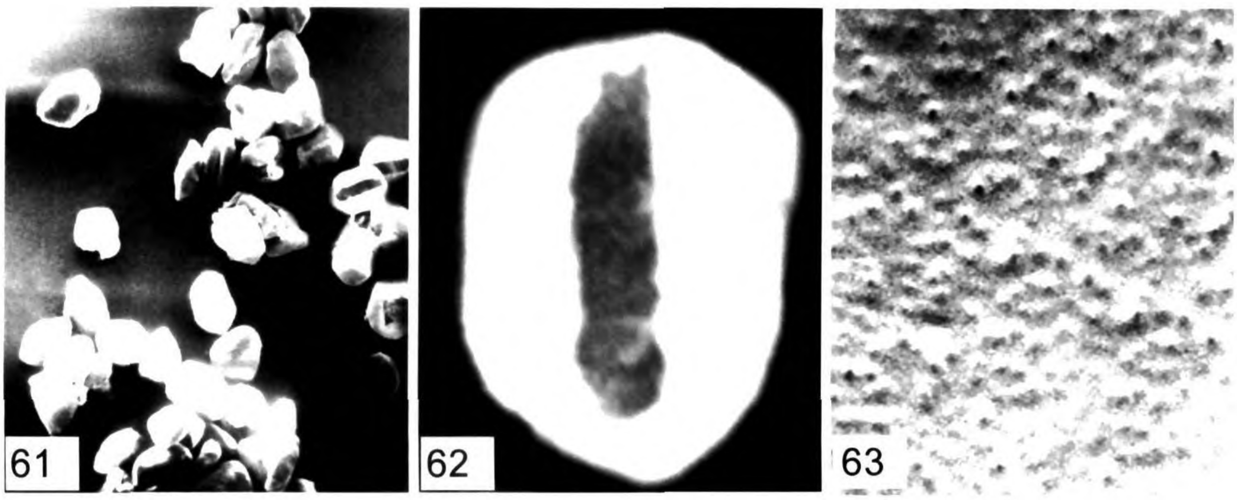
PLATE-VII



Kappadam



King Coconut



Kulasekhara Yellow Dwarf

PLATE VIII

FIGURES64- 72

Figs. 64-66: Laccadive Micro

64. Pollen group (X 240)

65. Single grain (X 800)

66. Surface (X 3600) Surface minutely puctate.

Figs. 67-69: Laccadive Ordinary

67. Pollen group (X 240); see elongate grains

68. Single grain (X 900); see colpus extending to proximal pole.

69. Surface (X 2400); granular aggregations in various sizes and shapes on lateral surface.

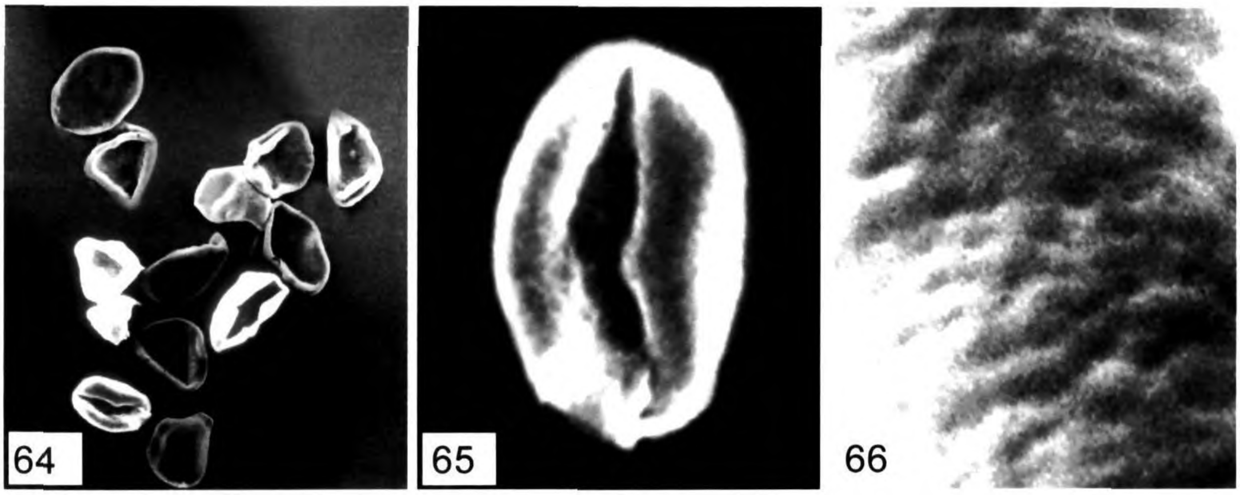
Figs.70-72: Leksha Ganga

70. Pollen group (X 240).

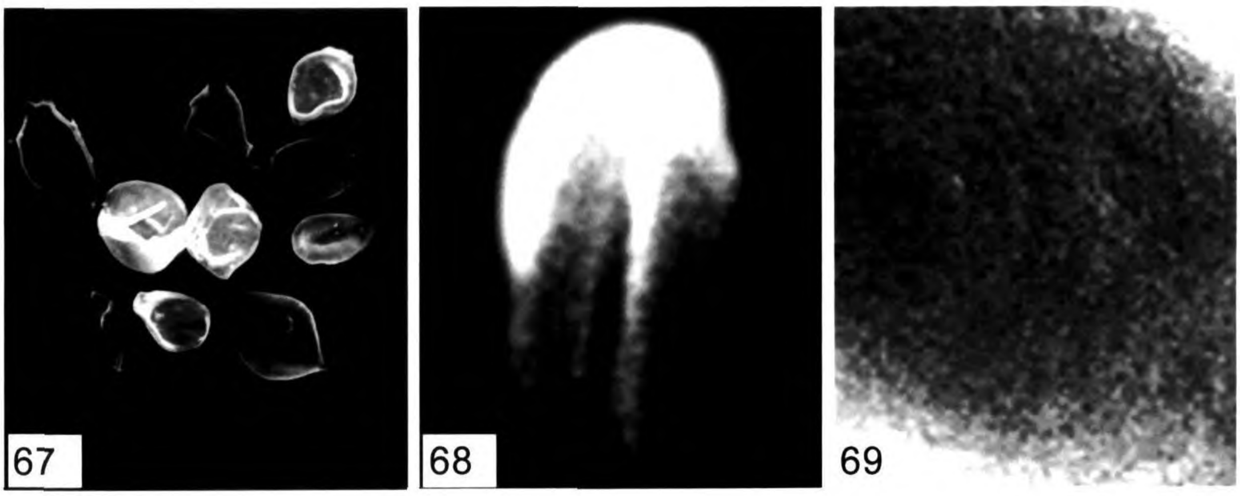
71. Single grain (X 800).

72. Surface (X 2400); Note: Zonate polar cap; cloudy lateral surface.

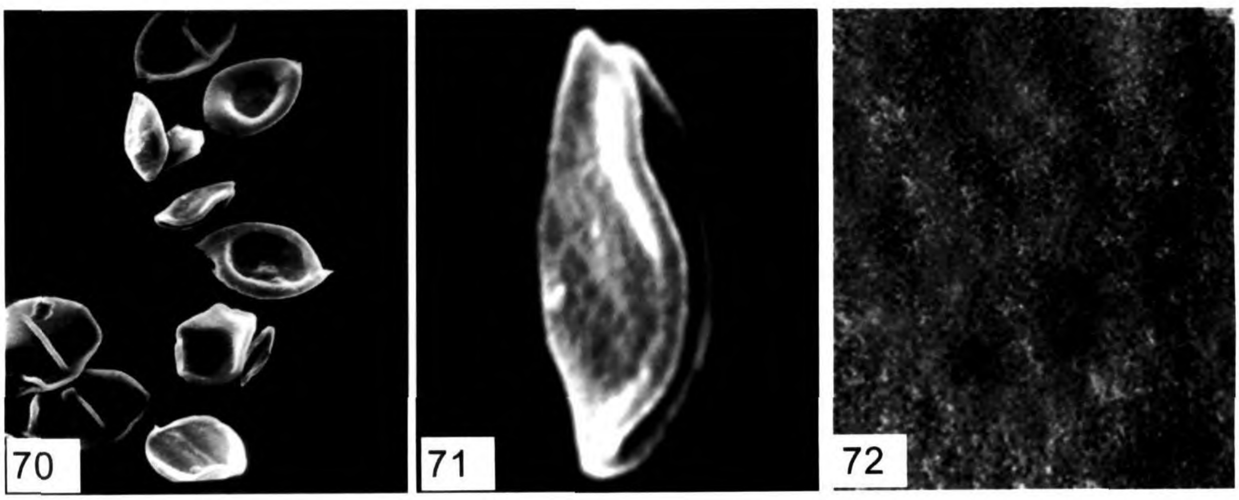
PLATE-VIII



Laccadive Micro



Laccadive Ordinary



Leksha Ganga

PLATE IX

FIGURES73- 81

Figs. 73-75: Lifou Tall

73. Pollen group (X 300).

74. Single grain (X 900).

75. Surface (2400); Note: uneven polar cap, with depressions, lateral surface with low circular mounds made up of modular formed of aggregations of spinuler and cloudly spread of granular groups.

Figs. 76-78: ***Malayan Green Dwarf***

76. Pollen group (X 240).

77. Single grain (X 900).

78. Surface (X 3600); Note : colpus edge with minute triangular projection, lateral surface rugulate striate.

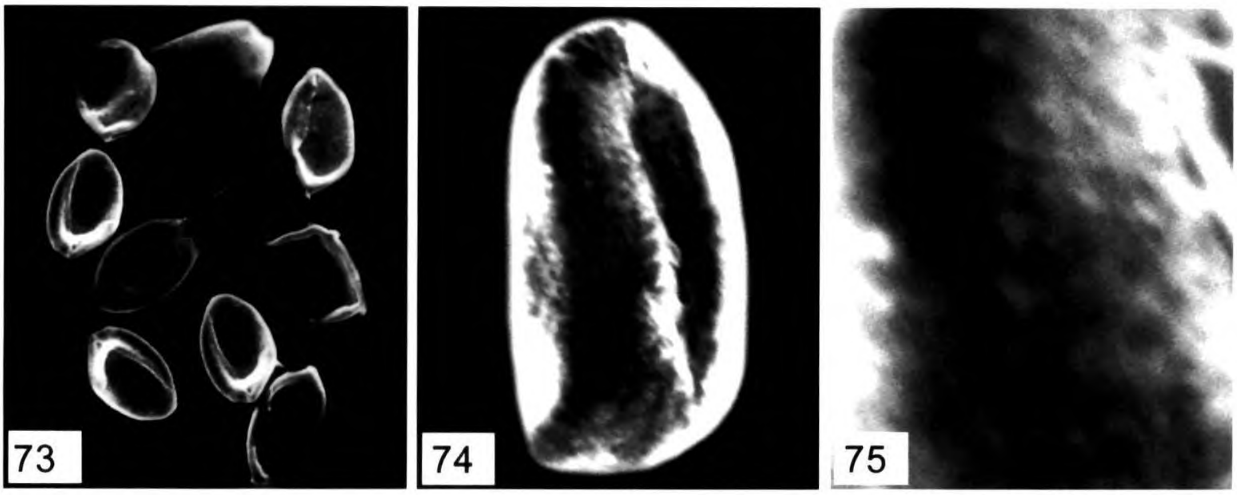
Figs.79-81 : ***Malayan Tall***

79. Pollen group (X 240); see elongate grains dominant.

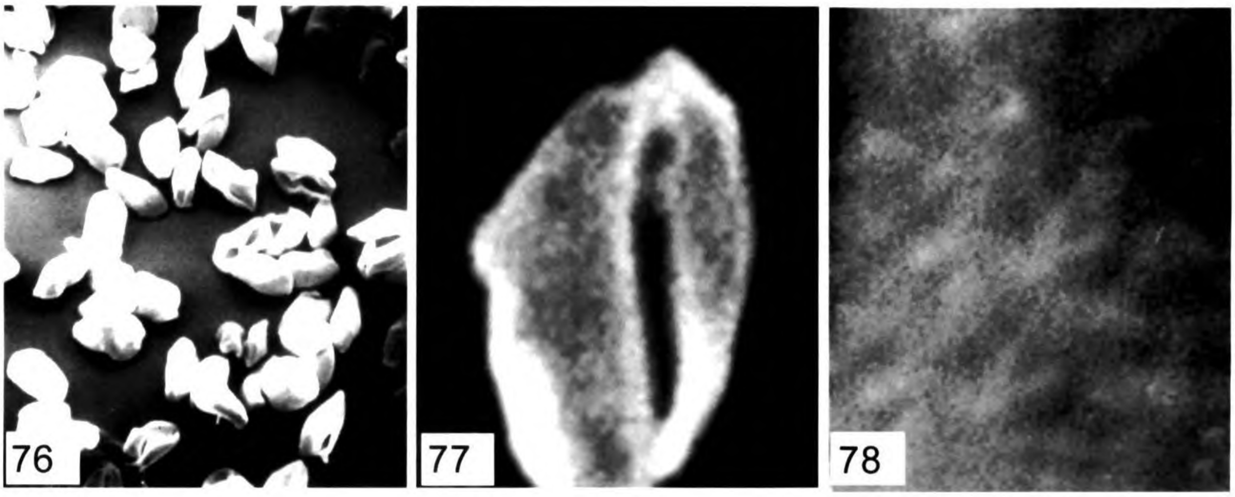
80. Single grain (X 900); see wide colpus.

81. Surface (X 2400); Note: colpus edge with triangular sparse projections and complementary depressions, striate echinulate, lateral surface.

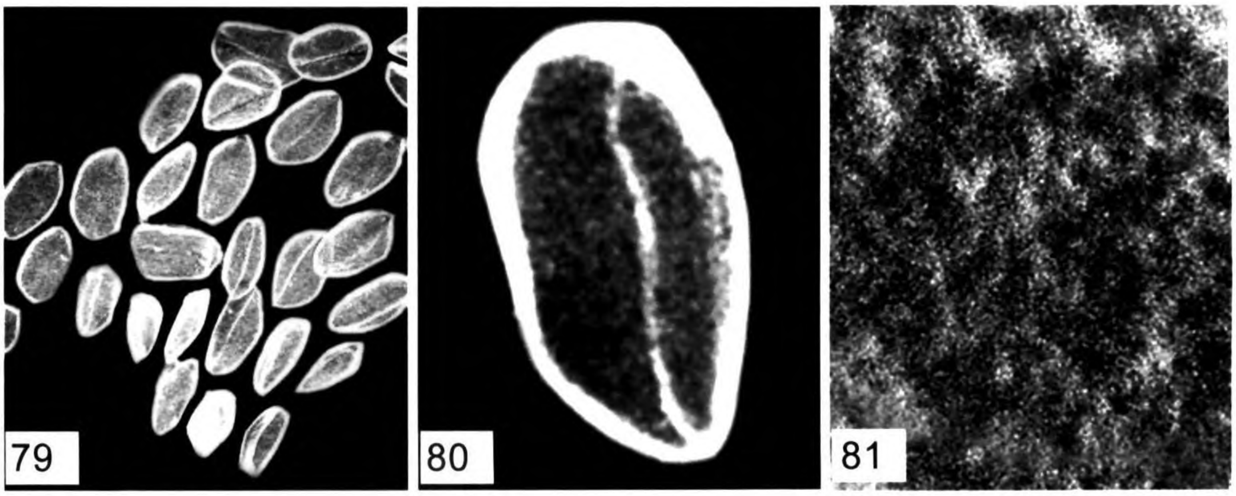
PLATE-IX



Lifou Tall



Malayan Green Dwarf



Malayan Tall

PLATE X

FIGURES 82- 90

Figs. 82–84: ***Malayan Yellow Dwarf***

82. Pollen group (X 240)

83. Sterile grains (X 900)

84. Surface (X 2400); Note : lax margin thickness, poorly defined colpus and no defined colpus edges; cloudy surface with granular aggregation.

Figs. 85–87: ***Markom Tall***

85. Pollen group (X 300); pollen shape.

86. Single grain (X 900); lax polar cap and colpus margin; depressed lateral surface;

87. Surface (X 2400); striate matted surface pattern, oriented along equatorial diameter, and evolving possibly to grooved depressions.

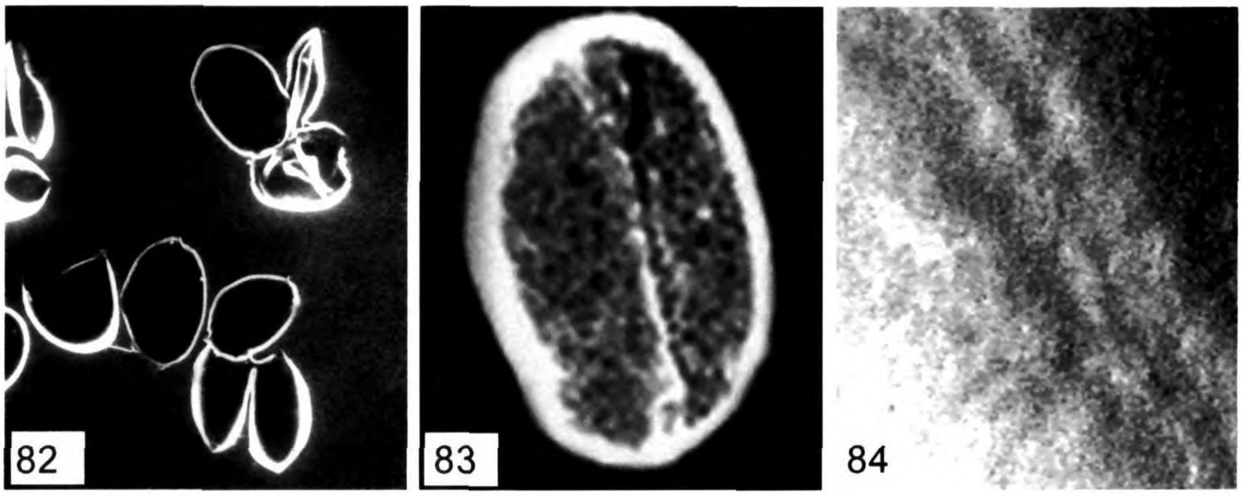
Figs. 88–90: ***Nadora Tall***

88. Pollen group (X 240); see dominant elongate forms.

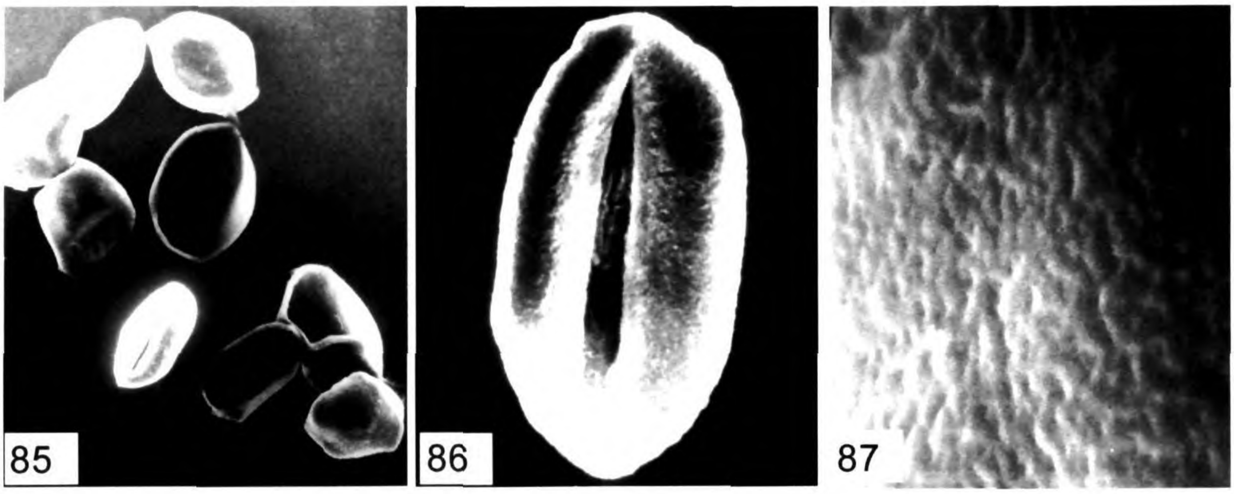
89. Single grain (X 900); see wide colpus.

90. Surface (X 2400); Note: Lax and wide polar cap, surface density striate with the ridges (lirae), poorly developed, sinuate and spread even with nodular aggregations of granular.

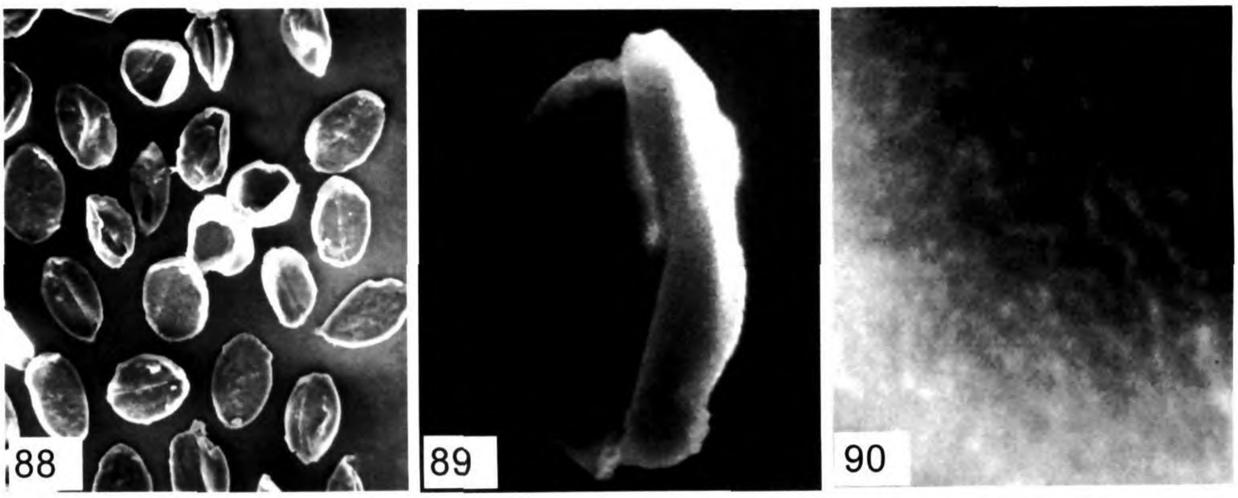
PLATE-X



Malayan Yellow Dwarf



Markom Valley Tall



Nadora Tall

PLATE XI

FIGURES91- 99

Figs. 91-93 : ***Niu Lekha Dwarf***

91. Pollen group (X 240)

92. Single grain (X 900); see wide colpus.

93. Surface (X 4000); Note: Rounded elevations, with foveolate pattern, on lateral surface.

Figs. 94-96 : ***Orissa Tall***

94. Pollen group (X 180).

95. Single grain (X 900); see corrugate colpus edge

96. Surface (X 2400); Note: twined matted striate pattern, equatorially oriented, wide muri (lirae) enclosing elongate (fossulate or grooved) or circular lumina.

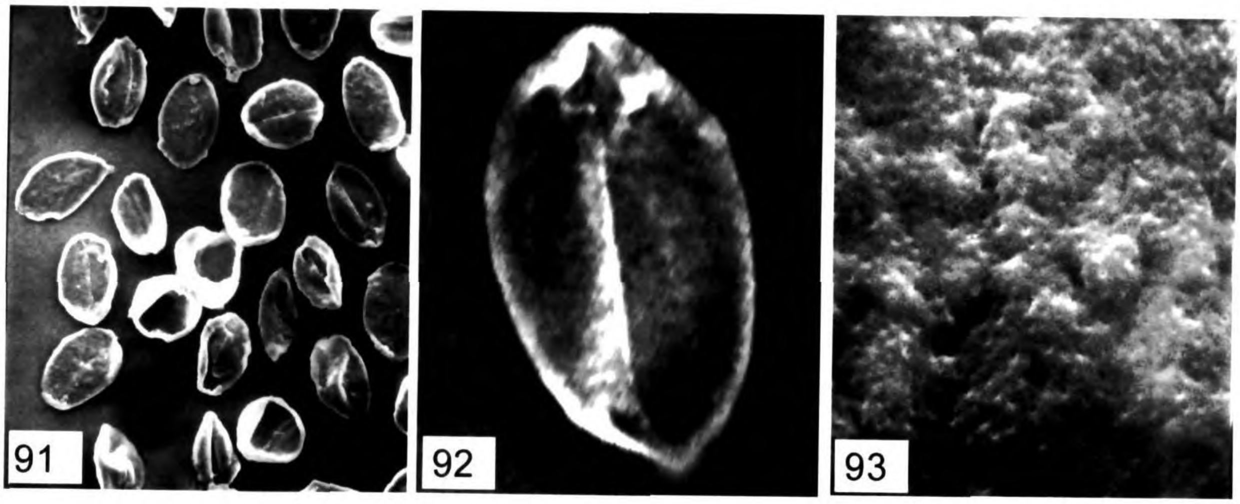
Figs. 97-99: ***Philippines Dalig***

97. Pollen group (X 240).

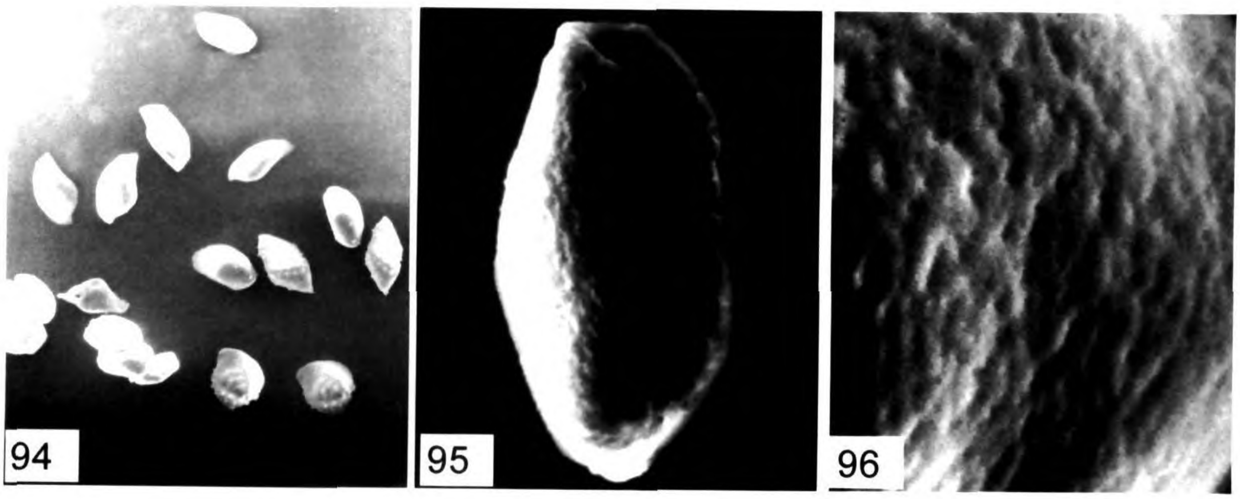
98. Single grain (X 900); see wide colpus.

99. Surface (X 2400); Note: Unvulate polar cap surface with striate lateral; large latenal depression.

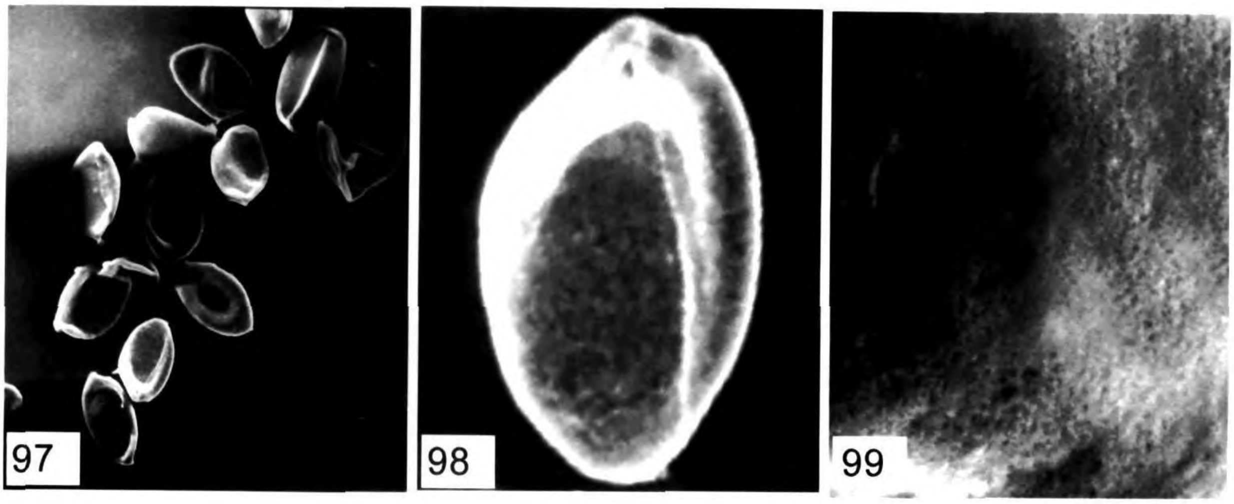
PLATE-XI



Niu Lekha



Orissa Tall



Philippines Dalig

PLATE XII

FIGURES 100- 108

Figs. 100-102: ***Philippines Laguna***

100 Pollen group (X 240)

101. Single grain (X 900); see colpus.

102. Surface (X 3600); Note: cleft polar cap; vartate colpus margin with equatorial striate pattern, having low conical projections on ridges (lirae).

Figs. 103-105: ***Philippines Ordinary***

103. Pollen group (X 240).

104. Single grain (X 900).

105. Surface (X 3600); Note: narrow disrupted colpus (being fused at places) and striate pattern with sinuate ridges (lirae) having nodular elevations.

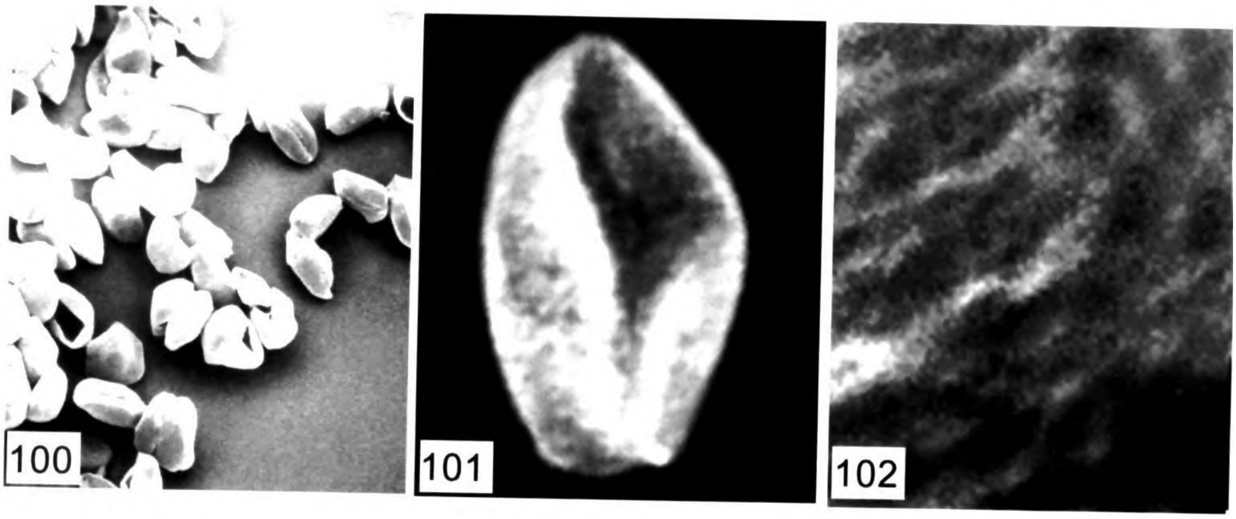
Figs. 106-108 : ***Saint Vincent***

106. Pollen group (X 240).

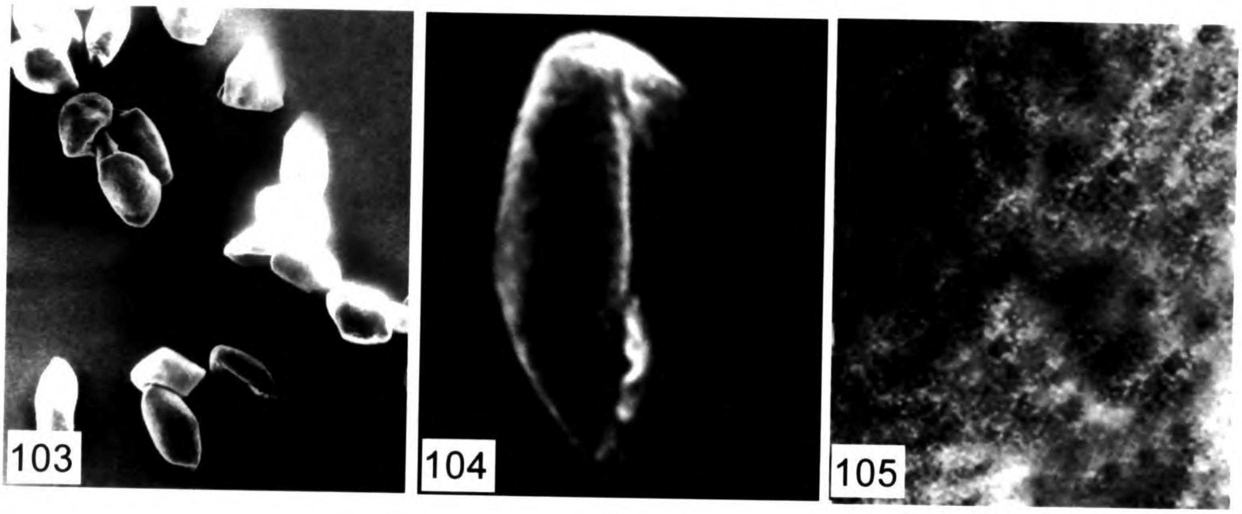
107. Single grain (X 750); see wide colpus.

108. Surface (X 2400); Note: zonate polar colpus with modular aggregation of granules.

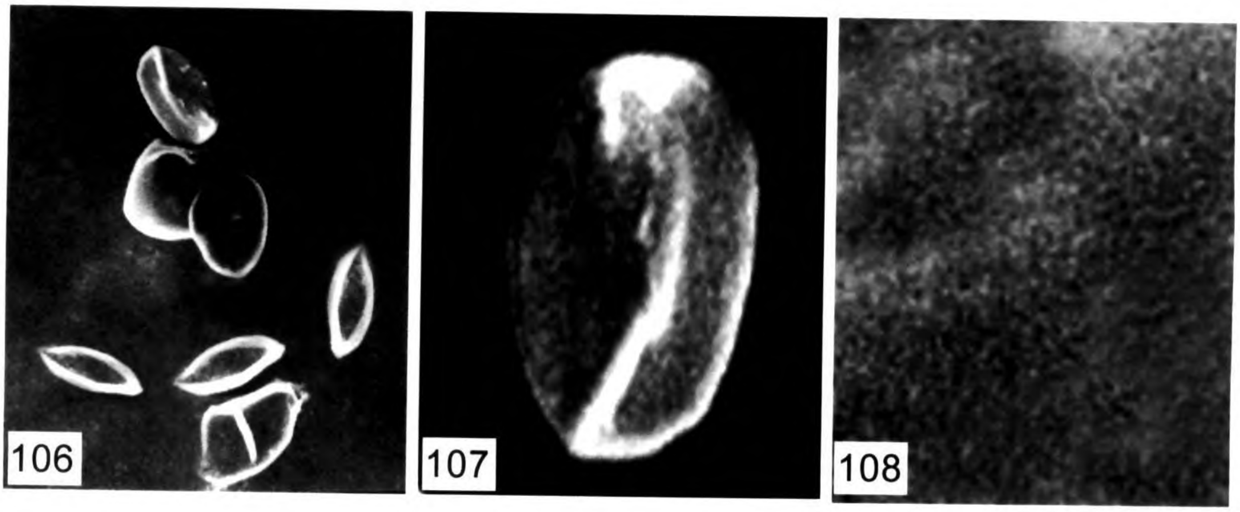
PLATE-XII



Philippines Laguna



Philippines Ordinary



Saint Vincent

PLATE XIII

FIGURES109- 117

Figs. 109-111: *San Ramon Tall*

109. Pollen group (X 240).

110. Single grain (X 900).

111. Surface (X 2400); Note : Echinate lateral surface.

Figs. 112-114: *Seychelles Tall*

112. Pollen group (X 240).

113. Single grain (X 750); see lateral beaks.

114. Surface (X 2400); regulate-striate matted pattern with wide muri (lirae) and echinuate depressions.

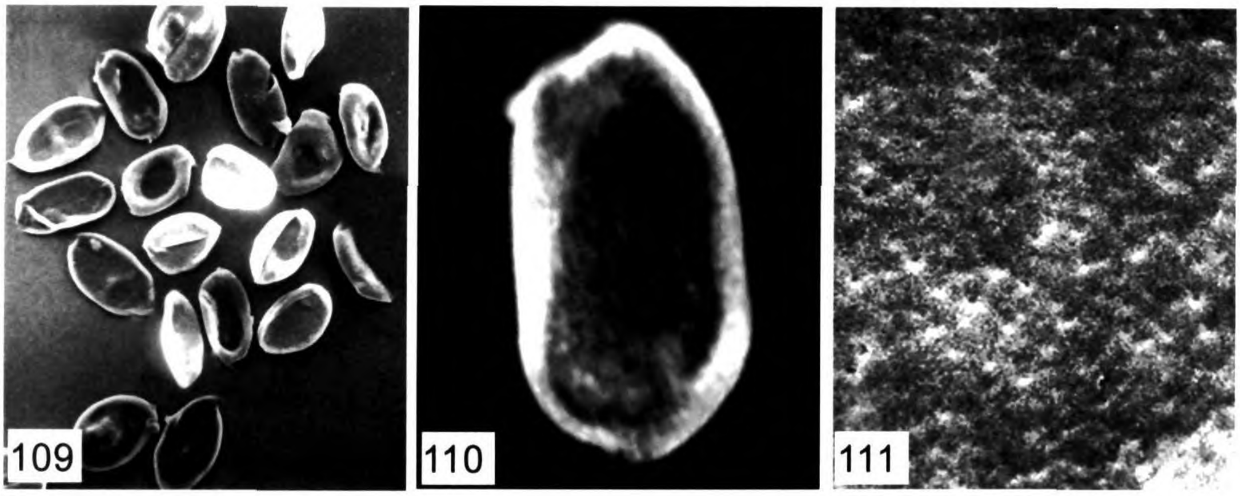
Figs.115-117: *Sri Lankan Tall*

115. Pollen group (X 240).

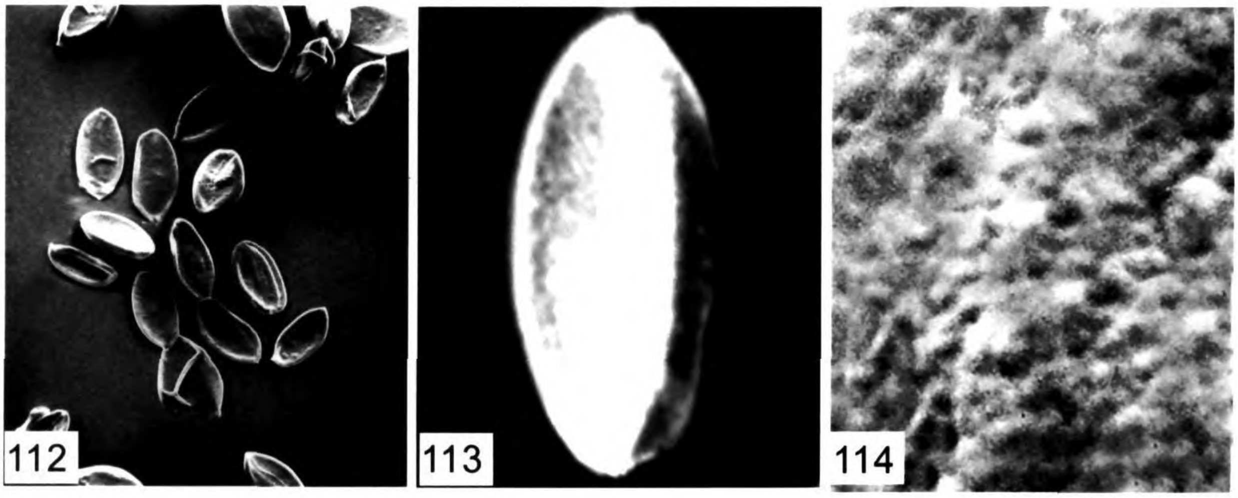
116. Single grain (X 900); see lateral beads.

117. Surface (X 4000); Note granulate lateral surface.

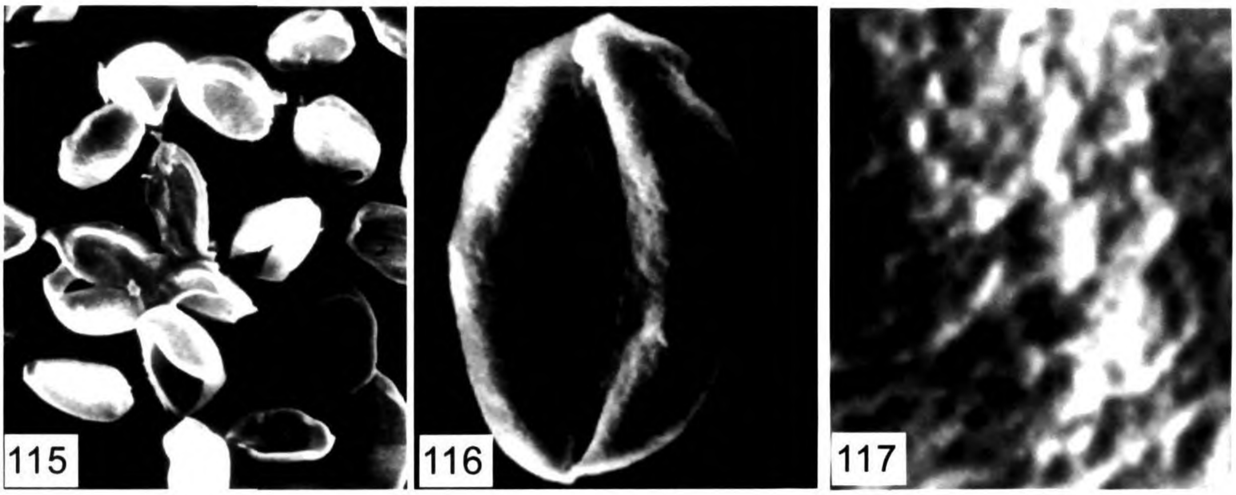
PLATE-XIII



San Ramon Tall



Seychelles Tall



SriLankan Tall

PLATE XIV

FIGURES118- 126

Figs. 118–120: ***Sri Lankan Yellow Dwarf***

118. Pollen group (X 240).

119. Single grain (X 950); see regenerated colpus edge.

120. Surface (X 2400); Note: cleared polar cap, low rounded elevations on lateral surface, striate–foveolate-nodular pattern.

Figs. 121–123: ***Striat Settlement Green Tall***

121. Pollen group (X 180).

122. Single grain (X 850); see wide colpus.

123. Surface (X 4000); Note: equatorially oriented, disrupted ridges in parallel rows.

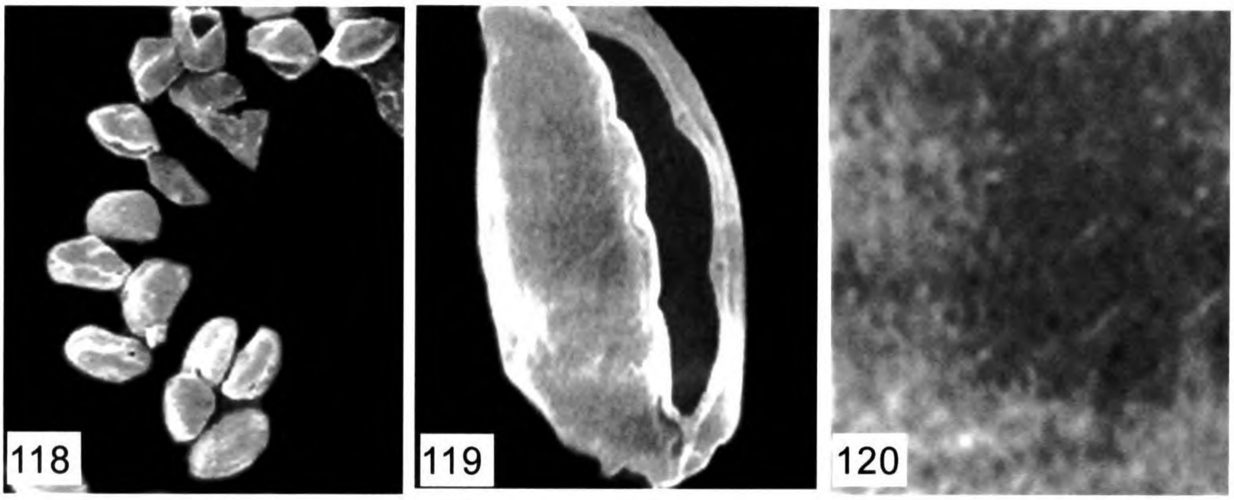
Figs. 124-126: ***Verrikobbarri***

124. Pollen group (X 300).

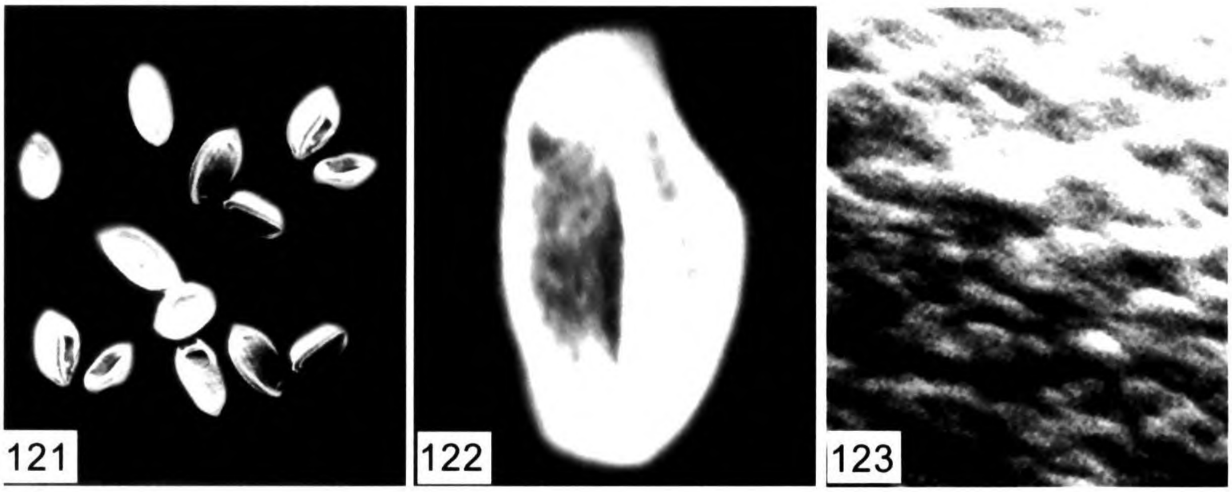
125. Single grain (X 900); see wide colpus.

126. Surface (X 3600); Note: ill defined large meshes with spot aggregations of granules on the muri.

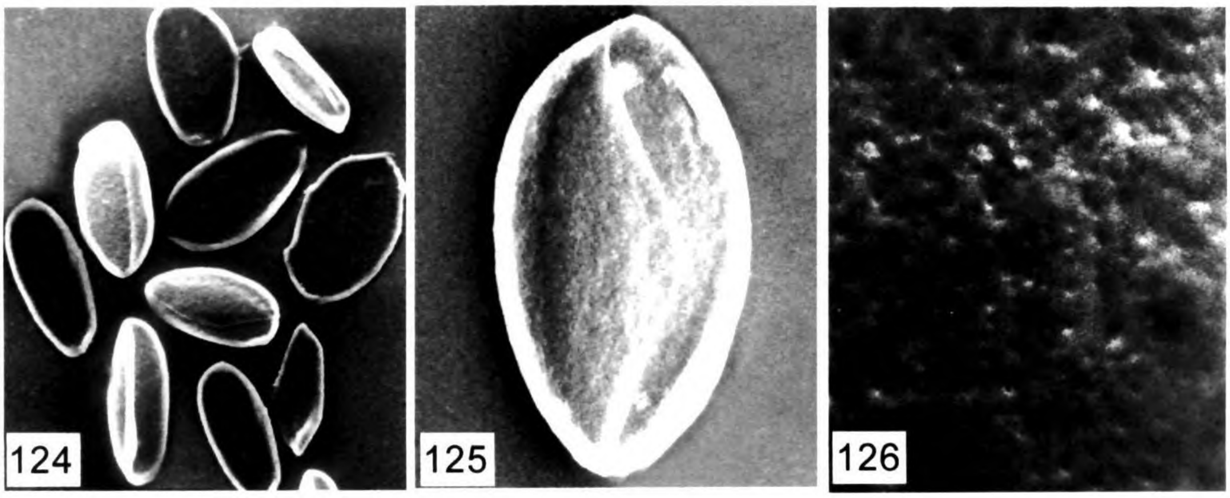
PLATE-XIV



SriLankan Yellow Dwarf



Strait Settilment Green



Verrikobbarri Tall

PLATE XV

FIGURES 127- 132

Figs.127-129: ***West Coast Tall***

127. Pollen group (X 240); see elongate grain dominance.

128. Single grain (X 900); see arched colpus.

129. Surface (X 4000); Note : Cloudy surface.

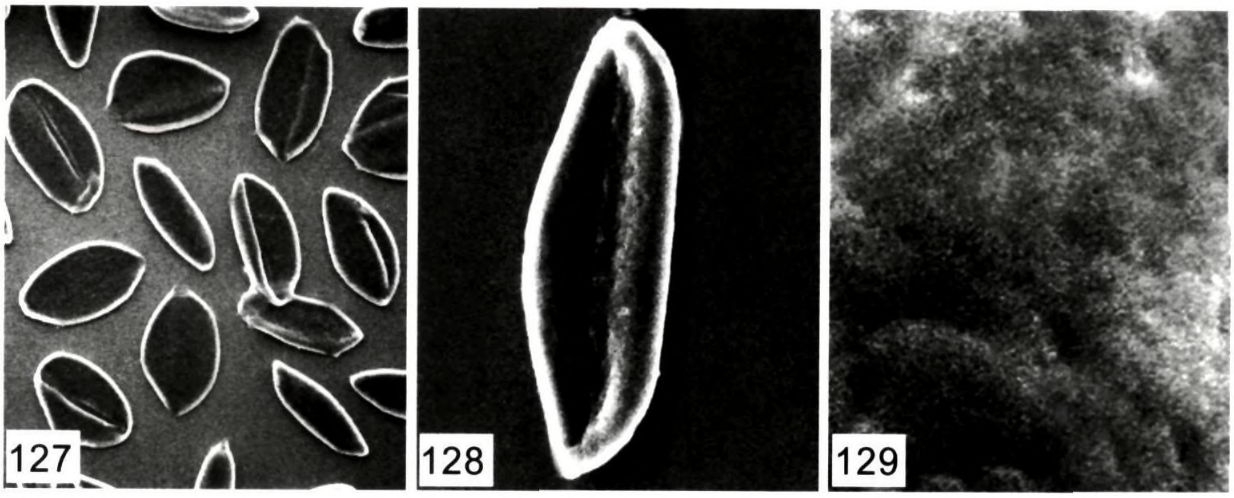
Figs. 130-132: ***Zanzibar Tall***

130. Pollen group (X 240).

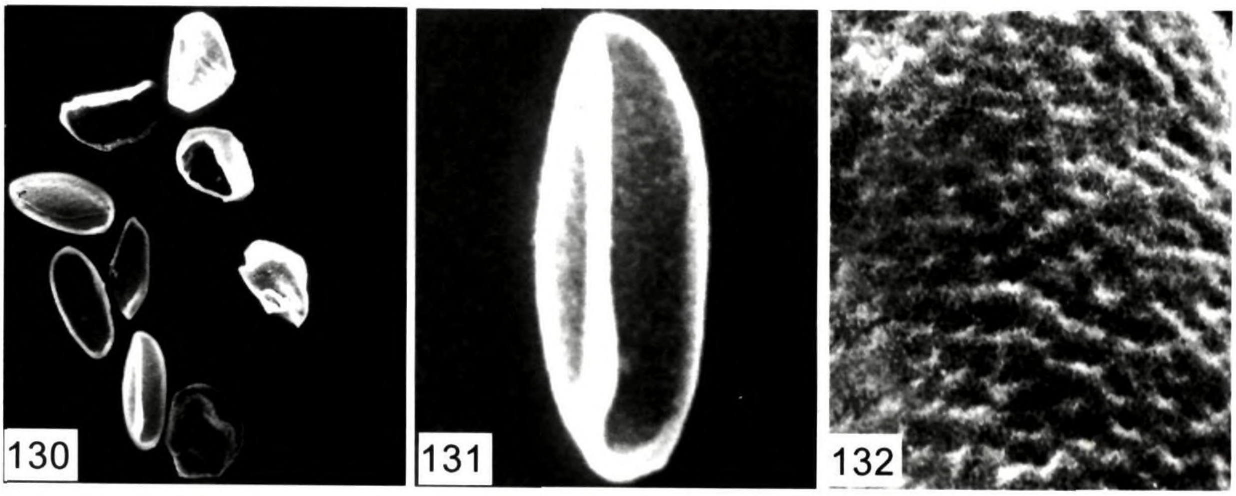
131. Single grain (X 900).

132 Surface (X 2400); Note: striate partially twined lateral surface, arched lirae, imposed, nodular granular aggregations placed end to end.

PLATE-XV



West Coast Tall



Zanzibar Tall