ANATOMICAL AND PALYNOLOGICAL STUDIES ON INDIAN MUSACEAE

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CERTIFICATE

This is to certify that the thesis entitled, "**Anatomical and Palynological studies on Indian Musaceae**" submitted to the University of Calicut, for the award of the degree of **Doctor of Philosophy** in **Botany**, is a bona fide record of the original research work carried out by **Hareesh V.S.** at Angiosperm Taxonomy and Floristics Division, Department of Botany, University of Calicut under my supervision and guidance and no part of the present work has formed the basis for the award of any other degree/diploma to any candidate of any University previously.

C.U. Campus
30.05.2019

Prof. M. Sabu
Supervising Teacher

DECLARATION

I, Hareesh V.S., hereby declare that the thesis entitled "**Anatomical and Palynological studies on Indian Musaceae**" submitted to the University of Calicut, for the award of the degree of Doctor of Philosophy in Botany is a bona fide record of the original research work carried out by me under the supervision and guidance of Dr M. Sabu, Professor, Department of Botany, University of Calicut and that it has not been submitted earlier either in part or full for the award of any degree/diploma to any candidate of any University.

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Hareesh V. S

Dedicated to

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Chapter 1

INTRODUCTION

INTRODUCTION

Monocotyledons (monocots) are one of the major radiations of angiosperms, consisting of nearly 60,000 species embracing 25% of the angiosperms (Simpson, 2006; Kress & Sherwood, 2009). They probably originated between 125 and 140 million years ago. Presence of single cotyledon (vs. usually two in other angiosperms) is one of the major differences between the monocots and other angiosperms. There are many more significant differences in the vegetative characters (Tomlinson, 1995), that would likely turn monocots to be monophyletic. Pickerel weeds and aroids, screw pines, onions and orchids, lilies, palms, gingers and bananas, dayflowers and grasses and bromeliads are the twelve major lineages recognised within the monocots (Kress & Sherwood, 2009).

A unique clade known as the 'commelinids' within the monocots, comprises the order Zingiberales, which has been recognized as a monophyletic or 'natural' group of plants often classified at higher taxonomic rank (Tomlinson, 1962; Cronquist, 1981; Dahlgren *et al*., 1985; Kress, 1990, 1995; Rudall *et al*., 1999; Stevenson *et al*., 2000; Kress *et al*., 2001; Liu *et al*., 2010; APG IV). The order serves as a model group for understanding the mechanism underlying the diversity through time (Kress & Specht, 2005). The major areas of distribution of the order Zingiberales include wet tropics of Asia, Africa as well as the Americas. However, some taxa reach into the subtropics, even into the temperate regions. APG II, (2003), APG III, (2009) and APG IV (2016) have also accepted Zingiberales as one of the primary orders in the monocotyledons. Molecular sequence data reveal that, an anticipated quick radiation on the Zingiberales during the cretaceous period (Kress & Specht, 2006; Sass *et al*., 2016), resulted in the eight families *viz*., Cannaceae, Costaceae, Heliconiaceae, Lowiaceae, Marantaceae, Musaceae, Strelitziaceae and Zingiberaceae, having implausible groups like bananas, gingers , heliconias and birds of paradise (Kress *et al.*, 2002). Even if less than 40% of the extant monocot species are confined within this clade, the members exhibit unique features. On the basis of the studies on morphological and anatomical characters, Tomlinson (1962) elucidated the diagnostic features of the order Zingiberales. The phenotypic diversity of the families varies extensively regarding the floral, vegetative and anatomical characters. The variations are mainly due the diverse life history strategies and environmental or ecological ranges (Kress, 1990; Kress & Specht, 2005, 2006).

Bromeliales are considered as the best out group for Zingiberales (Kress, 1990). According to Dahlgren *et al*. (1985) Bromeliales are sister group to Bromeliifoliae, that in turn comprises of Bromeliaceae, Haemodoraceae, Philydraceae, Pontederiaceae, Sparganiaceae, Typhaceae and Velloziaceae. *rbcL* sequence data used for the phylogenetic study reveals all the families within Zingiberales to be monophyletic, except one paraphyletic family, Musaceae (Smith *et al*., 1993).

Based on the fertile stamens, Zingiberales are informally divided into two morphological groups, namely the “ginger group” that is monophyletic and the “banana group”, which is paraphyletic. The “banana group” [Musaceae (*s.l.*)], comprises of the taxa that are now ranked in separate families such as Musaceae *s.str*. (*Ensete* bruce *ex* Horan., *Musa* L., *Musella* (Franch.) H.W.Li.), Heliconiaceae (*Heliconia* L.), Strelitziaceae (*Strelitzia* Banks, *Ravenala* Adans., *Phenakospermum* Endl.) and Lowiaceae (*Orchidantha* N.E.Br.) (Petersen, 1889; Lane, 1955; Dahlgren *et al*., 1982; Kress & Specht, 2005; Liu *et al*., 2010; Sass *et al*., 2016). Nakai (1941) and Hutchinson (1964) separated Musaceae *s.str*. from Musaceae *s.l*., Kress (1990, 1995) and Kress *et al*. (2001) stated Musaceae *s.str*. to be monophyletic, having the basal-most lineage within the order Zingiberales. The rest of the four families such as Cannaceae, Costaceae, Marantaceae and Zingiberaceae are collectively called the “ginger group”. Even though two informal groups exist by classification, all members of Zingiberales are commonly called ‘gingers’.

Musaceae are considered as the most ancient family in the order Zingiberales, with high relatedness to Strelitziaceae, Lowiaceae and Heliconiaceae (Tomlinson, 1962; Kress 1990, 1995; Kress *et al*., 2001). The separation of these four families began about 110 million years ago (Kress & Specht, 2005). There is a controversy regarding the basal position because of the limited sequence divergence among the families due to rapid radiation (Liu *et al*., 2010).

South East Asia is believed to be the place of origin of bananas, where the earliest domestication has occurred and serves as the major centre of the crop’s diversification (Simmonds, 1962), bordered by India in the west and Fiji, Samoa, and other South Pacific Islands on the east (Simmonds, 1966). South and South-East Asia to northern Australia and Africa are considered as the major distribution areas of Musaceae (Liu *et al*., 2002b; Chiu *et al*., 2011). Fossil records indicated the distribution of Musaceae in North America and Europe in the Tertiary period (Manchester & Kress, 1993). India, China, Malaysia and Myanmar regions (South and SE Asia) have the greatest concentration of Musaceae taxa.

The banana family, regarded as the world’s largest herb family, comprises three genera, *Ensete, Musella* and *Musa*. Apart from the general features of other families in Zingiberales, Musaceae members have unique characters like large pseudostem, long inflorescence, five stamens and one highly reduced staminode in the male flowers and big edible or non-edible fruits. The members are mainly grown in damp and humid places and also in the secondary forests. Mostly, high altitude species grow fully exposed to the sun.

Musa L. is regarded as one of the taxonomically complicated genera within the order Zingiberales because of the similarities in habit, large size and the difficulty in identifying the taxa from herbarium specimens in addition to the much more difficult collection of specimens from dense evergreen forests during monsoon season and the processing of bulky specimens. The main areas of its distribution include tropical Asia ranging from Himalayas to northern Australia as well as Africa (Cheesman, 1947a, b; Simmonds, 1962; Kress, 1990).

Ensete is a special genus (n=9) that could be propagated only by seeds and is infrequently distributed between tropical Africa and tropical Asia. The genus consists of seven species and one variety (Simmonds 1960, 1962, Joe *et al.,* 2016). In India, only two species, *viz. E. glaucum* (Roxb.) Cheesman and *E. superbum* (Roxb.) Cheesman, were recorded having distribution mainly restricted to the Peninsular India and Northeastern states (Joe *et al.,* 2016). *Ensete* can be easily distinguished from *Musa* by its monocarpic, non-stoloniferous habit, conical pseudostems with swollen base and bracts and flowers integral with each other and with axis etc. The monotypic genus, *Musella*, a monotypic genus, is confined to a small area in southwestern China (Li, 1978, 1979, 1981; Wu & Kress, 2000; Liu *et al*. 2002a, 2003).

The genus *Musa* is the leading economically important taxa, well known for the cultivated bananas. Kurz (1867) was the first who mentioned about the origin of edible bananas as bispecific, and it fell in oblivion until recognised by Cheesman (1947b). Subsequently, Simmonds and Shepherd (1955) proved it by crossing *M. acuminata* and *M. Balbisiana.* The result obtained was compared with the morphological and ploidy states of cultivated varieties, and concluded that the edible bananas have evolved from *M.*

acuminata and *M. balbisiana,* in five main stages (Fig. 1). Hence they are regarded as the 'Adam' and 'Eve' of today's edible bananas.

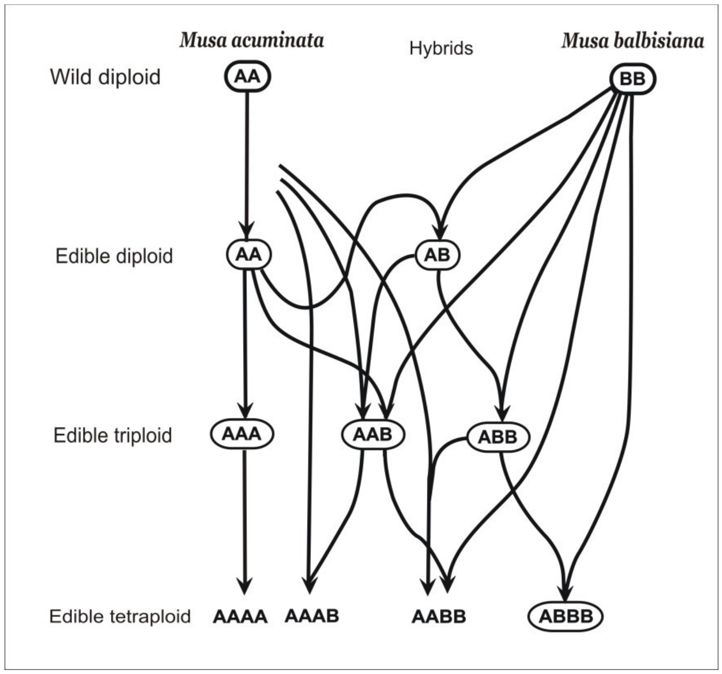

Fig. 1. The evolution of the banana complex. A, *M. acuminata;* B, *M. balbisiana.* Genotypes known to occur naturally are encircled; those known only from experiment are not encircled. Origins from diploid *M. acuminata* in which the parent might have been either wild or edible are shown as lines of indefinite origin. Crossing of tetraploid by diploid as a source of triploids has been neglected because natural tetraploids are very rare; many triploids have been made experimentally in this fashion (adopted from Simmonds & Shepherd, 1955).

India, famous for its enormous genetic diversity of Musaceae members is a proof of the fact that the origin of *Musa* is in the South and South-East Asia, which also includes Indo-Myanmar region. The family comprises of seeded wild species to seedless cultivars with various ploidy levels (Singh *et al.,* 2001; Prasad *et al*., 2013). *Ensete* and *Musa* are the two genera existing in Indian sub-continent and the family represented by 34 wild taxa are mainly distributed in the northeastern states, bordering China and Myanmar, followed by the Western Ghats, the Eastern Ghats and the Andaman and Nicobar Islands. The northeastern states form the centre of diversity of the genus incorporating 29 taxa with 20 endemic taxa (Joe & Sabu, 2019). A total of 20 taxa are endemic to India with great endemism seen in northeastern India with 15 endemics.

Banana, the staple food of many people in various countries (Asian countries like India, Philippines and Indonesia and in many African countries) belongs to the family Musaceae, the most economically important family in the order Zingiberales. Banana, whose cultivation dates back to 4000 BC in New Guinea is one of the chief and oldest food crops of human race (Denham *et al*., 2003, 2004). India ranks first in the production of banana with 15% of the total production (Uma, 2006a,b) and from time immemorial, the members are being used in Ayurvedic and traditional medicines. Many valuable ornamental plants are also included in this family (*Ensete glaucum*, *E. superbum, Musa velutina, M. ornata, Musella lasiocarpa etc*.). In addition, bananas are well known for their fibre content, especially species *viz. M. textilis* possesses strong fibre quality and the extracted fibre is widely used in textile industries. Fibre extracted from most of the wild and cultivated species are also used for making handicrafts.

Ensete edule, which is a staple food crop in Ethiopia, especially in the southern parts, is used to prepare 'kocho', a major food for millions in this area. Edible starch extracted from the corm and pseudostem is fermented to prepare it (Demeke, 1986; Sharrock, 1997). In North Uganda, the flower buds and seeds are cooked and eaten and the seeds are further used as beads (Mabberley, 2005). *E. superbum* is another species reported to be useful. The seeds of the plant is used to treat many human ailments like diabetes, dysuria, kidney stone, leucorrhoea, *etc*. (Kumar *et al*., 2010). The seed powder is used for painful urination (Yesodharan & Sujana, 2007; Diana & George, 2013).

For these reasons, the seeds have high market value of rupees 200–400 per kg in various states of South India (Kumar *et al*., 2010). The flower juice of the plant is useful in treating dysentery and excess bleeding in young girls during their menstruation period (Padal *et al*., 2010). Tribal people in South India use the pseudostem, flowers and fruits as vegetable also. In Meghalaya, the people use pseudostem of *E. glaucum* as vegetable (Rao & Hajra, 1976). The orange sap from the pseudostem of this plant is reported to have medicinal properties (Uma, 2006a). Large conical pseudostem and the leaf arrangement make species of *Ensete* ornamental with high aesthetic value. The present work is restricted to wild Indian Musaceae.

Objectives

1. To study the internal structure of vegetative parts and micromorphology of Indian Musaceae.
2. Detailed study on palynology of Indian Musaceae.
3. To study the seed morphology and anatomy.
4. Assessing the significance of anatomical, micro-morphological and palynological characters in the delimitation and identification of species.
5. Resolving nomenclatural problems of all taxa.
6. Construction of phenogram based on all above data.
7. Preparation of herbaria of all Indian taxa.

Importance of the study

Anatomical and palynological studies of Indian Musaceae are chosen, because of the lack of authentic and comprehensive works. *Musa* (Musaceae) is a taxonomically complicated genus within the order Zingiberales because of the similarities in habit, large size, ephemeral aspects of the flowers and the difficulty in identifying the taxa from herbarium specimens, in addition to the intricate collection of specimens from dense evergreen forests during monsoon season and the processing of bulky specimens. Recent taxonomic studies of the family reveal that still lot of confusions prevail in the species delimitation of Indian taxa even at flowering stage. So the study was chosen to learn the anatomical, palynological and seed micromorphological features of the Indian Musaceae. The result obtained from these studies will be correlated with taxonomic status of various taxa. The proposed work also aims to solve the confusions regarding the delimitation of the taxa and also to reveal the interrelationship between them. High diversity, rich endemism and great economic potential make the study important.

One of the major problems in Musaceae is their identity in vegetative morphology. The species delimitation is possible only on flowering and fruiting. Correct identities of these taxa are necessary for their proper utilization and conservation. In short, there are many factors which justify an in-depth study of the family in India, with respect to their morphology, anatomy, palynology, seed micro-morphology *etc*. The vulnerable nature of the plants and the looming risk of their extinction make it very important. It is in this background, the present work is taken up.

Chapter 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

General anatomy

Anatomical characters of vegetative organs are greatly appreciated in taxonomic research (Metcalf, 1951, 1952a,b; Stant, 1952), as they are useful in the preliminary identification from the herbarium material and to direct the evolutionary trends in the interrelationship of the taxa (Paliwal & Anand, 1978). In angiosperms, leaves are the organs with most varied anatomical characters and provide useful data in taxonomy (Carlquist, 1961) apart from other parts. But in certain cases, some groups exhibit distinct differences in the anatomy of their stem, seed coat, root *etc*. In general, the order Zingiberales are given little attention at specific level in the anatomical studies of vegetative parts when compared to other monocotyledons.

The anatomical studies of Zingiberales started in the early 1900's with the monumental work done by Skutch (1927). He gave the detailed account on external features such as distribution of leaf along stem, pseudostem, phyllotaxy, lateral buds, leaf parts (lamina and vernation) and anatomical studies on sheath, petiole, midrib, lamina and precursory appendage, as well as the morphology of *Musa sapientum* L. var. Hort. Gros Michel. Subsequently, in 1930, he made a detailed account of development and morphology of the same. The axis anatomy of (rhizome or bulb, aerial stem and inflorescence rachis) *Musa sapientum* sub. *seminifera* (Lour.) Baker and *M. sapientum* var. Hort. Gros Michel revealed that, there are no significant differences in the anatomy between the bulbs of two taxa (Skutch, 1932).

Fahn (1953) conducted studies in the Dwarf Cavendish banana, *M. acuminata* and *M. balbisiana,* on the development of the primordia of the flowers in the flower-groups and the development of the vascular bundles in the cushion and flowers. The study provides the evidence for the origin of inflorescence of banana and it also leads to the conclusion that the developments of the flower groups are phylogenetical from cincinni.

Tomlinson (1959) had carried out an anatomical approach towards the classification of Musaceae, which included the species of *Musa* and *Ensete* (present day Musaceae), *Ravenala, Strelitzia, Heliconia* and *Orchidantha* (now placed in separate families). He concluded that *Musa* and *Ravenala* are quite distinct from other genera and it supports the positioning of *Ravenala* in a separate family (Lowiaceae). *Ravenala* and *Strelitzia* are almost identical to each other and show affinities with structurally different *Heliconia*. Though *Musa* possesses distinct anatomical features, it shows affinities with *Ravenala-Strelitzia* complex. It could not be used in a cladistics analysis where careful evaluations of primitive and derived states are necessary, even though the uniqueness and affinities towards the genera is of concern. It well supports the positioning of the order Zingibarales in the present day classification system. He investigated the different parts from seven species of *Musa* and three species of *Ensete* and concluded that, apart from the slight differences in the cell size, the species of *Musa* are identical in structure. The major difference of *Ensete* to that of *Musa* is the presence of numerous equal numbers of stomata on either side of the lamina. Based on this data and along with Tomlinson (1956, 1960, 1961a, 1961b), he summarised the phylogeny of the Scitaminae in 1962.

Ram *et al*. (1962) studied various aspects of growth and development of banana plant. The study disclosed several features related to the origin of the inflorescence as well as to the floral development. The major changes during the phase of transition of the vegetative shoot apex to the reproductive one is observed. The study further focused on the structural changes involved in the growth and development of the fruit.

Rao and Menon (1963) studied the detailed anatomy of pseudostem, leaf sheath, midrib, lamina and epidermis of *Musocaulon indicum,* a petrified pseudostem collected from the Deccan intertrappean beds. The study revealed that characters such as psuedostem formed by overlapping leaf bases and abaxial position of major arc bundles in the leaf sheath are strongly analogous to those found in Musaceae.

Jain (1964) described *Musocaulon indicum* gen. et sp. nov. along with detailed anatomical descriptions of pseudostem and leaf-sheath.

Anatomical studies on the adventitious roots of *Musa acuminata* cv. Gros Michel revealed the presence of remarkable features like lysigenous lacunae in the cortical cells and stelar region consisting of large metaxylem vessels and internal phloem strands (Riopel & Steeves, 1964).

Tomlinson (1969) examined the lamina anatomy of 31 taxa belonging to two genera of Musaceae (*Musa* and *Ensete*). The result obtained from this study, subsequently altered his earlier interpretation of "the species of *Musa* are identical in structure" (1959). The study revealed that, even though there are distinct morphological differences, only few and possibly variable anatomical differences were observed in *Musa* and *Ensete.* In addition, the laminas possess no diagnostic anatomical characters at the sub-generic level except *M. coccinea* that differed from other species of *Musa* studied. *Musa coccinea* showed similarities with *M. ornata* in its single layered hypodermis and differed in the presence of transverse veins. The study concluded that *M. ornata* is the intermediate between *Heliconia* and *M. coccinea,* because of the presence of single layered hypodermis and absence of transverse veins.

Tilak and Pai (1974) gave a detailed description on the floral anatomy of *E. glaucum* and recommended that the dorsal carpellary and the staminal strands are united at the top of the ovary. Four to six minute strand pairs in connective tissue of the stamens are reduced in to a pair and end at the tip of the each anther. Subsequently Inta *et al.* (2015) agreed the data about the appendicular nature of ovary and the reduction of the androecium.

Wilson (1985) observed the production of different types of phytoliths in *Musa* growing in New Guinea. Later on, Piperno (1988 & 2006) found out similar type of phytoliths from the leaves and underground parts.

The teleomatic and anthomatic axes were analysed for the study of the structural organization in *M. rosacea* (Alquini, 1987). Large amounts of starch granules observed in the leaf sheaths suggested the possibility of economic uses of the plant.

Triplett and Kirchoff (1991) studied the architecture and anatomy of lamina of *Musa rosea, M. velutina, Musa* cv. *Go Sai Yung* and *Ensete* sp. The result showed that the four species were different in their cell structure.The result obtained from the study revealed that, all the species show distinct differences in their lamina thickness, number and nature of the adaxial hypodermis and nature of bundle sheath. Apart from the above mentioned characters, Musaceae could be easily recognised from its lamina with irregular apex.

While studying the structure and anatomy of the ovary of Heliconiaceae and Musaceae (*M. velutina, M. ornata* and *M. cv.* Go Sai Yung), Kirchoff (1992) pointed out that, ovary could be longitudinally divided into three regions: sublocular, locular and prolongation. The prolongation is the elongated closure of the top of the locules. The proportion of those regions has great diagnostic value at generic level, whereas, insignificant at species level. Apart from anatomy, he also had given a detailed note on the aril, and concluded that, the placental trichomes of the Musaceae are not homologous to the arils of the Zingiberales.

McDougall *et al*. (1993) reviewed the plant fibers' botany, chemistry and industrial processing and mentioned about the fibre obtained from the leaf sheaths of *M. textilis* as Manila hemp (*abaca*). It is a strong fibre generally used in ropes and for making strong flexible papers.

Studies on the rooting pattern of banana by Pushkaran *et al*. (1993) wrap up that, the plant possesses a shallow root system and the roots emerge in flushes.

Sandoval *et al*. (1994) studied the foliar anatomy of *Musa* cv. Grande Naine (AAA) plants grown *in vitro,* and after hardening were compared to field grown plants. The result highlighted that, though they had thin walls, greatest thickenings were observed in *in vitro* plants. The greater number of amphistomatic stomata were observed on abaxial surface of lamina.

Draye *et al*. (1999) examined the distribution of lateral root primordia in the root tips of four *Musa* landraces *viz*. *Grande Naine*, *Pisang Berlin*, *Ngok Egome* and *Yangambi Km5*. The field grown plants were evaluated for the range of genetic variation in the lateral root initiation. The study revealed that, the initiation of lateral roots in *Musa* does not affect the genetic variations in the root architecture.

Ennos *et al*. (2000) studied the functional morphology of petiole of *M. textilis* and the ability of petiole to provide the suitable rigidity for holding huge leaves in high winds using various tests. They confirmed that, it is due to some of the peculiar anatomical features of the petiole. The petiole possesses two groups of structures, the longitudinal portion and the transverse stellate parenchyma plates that help to prevent the dorsi-ventral flattening.

Somatic embryos developed from the meristematic apices of *Musa* (AAA) clone '*Gran enano*' were analysed for its origin through histological and morphological studies. Analysis of various developmental phases of the process pointed out that, somatic embryos developed directly from perivascular parenchyma cells of the leaves (Vidal *et al*., 2000).

Osuji *et al.* (2000) examined the calcium oxalate crystals in bract and fruit peel of *Musa* germplasm (mainly in cultivars) and concluded that presence of these crystals have taxonomic value. Subsequent studies on the epidermal characters and anatomical features of the bracts of two species of *Musa* revealed that, *M. sapientum* possesses papillae in the abaxial bract surface and raphide idioblasts in the adaxial surface which are absent in *M. paradisiaca.* These epidermal characters have diagnostic value in taxonomy (Osuji, 2006).

In Musaceae, the vegetative parts produce homogenous phytolith morphotypes, whereas the phytoliths are different in seeds. These features are used to separate *Musa* and *Ensete* (Lentfer, 2001).

The studies by Chaves and Reinhard (2003) revealed that, Musaceae produce phytoliths. Denham *et al*. (2003) identified that, the reported high percentage of phytoliths, from the leaves and seeds of banana (Musaceae) from Holocene produce moderately insufficient phytoliths than grasses.

While studying the phytoliths and the evidence for banana cultivation at Lapita Reber-Rakival site on Watom Island, Papua New Guinea, Lentfer and Green (2004) identified excessive phytoliths of *Eumusa* and moderate phytoliths of *Australimusa* members.

Studies were carried out to determine the developmental processes, before and after anthesis of the ovules of the seeded diploid *M. acuminata* and the seedless edible triploids. Similar analysis on edible triploids of *M. balbisiana* was also done. In addition to this, the embryo sac development, as well as the nature of reproductive tissues in the parthenocarpic fruits and seeded fruits was also considered. For the study, Fortescue and Turner (2005) examined the ovules histologically with a light microscope. They observed that the developments of both triploid and diploid ovules are similar. They also confirmed that the anatomical development of the ovules in seeded diploid, edible triploids and tetraploids have similar ontogenic patterns. Though the genus *Ensete* showed similarity with *Musa* members, in ovule ontogeny the former had significantly larger ovules when compared to other members in the family.

On the basis of relative study of wild and edible *M. acuminata* and wild *M. balbisiana* phytoliths, Ball *et al.* (2006) suggested that both species could not be distinguished morphologically. They observed that, phytoliths of *balbisiana* with 'BB' genome were appreciably larger than that of *acuminata* with 'AA' genome.

Ganan *et al*. (2008) studied the fibre structure of mature rachis in Musaceae and suggested that, the fibre structures are grouped into microscopic level and nanoscopic or ultra-structural level. The microscopic level is formed by conducting tissues, fiber bundles and their elementary fibers, and the nanoscopic levels are cellulose microfibrils that are grouped into microfibril bundles. In addition, the presence of crystal structures on the fibre surface implies its relationship with calcium oxalates.

Studies on the functional anatomy of *Musa* sp., cv. '*Grand Nain*' AAA leaf, along with the distribution patterns of Na^+ versus K^+ and Cl^- reveals that, the function of bundle sheath in lamina veins is analogous to that of the root endodermis (Shapira *et al*., 2009).

Costa *et al*. (2009) evaluated the physiological and anatomical performance, as well as survival of micropropagated banana plants (*Caipira* cultivar) in response to cultivation conditions, in the stage of *in vitro* rooting. The plants grown under natural light show major thickening in the palisade and spongy parenchyma in contrast to upper and lower epidermis and lower hypodermis compared to the artificial environment and the study concluded that, for micropropagation, the practice of natural light is an alternative source for artificial light. Subsequently, Rocha (2005) observed greater width of the lower and upper hypodermis in 'Prata-Anã' banana plants.

Sumardi and Wulandari (2010) studied the anatomy and morphology of five Indonesian banana cultivars (Penjalin, Kluthuk warangan, Ambon warangan, Raja nangka and Kluthuk susu) of different ploidy level. There were no differences noticed in the root and rhizome of diploid level (AA and BB genome) and triploid level (AAA, AAB, and ABB genome), whereas significant differences were observed in morphological characters of stem and leaf in diploid and triploid level.

Silva *et al*. (2010) carried out anatomical studies to distinguish normal banana plants from the somaclonal variants. They procured leaves of plants grown *in vitro* as well as in the field and paradermic sections were taken to analyse the stomatal complex. Transverse sections gave details of chlorophyll, parenchyma cells, midrib, epidermis etc. The work proved useful to determine the anatomical features that separate normal plants from their variants, as the plants exhibited structural variations in their developmental phases.

Amnuaysin *et al*. (2012) conducted studies on the anatomical fluctuations in the fruit peel of '*Hom Thong*' banana during different developmental stages. The results lead to the fact that, the proliferation of the cell, started in the early stages and was followed by the differentiation and enlargement. The modification in the shape of cell and arrangement continued during the fruit maturation, but thickness and cell layer number decreased during the ripening stage. It was due to the modification in the cell wall and the middle lamella.

Fingolo *et al.* (2012) studied the anatomical characters of the bracts and floral parts of *Musa acuminata* and revealed that characters such as pattern of epidermal cells of the bracts, crystals, aeration chambers, and other characters have great importance in taxonomy.

Luz *et al*. (2012) examined the morphological differences during the *in vitro* cultivation of banana plant cultivar '*Maca*' due to the addition of calcium silicate. The plant shows significant difference in their lamina thickness and exhibited increased photosynthetic rate.

According to Chen and Smith (2012), variations in the phytolith morphology within the members of Zingiberales can be considered as distinguishing feature of various families within the order. When drusses, troughs and hat-shaped phytoliths are seen in the vegetative parts, seed phytoliths show high variations. Troughs are seen in the families of Heliconiaceae and Musaceae. The study suggests that the extinct taxon *Spirematospermum* has close relation with Zingiberaceae, and not with Musaceae.

Harijati *et al*. (2013) studied the leaf anatomy of *Musa* and found that *M. brachycarpa* Backer and *M. sapietum* produce lactiferous cells in the palisade of lamina in association with vascular bundles. *M. brachycarpa, M. cavendish* and *M. sapietum* possess three layered adaxial hypodermis whereas it is two layered in *M. paradisiaca.* Hypodermis is followed by two layers of palisade cells in *M. brachycarpa* and *M. sapietum* and three layered in rest of the species. The spongy tissues are irregularly shaped, sometimes irregularly fused to form a large aerenchyma as found in *M. paradisiaca.* He also quantified the fibres of the four species and came to a conclusion that, compared to all other species *M. brachycarpa* has larger number and wider fibre diameter.

On analysing the extraction of the pseudostem and peduncle fibres from four cultivars (Grand Naine, Poovan, Monthan and Nendran), Preethi and Murthy (2013) pointed out that maximum pseudostem and peduncle recovery were obtained from Poovan and the minimum from Grand Naine. Among them, greatest cellulose content was obtained from Nendran peduncle fibre followed by Nendran pseudostem fibre.

The anatomical plasticity of leaf was observed in five banana genotypes (*Maca*, *Thap Maeo*, *Caipira*, *BRS Platina* and *Princesa*) obtained from micropropogation with respect to change in the spectrum of radiation. Out of the four nets (blue, black, red and white), cultivation under white net produced considerable increase in the thickness of epidermis, adaxial hypodermis, palisade and stomatal density on adaxial side (Silva *et al*., 2014).

Floral anatomical characters of *Ensete superbum* and *E. glaucum* showed vast similarities in its cellular composition, even though some characters such as number and position of vascular bundle rings in tepals, presence of hypodermis, epidermal cell shape of stigma and ovary and cortical cell shape of the ovary are noteworthy characters for distinguishing them (Inta *et al.,* 2015).

Hareesh *et al*. (2017b) conducted studies on the anatomy of lamina, petiole, midrib, bract and fruit peel of *Musa velutina* and *M. velutina* subsp. *markkuana.* The study concluded that, apart from the morphology, both species shows significant differences in the anatomy. Based on these characters, they raised the subspecies status of *M. velutina* subsp. *Markkuana* to species level.

Oso *et al*. (2017) studied the macro and micro-morphological characteristics of *M. sapientum* and *M. paradisiaca* spathes. The study revealed that, both species have similarities in the abaxial epidermal peelings, in the presence of open paracytic stomata with raised stomata sledge, raised polygonal parenchyma cell wall and presence of raphide bundles. They strongly differ in the presence of more raphide bundles in the adaxial surface of *M. sapientum.*

Palynology

According to Dafni (1992), the pollen histochemistry is very much related to the pollination mechanism as well as phylogeny. Pollen grains of angiosperms contain reserved food materials either in the form of starch (starchy) or lipids (starchless) (Baker & Baker, 1979). Starchy pollen grains are the features of wind-pollinated (anemophilous) plants, whereas starchless pollens are seen in insect-pollinated (entomophilous) species (Baker & Baker, 1979).

Palynology plays a significant role in Taxonomy as well as in Phylogeny of complex orders like Zingiberales (Kress & Stone, 1983). Though Systematic Botany greatly relies on pollen features for identification, several species of Musaceae are still palynologically unknown (Stone *et al.*, 1979). The surface characters of both the reproductive parts in angiosperms are highly significant for their variety and hence in evolutionary studies (Edlund *et al.,* 2004).

Exineless pollen grains are the characteristics of Zingiberales (Kress *et al.*, 1978). Exine thinning and intine thickening are the two most important aspects of pollen wall evolution (Stone, 1987).

Zingiberales possess inaperturate pollen grains, whereas Costaceae possesses aperturate and acetolysis-resistant pollens (Stone *et al.,* 1981). The sporoderm in Zingiberales is highly different from that of other groups. The exine is reduced to some spinules and a thin connective stratum encases the surface (Kress & Stone, 1983).

Von Post (1933) explained the potassium hydroxide technique for the slide preparation of pollen grains taken from herbarium specimens. This method, further customised by Fibras (1937), proved to be the most suitable technique, for flimsy pollen grains of Cannaceae, Marantaceae, Musaceae and Zingiberaceae (Erdtman, 1952; Traverse, 1965; Reitsma, 1969).

Pollen grains of *Musa* possess thin granulated surface, which is much smaller than that of *Ensete.* In *Ensete* the surface is regularly warty and large (Simmonds, 1960).

Fortescue and Turner (2004) studied the pollen viability of *Musa* species in Australia using Alexander's staining procedure. Their study revealed that, the diploid species *M. acuminata* and *M. balbisiana* have more viable pollens than the edible diploids and the tetraploids also have more viable pollens than the edible triploids. The triploids are characterised by highly sterile male and female structures (Nyine & Pillay, 2007).

Musaceae possesses non-aperturate pollen grains with two locules and thin exine, which may be sometimes absent, but have a thick intine. Anthers have a glandular secretary tapetum (Dahlgren *et al.*, 1985; Fortescue & Turner, 2004).

Majumdar *et al.* (2013) mentioned that the structure of pollen grains of *E. glaucum* is large, rounded about 334.9–386.4 µm, with watery surface and thin exintine. No comprehensive work on the palynology of Musaceae has been carried out.

Oselebe *et al.* (2014) examined the diversity and viability of pollen within five different *Musa* genotypes of Abakaliki, Nigeria. They observed three different types of pollens *viz.,* big, moderate and small, with corresponding apertures and pores.

According to Inta *et al.* (2015), *Ensete glaucum* possesses spheroidal pollen grains with exine having verrucate ornamentation, whereas pollen grains of *E. glaucum* have perforated ornamentation on the exine.

Hareesh *et al.* (2017b) studied the pollen morphology of *M. velutina* and *M. markkuana* and concluded that, both species have spheroidal pollen with rugose exine ornamentation patterns. However, the scabrations are more prominent in *M. velutina* and less in *M. markkuana.*

Morphology and anatomy of Seed

According to Humphrey (1896), ovules and seeds of *Musa rosea* of Jamaica have no specific anatomical features, except, lengthy simple trichomes besides the funiculus. Trichomes or arils are absent in seeds. However, the seeds exhibit notable lateral extension than the ovules because of much shorter than broader embryonal cavity. Distinctive layers of palisade and cuboidal cells are present in testa.

McGahan (1961a) provided a detailed description on the seed anatomy of *M. balbisiana* Colla. The seed is developed from a bitegmic anatropous ovule and is divided in to two chambers; larger chamber with embryo and endosperm and smaller chamber with chalazal mass. The seed coat consists of sclerified, multi layered integuments. The innermost layer of the integument is the thick cuticle. The micropylar plug and collar, and the chalazal mass composed of gelatinous cells are the typical characters of the genus. The embryo is 'mushroom-shaped' and the large cap like portion is the haustorium, consisting of large intercellular spaces. Finally he concluded that, there is no fundamental difference in the seed structure between *M. balbisiana* and other *Musa* species so far described. Further, anatomical and morphological studies on the seedling of *M. balbisiana* by McGahan (1961b) revealed that the first external evidence of seed germination was observed during the displacement of the micropylar plug by the elongation of the hypocotyl-radicle axis.

Jain (1963) studied the morphology and anatomy of the seeds of fossil banana *viz*., *Musa cardiosperma,* from the Deccan intertrappean series of India. He observed that, they are striated with pericarp made of similar parenchymatous cells with some tannin cells intermingled with fibres and vascular bundles.

Manchester and Kress (1993) compared the seed characters of extant Zingiberales with that of the fossil Zingiberalean ones. They observed that, the species with bulb-shaped to cylindrical embryo hang from the hilar end. But, Musaceae have aril less seeds with short embryo. *Ensete oregonense,* a new species, has an operculum, definite chalazal chamber, well developed micropylar collar and a broader hilar cavity and their seeds are the first unambiguous fossils of Musaceae from the Clamo Formation (Middle Eocene) of Oregon.

The study of De la Rosa and Cevallos-Ferriz (1994) on the Upper Cretaceous Zingiberalean fruits, from the southeastern region of Coahuila, Mexico, reveals that, one of the taxa, namely *Striatornata sanantoniensis* gen. et sp. nov. shows similarities with *Spirematospermum,* in the presence of distinct chalazal chamber and hilar cavity. These are recognised as the members of Musaceae. The opercular structure, anatomy of the integuments and fruit morphology supports the recognition of *Tricostatocarpon silvapinedae* gen. et sp. nov. in Zingiberales with *Musa cardiosperma* as a possibly allied one. The study revealed that, though fossils have similar construction patterns within the seed integument, are not analogous to the patterns in the existing members of Zingiberales and there are differences in the reproductive biology.

The study on the germination and storage of banana seeds by Chin (1996) exposed the existence of two types of seeds *viz.* cylindrical type and sub globular-angular type, though their fundamental structure and anatomy are alike.

Graven *et al*. (1996) studied the structure and macromolecular composition of eleven taxa of Musaceae including three genera and concluded that, all the three genera of the family possess homogenous structure of the seed coat. He provided detailed anatomical slides of *M. balbisiana*, *M. paradisiaca* and *M. mannii* for describing the representatives of the genus *Musa.* The seed consists of arils, followed by the epidermal cells with multi angular silica bodies situated against the inner periclinal wall. The epidermal cell walls are thin, and are covered with net-like silica structure. The longitudinal section of the seed coat consists of operculum, hilum and micropyle with micropylar collar, situated at the top of the operculum. The distal part of the seed coat consists of a broad chalazal disc. The middle layer of the outer integument comprises 20–25 layers of sclerotic cells that are diverse in shape, size and ornamentation. The innermost layer develops in to an endotesta consisting of U-shaped thickened cells. Testa and tegmen are free from each other and are not separated by distinct cuticular layer. Tegmen consists of two layers of longitudinally elongated cells, filled with a spongy-like structure followed by thickened layers. The innermost layer of the seed coat has partially nucellar origin cuticle.

According to Liao *et al*. (2004), anatomy of seeds of *Ensete glaucum* includes seed coat, perisperm, endosperm and embryo, while aril is absent. The seed coat gets differentiated into epidermis, sclerenchyma and sclereids. Sclereids are thickened on the anticlinal and inner periclinal walls. Though the chalazal chamber and chalazal mass are well distinguished, the endotesta is incessant in the chalazal region. Micropylar collar and operculum exist in micropylar region. The operculum consists of only sclereid, endotesta extends to a hilum cavity within this region. While perisperm consists of only one layer of cells, endosperm is massive with abundant starch grains.

Puteh *et al.* (2011) studied the morphology and anatomy of seeds of three *M. acuminata* ecotypes. The study revealed that the size of the seeds and that of embryo shows significant differences in each ecotype. Apart from seed morphology, Scanning Electron Microscopic studies of seed coat also showed differences in the number and structure of testa and tegmen layers. The width of water channel appeared to be narrower in fresh seeds when compared to the dried seeds. The increasing width of water channel between testa and operculum was due to the shrinking of operculum and surrounding cells.

Transverse section of seed coat of *Musa balbisiana* consists of two distinct zones, testa and tegmen. The testal layer is differentiated in to palisade-like elongated malpighian cell layer followed by much broader, closely packed paranchymatous cellular zone with tannin deposition. Tegmen consists of single layered smaller or more or less oblong, compactly arranged thin walled cells followed by thick layer of periplasm with tannin depositions. The periplasm is followed by endosperm layer with starch grains (Panja & Maiti, 2012).

Findings of Karlsson *et al*. (2013), based on the studies related to the morphology and germination of the seeds of *E. ventricosum* (Welw.) Cheesman is quite interesting. He observed that the embryo size was so small in relation to the seed. Neither the embryo elongates inside the seed before radicle emergence nor do the seed undergo any dormancy stage.

Benedict *et al.* (2016) investigated the comparative seed morphology and anatomy of 166 members of the order Zingiberales. He analysed 51 characters using synchrotron based 3D X-ray tomographic microscopy

(SRXTM) to determine the phylogenetically informative characters and to understand the distribution of morphological disparity within the order. The study includes 17 species of Musaceae from two genera. Out of the 51 characters, Musaceae shares 27 characters, in which Musa-type chalazal chamber was found to be unique in all the taxa of the family and absent in all other family. So this character is considered as the autapomorphy for the families. It also revealed that the chalazal chamber column reported by McGahan, (1961) and Bouharmont (1963) in Musaceae seeds, was absent in the species under investigation. So this character is not taken as a diagnostic one within Musaceae.

Hareesh *et al*. (2017b) studied the seed micromorphology and anatomy of *M. velutina* and *M. markkuana.* Both species possess reticulate ornamentation patterns. But it differs in their nature of isodiametric cells *i.e.,* rugose type in *M. velutina* and smooth type in *M. markkuana.* In addition, both species show differences in their seed coat anatomy.

Aril

The various inconsistent reports on the existence of aril in Musaceae create several confusions. According to Friedrich and Strauch (1975) trichomes are homologous to arils and the presence of multicellular trichomes in *Musa discolor* is reported by Wittmack (1868). Study by White (1928) supports the earlier concept of homology of trichomes with aril.

According to Humphrey (1896), Musaceae do not possess aril. Though the author has not given details regarding this conclusion, he has specified the absence of trichomes within the seeds. Fahn and Kotler (1972) has not followed the concept of homology of trichomes. Though Simmonds (1953) has reported the presence of the trichomes, he has not stated about homology. It is considered that the aril of Zingiberaceae has its development from the outer integument (Humphrey 1896; Grootjen and Bouman 1981; Grootjen 1983). As the structure of the trichome is dissimilar to the structure of aril in the Zingiberales (Pfeiffer 1891; Humphrey 1896; Grootjen and Bouman 1981; Grootjen 1983), none of the studies support homology of trichomes with aril (Kirchoff, 1992).

Recent studies on the seed morphology and anatomy of Musaceae states that, *Ensete* spp. such as, *E. glaucum* (Liao *et al*. 2004), *E. lasiocarpum* and *E. ventricosum* (Benedict *et al.,* 2016) do not have aril. Whereas, *M. textilis* and *M. coccinea* exhibit the presence of aril in seeds (Benedict *et al.,* 2016). Though, several contradictory reports on the presence of aril in Musaceae are available, we follow the examination by Kirchoff (1992).

Phylogeny

The order Zingiberales is a natural group and the phylogenetic, molecular and morphological studies support the monophyly of the plants (Kress, 1990; Smith *et al*., 1993; Kress *et al*., 2001; Specht *et al*., 2001). However, the inter-familial phylogenetic relationships are weakly supported (Kress *et al*., 2001; Kress & Specht, 2005, 2006).

Phylogenetically, tropical Zingiberales are entrenched within derived eumonocots such as Arecales, Commelinales and Poales and include many prominent taxa (Kress *et al*., 2002). As per recent phylogenetical hypotheses, Zingiberales form sister group to Commelinales included in the informal clade 'commelinid monocots' mainly based on molecular data (Chase, 2004; Chase *et al*., 2006; Davis *et al*., 2004; APG, 2009). Dahlgren and Rasmussen (1983) were the first to infer the historical relationships among eight families of the Zingiberales using Phylogenetic Systematics. In 2005, Johansen presented a phylogenetic analysis of Zingiberales based on 613 parsimony informative characters of the plastid *matK* gene, the *trnL-trnF* region, the *rps16* intron, and a conservative part of the nuclear ribosomal ITS region (part of the 18S, 5.8S, and 26S rDNA). According to the phylogenetic classification system proposed by Kress (1990), which is based upon the cladogram, recognises two superfamilies, namely, Zingiberariae and Cannariae, eight families, *viz*., Musaceae, Strelitziaceae, Lowiaceae, Heliconiaceae, Zingiberaceae, Costaceae, Marantaceae and Cannaceae and five suborders, *viz*., Musineae, Strelitzineae, Lowineae, Heliconineae and Zingiberineae, within Zingiberales.

Members of the family Musaceae are widely distributed in tropical areas of Asia, Africa, as well as Australia. The positioning of Musaceae within the order Zingiberales is quite reasonable as it is closely related to Heliconiaceae, Lowiaceae and Strelitziaceae and the molecular phylogenetic analyses using nrITS and chloroplast sequence data further provide strong support for the monophyly of the family (Kress *et al*., 2001; Kress & Specht, 2005). Despite several studies, the phylogeny within the family showed uncertainity for many years and several attempts are made to resolve these problems. The comparative restriction fragment length polymorphism (RFLP) studies on wild bananas, to explore the genetic diversity at the inter- and intra-specific level provided results that largely disagreed with Cheesman's sectional classification (Gawel & Jarret, 1991; Gawel *et al*., 1992; Jarret *et al*., 1992). For the re-evaluation of the previous systems of classification and to provide a better phylogenetic framework for morphological and biogeographic distribution studies, Liu *et al*. (2010) used molecular phylogenetic evidence based on nuclear ribosomal structures (ITS) and chloroplast (*trnL-F*). But the results were in contrast to the sectional classification. As per many other molecular phylogenetic studies on *Musa* (Ude *et al*., 2002; Wong *et al*., 2002, 2003; Jarret & Gawel, 1995; Nwakanma *et al*., 2003; Bartos *et al*., 2005; Heslop-Harrison & Schwarzacher, 2007; OECD, 2009; Li *et al*., 2010; Miller *et al*., 2010; Christelova *et al*., 2011;

Hribova *et al*., 2011; Xavier *et al*., 2011) their sectional classification, based on morphology is found to be wrong. Not more than two infrageneric clades were recognised and the identified clades tally well with the basic chromosome numbers of n = 11 and n = 10/9/7, correspondingly. Out of the two clades, one comprises of species from *Musa* sect. *Musa* and sect. *Rhodochlamy*s, while the other contains species from *Musa* sect. *Callimusa*, sect. *Australimusa* and sect. *Ingentimusa* (Li *et al*., 2010; Christelova *et al*.,2011). Multiple nuclear Chloroplast DNA fragments were used to question the authenticity of the sectional classification (Li *et al*., 2010). Similarly, Wong *et al*. (2002) used AFLP, for the same cause. Based on the above cited DNA analysis tests, genus *Musa* has been merged into two sections, namely, sect. *Musa* and sect.*Callimusa*. (Hakkinen, 2013).

In 70 Musa cultivars studied for isozyme polymorphism, seven enzymatic systems were found appropriate for cultivar recognition (Bhat *et al*., 1992a, b). To discriminate miscellaneous groups of *Musa*, the technique of RAPD had been used (Kaemmer *et al*., 1992; Howell *et al*., 1994; Bhat & Jarret, 1995). Further, 116 amplification products were identified by using nine primers (Howell *et al*., 1994).

Padmesh *et al*. (2012) used ISSR markers for the studies on the genetic diversity of *M. acuminata*, that are dispersed in the moist forests of south Western Ghats of peninsular India. Wong *et al*. (2001) conducted similar work in *M. acuminata* of Malaysia, but used AFLP. D^2 analysis, RAPD markers and microsatellite DNA markers were used for identifying and revealing the genetic relationships and genotypes of cultivated bananas (Abdullah *et al*., 2009, 2012; Rekha *et al*., 2001). RAPD analysis gave prominent results on intraspecific relationships within Indian wild *M. balbisiana* (Uma *et al*., 2006 b). The study further provided data that proved that taxa collected under various local names from different parts of India showed notable variations and thus could be treated as separate varieties.

The authenticity of the current usage of four sections in the genus *Musa* was tested by AFLP (Wong *et al*., 2001, 2002, 2003). The same technique was employed to determine the sectional placement of 3 Bornean species and 2 New Guinea species. Transmission of maternal chloroplast DNA (cpDNA) and paternal mitochondrial DNA (mtDNA) had been observed in *M. acuminata*, which is considered as the ancestor to most of the cultivated bananas species (Faure *et al*., 1994). Carreel *et al*. (2002) used restriction fragment length polymorphisms (RFLP) in combination with hybridization of heterologous mitochondrial and chloroplastic probes to study the interrelationships between and within the wild clones and their diploid and triploid cultivars using 71 wild Musa accessions and 234 cultivars that covers all ploidy levels.

Two introns, namely, rpl16 and ndhA, and two intergenic spacers, namely, psaA-ycf3 and petA-psbJ-psbL-psbF were sequenced and the data obtained were combined to check the effectiveness of chloroplast loci and further, to give additional information related to hybrid evolution in *Musa*. (Swangpol *et al*., 2007)

Raboin *et al*. (2005) made attempts to recognise the diploid ancestors of the export bananas, namely, '*Cavendish*' and '*Gros Michel*' (both AAA), by comparing the RFLP patterns, as given by 36 probe/enzyme combinations, of 176 diploid clones (both wild and cultivated), that represented the whole range of variability in cultivated bananas. Using 11 polymorphic primers, Crouch *et al*. (2000) used RAPD for a profound study on the varietal diversity in the plantain banana of tropical Africa. The range and nature of variability, in 76 plantain landraces were studied that represented west, central, and east Africa.

Hribova *et al.* (2011) made the first attempt to provide details on the diversity of the ITS sequence in the genus *Musa*. They studied the structure and diversity of the ITS region within 87 plants in the family Musaceae and described the existence of more than one type of ITS sequence in each of the representative species. Amplified ITS regions were subjected to Sanger sequencing and whole genome 454 sequencing that gave similar results. ITS sequence based phylogenetic reconstruction had divided *Musa* into two clades - *Callimusa* and *Australimusa* and *Eumusa* and *Rhodochlamys*. When intraspecific banana hybrids were analysed, they contained conserved parental ITS sequence hinding incomplete evolution of rDNA loci.

Novak *et al.* (2014) analysed repetitive genome fractions of 6 species of Musaceae, namely *Ensete gilletii, M. acuminata, M. balbisiana, M. beccarii, M. ornata* and *M. textilis*. Low-pass sequencing of these species using 454/Roche platform revealed quantitative differences as well as sequence variations. These differences were prominent for species from different taxonomic sections, whereas closely related species exhibited similar repetitive elements.

Janssens *et al.* (2016) attempted to derive a link between the diversity and bio-geographical features of the family Musaceae and the geological and climatic aspects of Southeast Asia.

Deng *et al.* (2016) reconstructed the phylogenetic and ancestral geographical area of Zingiberales using plastid genome. 76 coding genes and 4rDNA loci of 17 species were considered to represent eight families. They used Bayesian Binary Markov Chain Monte Carlo (BMM) method for the study.

Lamare *et al.* (2017) suggested that the sectional classification of the genus *Musa* should be reviewed by combining *Eumusa* and *Rhodochlamys* as one section, *Australimusa, Callimusa* and *Ingentimusa* as another section. According to their findings, not even one of the five sections of *Musa* could be recovered in the molecular phylogenetic analysis with cpDNA and nr DNA.

Hernandez *et al.* (2019) made a thorough investigation on the evolutionary history of Musaceae using modern techniques to understand the ancient distribution of the family and its modern lineages. Their study hypothesized North America and Europe as the grave of ancient lineages and tropical Asia as the cradle of recent lineages. Combination of the fossil information with ancestral reconstructions also helped to improve the concepts regarding biogeographical history of Musaceae.

Systematic position of Family Musaceae

Musaceae comes under the Order Zingiberales, Suborder Musineae and Family Musaceae (Kress *et al*., 2001).

Infrageneric classification of the genus *Musa*

The very first attempt to classify genus *Musa* was by Colla (1820). He classified *Musa* into two groups namely '***Spermophorae***' that includes plants with seeds and '***Aspermae***' that includes plants without seeds. These two groups were again divided into two subgroups on the basis of the inflorescence type. Group with pendulous inflorescence was termed 'Spadicenutante' and group with erect inflorescence was termed 'Spadiceerecto'.

In 1846, Spach attempted to divide *Musa* into two sections. Species that are perennial, big and produce new shoots or suckers every year were placed in first section. Plants that totally perish after the ripening of fruits and are non-stoloniferous with fibrous roots were placed in the second section. Section 1 was again grouped to 2 groups.

Group 1 - Plants with pendulous inflorescence

Group 2 - Plants with erect inflorescence.

“Rational grouping of the species” was the concept of Sagot (1887) who divided *Musa* into 3 sections.

1. ‘Giant bananas’ of the type *M. ensete*.
2. ‘Bananas with fleshy fruits that are often edible’, of the type *M. sapientum* and
3. ‘Ornamental bananas’ with upright inflorescences and brightly coloured bracts.

Baker (1893) followed Sagot’s classification and placed the species in 3 subgenera, namely, *Physocaulis, Eumusa* and *Rhodochlamys*.

The features of Subgenus *Physocaulis* include: Bottle-shaped stem, flowers numerous in a bract, tricuspidate petals (regularly), non-edible fruits.

The features of Subgenus *Eumusa* include**:** Cylindrical stem, flowers numerous in a bract, ovate-acuminate petals, green bracts, brown to dull violet, fruit generally edible.

The features of Subgenus *Rhodochlamys* include**:** Cylindrical stem; few flowers in a bract; linear petals, bright, often red-coloured bracts. Non-edible fruits (rarely edible).

Cheesman (1947a) brought together all the plants of Sagot’s ‘Giant bananas’ and Baker’s *Physocaulis* to revive *Ensete*. Consequently Cheesman

(1947b) divided the genus *Musa*, into four divisions, mainly on the basis of morphological characters and chromosome numbers.

The section *Eumusa* and *Rhodochlamys* share similarities in chromosome number (x=11) and reproductive characters such as more or less sulcate and glaucous bracts with rarely polished on outer side, convolute or more or less imbricate in bud, strongly revolute, occasionally sub-globose or dorsi-ventrall compressed seeds. *Section Musa* possesses long pseudostem, which is more than three meter high, pendent or semi-pendent inflorescence, numerous flowers arranged in two rows in a bract and green, brown to dull purple or dull-coloured bracts. Whereas, *Sect. Rhodochlamys* has short pseudostem (less than three meter high), erect inflorescence, few flowers arranged in single row in a bract and brightly coloured bracts.

Section *Australimusa* and *Callimusa* share similarities in chromosome number (x = 10) and reproductive characters such as bracts plane with firm texture, polished, rarely glaucous and strongly imbricate to slightly revolute. *Section Australimusa* shows sub-globose or more or less dorsi-ventrally compressed seeds with small perisperm chamber. However, *Sect. Callimusa* shows cylindrical to barrel or top-shaped seeds with well developed perisperm chamber.

After this, a new section named, *Ingentimusa*, was uplifted as the fifth section. The section was based on *M. ingens* (x = 14), a species from Papua New Guinea (Argent, 1976).

On the basis of molecular data and DNA analyses, the genus *Musa* was divided into two sections, *sect. Musa* and *sect. Callimusa* (Hakkinen, 2013). In India, genus *Musa* is represented by only one section, *Musa* sect. *Musa*. The present study follows Hakkinen’s system of classification.

Chapter 3

AREA OF STUDY

AREA OF STUDY

India is considered as one of the greatest diverse biogeographic regions of the world. The landmass of India lies between 8^0 4′ to 37^0 6′ N latitude and 68^0 7′ to 97^0 25′ E longitudes. It has a total area of 328723 km^2, land boundary of about 15200 km and coast line of 7517 km. Northern side of India is bordered by Nepal, Bhutan and China and North-West by Pakistan. North-East is bordered by Myanmar and Eastern face by Bangladesh. The Southern Peninsula extends into the Indian Ocean with Bay of Bengal lying to the South-East and the Arabian Sea to the South-West (Map 1).

Indian mainland is divided into six physiographic regions, *viz*., The Northern Mountains or The Himalayan Mountains, The Peninsular Plateaus, Indo-Gangetic Plains, Thar Desert, The Coastal Plains and the Islands.

The Himalayas, geologically young and structurally fold mountains stretch over the northern borders of India. They are recognized as the highest mountain ranges in the world, with its tallest peak Mt. Everest (8848 m). The mountain ranges run in an east-west direction from the Indus to the Brahmaputra forming an arc manner. It covers a distance of about 2,400 km and width of 400 km from Kashmir to 150 km in Arunachal Pradesh. The Himalayas consisting of the Himalayas of Nepal, Hindu Kush and Patkai ranges define the northern Indian subcontinent.

The Peninsular plateau is composed of the old crystalline, igneous and metamorphic rocks. This region consisting of undulating lands forms a vast area extending over much of India. They extend from the south of Indo-Gangetic Plain to Kanyakumari and forms a triangular shape. The plateau comprises the Vindhya Range, the Malwa Plateau, the Deccan Plateau, the

Chota Nagpur Plateau, the Satpura Range, the Aravalli Range, the Western Ghats and the Eastern Ghats.

The Indo-Gangetic plain (the Great Plains), stretches from Jammu and Kashmir in the West to Assam in the East and drain most of northern and eastern India. They are large alluvial plains dominated by three important rivers, the Indus, the Ganges, and the Brahmaputra.

The Thar Desert forms a significant portion of the western India and is mostly situated in Rajasthan and extended in to Gujarat, Punjab and Haryana. About 90 percent of the region includes compact salt-lake bottoms, craggy rock forms and interdunal and fixed dune areas and the remaining 10 percent is the sand dunes.

The coast includes eastern coastal Plains, that lies between the Eastern Ghats and oceanic boundary of India as well as western coastal Plains lying between the Western Ghats and the Arabian Sea. The eastern coastal plains are broader and are an example of emergent coast, while the western coastal plains are narrower and an example of submerged coast.

Lakshadweep and Andaman and Nicobar Islands are the major Island groups of India situated in Arabian Sea and Bay of Bengal respectively. The other important islands are Diu Daman, Elephanta, Sriharikota, Salsette Island *etc*.

In addition, ten biogeographic zones are recognized in India. They are (1) Trans Himalayan zone, (2) Himalayan zone, (3) Desert zone, (4) Semiarid zone, (5) Western Ghat zone, (6) Deccan Plateau, (7) Gangetic plain zone, (8) Northeast zone, (9) Coastal zone and (10) Islands.

1. Trans Himalayan zone

The Trans-Himalayan zone mainly comprises the districts of Ladakh and Kargil in Jammu and Kashmir, the Spiti valley, Lingti plains (Lahaul valley), Pooh tehsil (district Kinnaur) in Himachal Pradesh and small areas of Nanda Devi range (Uttaranchal) and Kangchendzonga range (Sikkim).

2. Himalayan zone

The Himalayan zone comprises about 6.41% of the country's total land surface with an area of 21,0662 km^2. It includes northwest Himalaya, west Himalaya, central Himalaya and east Himalaya.

3. Desert zone

The zone includes the northwestern boundary of India and covers mainly the western and northwestern region of Rajasthan and part of Kachchh region of Gujarat in the southwest. The elevation varies from about 350–450 m above sea level in the east of Aravalli range and about 100 m in the south and west and about 20 m in the Rann of Kachchh.

4. Semiarid zone

Semiarid zone includes the areas adjoining the desert and is the transition zone between the desert and the dense forests of the Western Ghats. This region consists of thorny forests.

5. Western Ghat zone

The Western Ghats are a narrow stretch of mountains running along the west coast of India from the south of Tapti River in the North and Kanyakumari in the south. It covers the states of Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra, and Gujarat. The mountains have a long stretch of 1,600 km interrupted by two major gaps, *viz.,* Palghat Gap and Goa Gap covering an area of about 140000 km^2. Doddabetta is the highest peak (2920 m) of Western Ghats situated in the Nilgiris. The average altitude of the mountains ranges from 900 m to 1500 m above sea level and creates a rain shadow region to its east by intercepting monsoon winds from the southeast. The major vegetation types of Western Ghats are evergreen forest, semi evergreen forest, moist deciduous forest, dry deciduous forest, dry scrub vegetation, shola forest and the grass lands.

6. Deccan Plateau

The Deccan Plateau lies in the rain shadow regions of the Western Ghats. This forms the largest unit of Peninsular Plateau of India. The Deccan Plateau is located between Western Ghats and the Eastern Ghats, and extends over eight Indian states.

7. Gangetic plain zone

This region stretches from eastern Rajasthan, Uttar Pradesh, Bihar and West Bengal and bounded by Siwalik Hills in north. This region is characterised by human populated areas and the diversity is represented in the secondary forest patches.

8. Northeast zone

The eastern Himalaya of northeastern India includes one of the least studied biodiversity hotspots in the world (Myers et al. 2000). The region has received some attention from foreign plant collectors during 18th and 19th century. Major hindrance for field exploration includes topography, monsoon resultant landslides, insurgency and inaccessibility into more remote regions and higher elevations. Northeast includes Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. The zone is the place of assemblages of Himalayan Mountains and peninsular India, hence it is known as the biogeographic gateway for plant migration. Khasi and Jaintia hills of Meghalaya are considered to be the luxuriant botanical habitat in Asia.

Mawsynram in Meghalaya is reported to be the wettest place on earth with an average annual rain fall 11872 mm. The main vegetation types found are tropical evergreen and semi evergreen forests, tropical deciduous forest, tropical bamboo forests, tropical grass land, swamp vegetation, subtropical evergreen and semi evergreen forest, subtropical pine forest, temperate forest and sub alpine forests. Almost all species except *E. superbum, M. kattuvazhana* and *M. sabuana* are distributed in this zone.

9. Coastal zone

The coastal zone is extended form Gujarat to Kanyakumari (Cape Comorin) in the west and from Cape Comorin to the Sundarbans in the east. The west coast is characterised by backwaters and the east coast characterised by extensive deltas.

10. Islands

Andaman and Nicobar Islands and Lakshadweep Islands are the two Island groups of India. The Andaman and Nicobar Islands consisting of an elongated North-South oriented group of 572 Islands in the Bay of Bengal have an area of 8249 km^2. The Andaman groups of Islands are separated from Nicobar group of islands by a deep channel at 10^0 N latitude or Ten degree channel with a distance of 150 km. Saddle peak (732 m) in North Andaman is the highest peak in Andaman and Nicobar group of Islands. The major forest types in the Islands are evergreen, semi evergreen, deciduous, mangrove and grass lands. The Island is characterised by the endemic and peculiar species *M. sabuana* with green to purple coloured bract. The Lakshadweep Islands consist of 27 small islands stretching from 8° to 12° N latitude and 71° to 74° E longitude in the Arabian Sea. It is situated 320 km away from the Kerala coast.

Chapter 4

MATERIALS AND METHODS

MATERIALS AND METHODS

Literature Survey

Relevant literature and informations related to the present study were collected from various sources, such as articles and papers published in various scientific correspondences and books available in libraries and information retrieval system. Electronic reference *viz.* database of Indian dissertations and Ph.D. Thesis repository Elsevier, JSTOR, Science Direct, Shodhganga, Springer link, UGC-JCC-infonet database, Wiley *etc.* were also used. The literature retrieval system such as Biodiversity heritage library of New York Botanic Garden (https://www.biodiversitylibrary.org), online Periodicals repository of NISCAIR (http://nopr.niscair.res.in), Botanical literature from the Missouri Botanical Garden Library (http://botanicus.org), International Plant Name Index (www.ipni.org), Plants of the world (http://www.plantsoftheworldonline.org), Tropicos (www.tropicos.org) and World Checklist of Selected Plant Families (http://wcsp.science.kew.org), were also utilized.

In addition, specimens housed at different herbaria (ASSAM, CALI, CMPR, E, K, KFRI, PBL, SING and SUK) were consulted. The list of herbaria consulted along with their details is provided. The acronyms of herbaria are in accordance to Index Herbariorum (Thiers, 2011).

ASSAM	Botanical Survey of India (BSI), Eastern Circle, Shillong, Meghalaya, India
CALI	Herbarium, Department of Botany, University of Calicut, Kerala, India
E	Herbarium, Royal Botanic Garden, Edinburgh

CMPR	Herbarium, Center for Medicinal Plant Research, Kerala, India
K	Herbarium, Royal Botanic Gardens, Kew, England, UK
KFRI	Herbarium, Division of Botany, Kerala Forest Research Institute, Peechi, India
PBL	Herbarium, BSI, Andaman & Nicobar Circle, Port Blair, India
SING	Herbarium, Singapore Botanic Garden
SUK	Herbarium, Department of Botany, Shivaji University, Maharashtra, India

Specimen collection

Extensive field trips were conducted throughout India for the collection and documentation of Musaceae specimens. The forest areas of North-East India, Uttarakhand, Kerala, Karnataka, Tamil Nadu and Andaman & Nicobar Islands were visited during different seasons from 2015 to 2018. The habitat and habit photographs of the plants including the reproductive and vegetative parts were taken separately during the collection itself. All the field observations including the species' associations were noted. Reproductive and vegetative parts were preserved in Formalin-Acetic acid-Alcohol (FAA) for the preparation of herbarium. In addition, the petiole, midrib and lamina were also preserved in FAA for anatomical studies, pollen grains were preserved in 100% alcohol for palynological studies and mature seeds were stored in small vessels for seed morphological and anatomical studies.

Germplasm conservation of Wild Musaceae

The plant materials (rhizomes and seeds) collected from the natural habitat were introduced into Musaceae germplasm of Calicut University Botanical Garden (CUBG) in order to enrich the existing germplasm for further studies. The rhizomes were directly planted in the germplasm, mature seeds were first sown in the pots, after germination, the seedlings were transplanted into the germplasm. The traditional banana cultivation was adopted for the maintenance and conservation of the germplasm. All accessions collected were properly labelled with standard, metallic T-labels (15 × 5 cm) indicating the details such as name of the taxon, collection number and collection locality.

Herbarium Preparation

The specimens collected from the field were trimmed in to appropriate size, then treated with formaldehyde and sealed in polyethylene covers. Herbaria were prepared following wet method (De Vogel, 1987; Bridson & Forman, 1998). The specimens were dried in oven and were mounted on standard handmade sheets (28 × 42 cm). The sheets were labelled with standard labels (14.5 × 11 cm) and are deposited in CALI.

Morphology

The required samples were collected from the natural populations and also from the different accessions in the Calicut University Botanical Garden. The voucher specimens are deposited in Calicut University herbarium (CALI) Kerala, India. Measurements of plant and floral parts have been made using measuring tape or with a photo scale. The descriptions of all the species were made from live samples as well as preserved herbarium specimens. Photographs were taken with Sony alpha 58 cameras.

The specimens were identified by using articles, Floras, Monographs, Revisions, publications, *etc*. The identity of the taxon was confirmed by comparing with types and protologues.

Vegetative anatomy

Anatomical studies were carried out on fresh as well are preserved specimens. For the investigations, third leaf from the top of the plant after the emergence of inflorescence was taken. From the leaf, middle portion of the petiole, midrib and lamina were selected (Fig. 1 A, B). The epidermal peelings were taken from both the adaxial and abaxial surfaces of the lamina using scalpel. Free hand sections of the vegetative parts were made by using double edge razor. The sections were stained using safranin, and mounted on a clear glass slide using glycerin. Photomicrographs were taken by using Axio Lab.A1 ZEISS AxioCam ERc 5s with 5X to 100X magnifications. To get ground plan of the cross section of petiole and midrib, the sections were viewed under HP Scanjet 4850 scanner.

Stomatal index was determined on the basis of average value obtained from 20 readings from adaxial and abaxial surfaces of the lamina. Stomatal index was calculated by Salisbury's (1927) formula.

$$\text{Stomatal Index} = \frac{\text{Number of stomata}}{\text{Number of stomata+Number of epidermal cells}} \times 100$$

Palynology

Palynological studies were carried out on pollen grains preserved in 100% ethanol. The pollen grains were washed with 70% alcohol and centrifuged at 5000 rpm for 3–5 minutes. The supernatant was removed and the sediments were treated with hexane for 10–15 minutes in-order to remove the chemical coating. Measurements and observations were made using a Leica M80 light microscope. To determine their exine ornamentation, the hexane treated pollen grains were analysed under Scanning Electron Microscope (SEM). Due to the paucity of sufficient palynological studies of

Musaceae, the terminology for the pollen grains was followed by Fortescue and Turner (2004) and Dahlgren *et al*., (1985).

Seed morphology and anatomy

Seeds were collected from the field and also from the herbarium (CALI). The seeds were selected from middle part of the mature fruits from the first inflorescence hand (Fig. 2 C, D), because the seeds taken from the basal and top region possess differences in its shape due to the tight package. The measurements of the seed size including the longitudinal parts were done using Leica M80 stereomicroscope. A total of 15–20 mature seeds were measured in order to determine the average seed size. Longitudinal sections of seeds were subjected to SEM analysis for viewing the detailed structure of seed coat. Seed coat in between chalazal chamber and operculum was taken for measuring the thickness (center of the seed) (Fig. 1 C, D). Barthlott (1981) and Stearn (1992) were followed for the descriptive terminology of seed surface sculpturing. For seed morphology and anatomy, Benedict *et al.* (2015a, b, 2016), Graven *et al.* (1996) and McGahan (1961a) were followed.

For SEM analysis, the specimens (seeds and pollen grains) were placed on aluminum stubs using double-sided adhesive tape and sputter coated with gold using a Hummer VII gold coating apparatus. They were observed and photographed under JEOL Model JSM—6390LV SEM and GeminiSEM 300 with different magnifications.

Figures of various characters (Fig. 2–5) such as epidermal and hypodermal cells characters, vascular bundle types, petiole and midrib (Fig. 2, 3); pollen sculpturing, seed types and sculpturing and seed anatomical features (Fig. 4, 5) are provided for better understanding of individual figures of different taxa.

Statistical analysis

All statistical analyses were done using the SPSS Version 20 software programme. The data obtained were subjected to one way Analysis of Variance (ANOVA) and Duncan's multiple range tests to validate the results. The results were expressed as mean ± Standard error. For the analysis of lamina, pollen and seeds, about 15 to 20 different samples of each were used.

Phenetics

Operational Taxonomic Unit (OTU) (Sneath & Sokal, 1973) of thirty two wild Indian Musaceae for fifty five characters from both vegetative and seed anatomy, palynology and seed micro-morphology were considered for the analysis. This includes 23 vegetative and 32 reproductive (4 pollen and 28 seed) characters that falls under 36 qualitative and 19 quantitative. PAUP* 10^{beta} version software was used for analysis and construction of tree, Unweighed Pair Group Method with Arithmetic Mean (UPGMA) method (Optimum criterian = distance; Branch swapping algorithm – Tree Bisection Reconnection (TBR); Bootstrap = 100) was used. Here the characters were directly converted to codes using different character states. For the analysis, all the 55 characters were plotted against the 32 taxa using character codes and this tabulated data was used for the construction of phenogram.

PRESENTATION OF DATA

The introductory part (chapter 1) begins with the general anatomy of monocotyledons, followed by the characteristics of Zingiberales and finally that of the family Musaceae, and further by objectives and importance of the present study. Second chapter deals with review of literature in the sequence of general anatomy, palynology, seed micro-morphology and anatomy, phylogeny and infrageneric classification of *Musa*. The third chapter deals with area of study, and materials and methods are dealt in the fourth chapter.

Results (Chapter 5) begin with the key to the genera and species based on anatomy, palynology and seed micro-morphological characters. Name of each taxon followed by citation, brief morphological description, detailed vegetative anatomical description (epidermis, lamina, petiole and midrib), pollen morphology, seed morphology (macro & micro) and anatomy, and further by distribution. All the specimens studied were cited as voucher specimens and given in the following sequence: **COUNTRY**, State: **District**, collection locality, date of collection, *collector/collectors name and collection number*, and acronym of the depository is given in parenthesis. A colour plate of each taxon with general habit, inflorescence and vegetative anatomical characters are included in the first figure, followed by pollen morphology, seed morphology, micro-morphology and anatomy in the second figure of each species. The species are presented in alphabetic sequence. A key to the infraspecific taxa is also presented under the respective species.

A comparative vegetative anatomy (epidermis, lamina, petiole and mid rib), pollen morphology, seed morphology (macro & micro) and anatomy of seeds are provided after the results part in sixth chapter along with figures and comparison tables. Seventh chapter deals with Phenetics based on all the studied characters. Those characters and character states are listed in the table (13). Phenogram is constructed based on all the above characters (vegetative anatomy, pollen morphology and seed micro-morphology) and discussed in detail. This is followed by summary (chapter 8), and concluded by reference section. List of articles published in National and International journals and presentations in International symposia/seminars are also listed.

Chapter 5

RESULTS

RESULTS

The members of Musaceae are well known for their various uses as food, ornamental, medicine etc. The present study deals with the wild bananas of India, which are much complicated in their taxonomy. Even in the flowering stage itself the species delimitation is difficult. Apart from the morphological characters, vegetative anatomy, pollen morphology as well as seed micro morphological and anatomical characters play an important role in the delimitation of taxa within Musaceae. The major vegetative characters observed include shape of epidermal cells, number of layers and shape of hypodermal cells, thickness of lamina, shape and attachment of larger vascular bundle, nature of adaxial bundle strand, shape of petiole and distribution of stomata on adaxial and abaxial surfaces. The major pollen characters studied were thickness of intine, exine and type of pollen surface sculpturing. Seed morphological and anatomical characters, which are more stable and reliable include seed shape, seed size, seed body characters (tapering at micropylar or chalazal region) and seed surface sculpturing under light microscopy and scanning electron microscopy, thickness of seed coat and endotesta, tegmen and aleurone layer. One of the unique characters of Musaceae from other members of Zingiberales is the presence of large air canal or parenchymatous transverse septa in the mesophyll.

Key to the genera of the family Musaceae in India based on vegetative anatomy, pollen morphology and seed micro-morphology and anatomy

1. Hylar rim prominent; outer cell wall not separated from the exotesta and not form secondary inner surface; arc I of petiole U-shaped............. ***Ensete***

1. Hylar rim inconspicuous; outer cell wall separated from the exotesta and form a secondary inner surface sculpture; arc I of petiole V or Y-shaped.... .. .. ***Musa***

Key to the species of the genus *Ensete* in India

1. Seed surface sculpturing tuberculate, periclinal wall convex smooth to finely folded.. .... ***E. glaucum***
1. Seed surface sculpturing colliculate, periclinal wall convex, smooth….. .. ..***E. superbum***

1. ***Ensete glaucum*** (Roxb.) Cheesman, Kew Bull. 2(2): 101. 1947.

(Fig. 6, 7)

Rhizomatous, monocarpic, non-stoloniferous, non-suckering herbs. Pseudostem 1–5 m tall, conical with swollen base, pale green to green, glaucous. Leaves arranged at the apex of pseudostem; petiole glaucous, yellowish-green to green. Inflorescence pendulous; female and male bud lanceolate, imbricate; bracts and flowers integral with each other and with axis; bracts green on both surfaces, persistent; flowers arranged in two rows. Infructescence compact with 5–14 hands; fingers perpendicular to the rachis, sessile, straight, faintly ridged, acuminate or blunt at apex with floral relicts, faintly glaucous, green, yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 13.77–15.76 × 19.97–27.86 µm, polygonal, isodiametric to broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded; inter-costal cells 8.23–14.87 × 17.45–42.21 µm, irregularly-polygonal, broader than high, cell wall straight to folded. Abaxial costal cells 11.53–14.42 × 13.51–33.35 µm, polygonal, isodiametric to broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded; inter-costal cells 10.98–16.27 × 12.52–55.23 µm, irregularly-polygonal, broader than high, cell wall straight to folded or wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 28.15–31.58 µm long, abaxial guard cells 25.47–28.05 µm long. Adaxial stomatal index 0.2–2.70, abaxial stomatal index 2.63–6.86.

C.S. of lamina: 470–510 µm thick. Epidermis: adaxial epidermal cells 8–12 × 13–29 µm, rectangular, broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 7–12 × 12–25 µm, rectangular, broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 27–43 × 45–70 µm, hexagonal, broader than high, 3-layered upto both sides of the 2^{nd} smaller vascular bundles, then 2-layered upto next two or three bundles and further 1-layered, cell length reduced adjacent to the smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, outer cells smaller than inner, outer 51–65 × 27–31 µm, polygonal, higher than broad; inner 65–72 × 25–29 µm, polygonal, higher than broad; abaxial hypodermal cells 16–19 × 28–34 µm, hexagonal, broader than high, 2-layered upto both sides of the 2^{nd} smaller vascular bundles and further 1-layered. Mesophyll: 323–361 µm thick, divided in to 2 or rarely 3-layered palisade and 10–13-layered parenchymatous septa (rarely traversed by chlorenchymatous cells) or with air canal; palisade 85–104 µm thick, cells 27–32 × 10–15 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 238–257 µm thick, cells 25–32 × 24–37 µm, chlorenchymatous, circular to ovoid. Larger vascular bundle 440–444 × 279–283 µm, ventricose, attached to either adaxial or both hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled, sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 100–118 × 153–163 µm, 10–14-layered, cells thick-walled with smaller lumen; abaxial bundle sheath 50–53× 112–118 µm, 6–14-layered; protoxylem 2; metaxylem 45–55 µm in diameter, ellipsoid, surrounded by isodiametric, parenchymatous cells; phloem 60–64 × 83–88 μm, 6–8-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to both adaxial and abaxial epidermis, variable in cellular shape and number. Calcium oxalate crystals such as rod-shaped, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial surface U-shaped, abaxial surface wide U-shaped. Abaxial epidermal cells rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, broader than high, 1-layered sclerenchymatous thick-walled with large lumen, followed by 1 or 2-layered collenchyma and further large parenchymatous ground tissue. Air canals larger with one arc of 34–42 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in wide U-shape; Arc II consists of numerous small vascular bundles situated between air canal and abaxial tissues, vascular bundles with well developed fibrous sheaths pectinating with fibrous strands; Arc III consists of small vascular bundles and numerous fibrous bundles.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S. shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 120–130 × 111–131 μm, exine 1.02–2.02 μm thick, intine 5.22–11.25 μm thick, P/E ratio 0.98, oblate-spheroidal, inaperturate with verrucate sculpturing.

Seed morphology and anatomy

Seeds ovoid, 5.50–7.00 × 6.50–8.75 mm, non-arillate, smooth, black. Seed shape contorted by tight packing in fruits, seed body flat at micropyle, rarely minutely notched at chalazal region, hilar rim prominent. Micropylar region conical, micropylar plug 2.00–2.75 mm diameter at top, operculum apical.

Outer surface tuberculate, tubercles sparsely arranged, connected to each other with several fine thread-like reticulate tissues, cells irregularly-polygonal; periclinal wall convex, smooth to finely-folded; Anticlinal wall shallow, straight to wavy, smooth to folded, unevenly thickened. Seed coat 326.48–383.93 µm thick, 42–48-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 39.82–46.03 µm thick, 1-layered, cells U-shaped; tegmen 35.11–37.49 µm thick, 2-layered, cells elongate, spongy; aleurone or inner endosperm layer 10.70–11.58 µm thick. Micropylar mesotestal proliferation 1051.57–1166.20 µm thick; micropylar collar 1284.35–1357.98 µm, straight. Chalazal chamber 1.10–1.60 × 2.55–3.00 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 703.40–794.46 µm thick. Chalazal mucro and chalazal chamber column absent. Embryo base bulbous.

Distribution*:* China, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland & Tripura), Indonesia, Laos, Myanmar, Philippines, Papua New Guinea and Thailand.

Voucher specimens: **INDIA, Kerala:** Malappuram District, Calicut University Botanical Garden (Cultivated), 25 January 2014, *A. Joe & M. Sabu 130897* (CALI); **Meghalaya,** West Garo Hills, Tura Peak, 02 June 2017, *V.S. Hareesh 152715* (CALI).

2. ***Ensete superbum*** (Roxb.) Cheesman**,** Kew Bull. 2(2): 100. 1947.

(Fig. 8, 9)

Rhizomatous, monocarpic, non-suckering, non-stoloniferous herbs. Pseudostem 1–4 m tall, conical with swollen base. Leaves arranged from middle towards the apex of pseudostem; petiole faintly glaucous, green or yellow-green. Inflorescence pendulous to sub-horizontal; female and male bud lanceolate, imbricate, bracts and flowers integral with each other and with axis; flowers arranged in two rows. Infructescence compact with 3–14 hands; fingers perpendicular to the rachis, pedicellate, straight, minutely ridged, slightly pointed at apex with floral relicts, green, faintly glaucous, yellow when ripe.

Vegetative anatomy

Epidermis: Adaxial costal cells 20.64–23.98 × 27.29–38.34 µm, polygonal, isodiametric to broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded or wavy; inter-costal cells 14.6–28.7 × 22.2–50.56 µm, irregularly-polygonal, broader than high, cell wall straight to folded or wavy. Abaxial costal cells 21.23–24.53 × 23.6–64.16 µm, polygonal, isodiametric to broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 13.51–24.28 × 16.29–42.68 µm, irregularly-polygonal, broader than high, cell wall straight to folded or slightly wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 30.35–34.6 µm long, abaxial guard cells 25.38–29.36 µm long. Adaxial stomatal index 2.17–3.84 , abaxial stomatal index 6.89–10.60.

C.S. of lamina: 389–508 µm thick. Epidermis: adaxial epidermal cells 8–14 × 13–23 µm, rectangular, broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–8 × 10–24 µm, rectangular, broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 43–64 × 50–62 µm, hexagonal, isodiametric to broader than high, 2-layered upto both sides of the 2nd or 3rd smaller vascular bundles, and further 2-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, upper larger than lower, 9–28 × 15–34 µm, hexagonal, broader than high, lower 8–15 × 11–18 µm, hexagonal, isodiametric; abaxial hypodermis 20–63 × 13–16 µm, hexagonal, higher than broad, 1-layered. Mesophyll 250–352 µm thick, divided in to 2 or 3-layered palisade and 7–10-layered parenchymatous septa or with air canal, traversed by chlorenchymatous cells; palisade 85–117 µm thick, cells 47–60 × 9–12 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 186–235 µm thick, cells 16–34 × 23–102 µm, irregularly-shaped, traversed by chlorenchymatous cells. Larger vascular bundle 422–428 × 225–233 µm, ventricose, attached to the adaxial and abaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 88–95 × 149–158 µm, 5–7-layered, cells thick-walled with smaller lumen; abaxial bundle sheath 26–29 × 38–46 µm, 4 or 5-layered; protoxylem 2 or 3; metaxylem 44–55 µm in diameter, circular to ellipsoid, surrounded by smaller isodiametric parenchymatous cells; phloem 30–36 × 25–28 µm, 5 or 6-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to both adaxial and abaxial epidermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shaped, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial surface U-shaped, abaxial surface wide U-shaped. Abaxial epidermal cells rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, broader than high, 1 or 2-layered sclerenchyma, followed by 2 or 3-layered collenchymatous cells and further large parenchymatous ground tissue. Air canals larger with one arc of 36–40 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal arranged wide U-shape; Arc II consists of numerous small vascular bundles situated between air canal and abaxial tissues, vascular bundles with well developed fibrous sheaths pectinating with fibrous strands; Arc III consists of small vascular bundles and numerous fibrous bundles.

C.S. of mid rib: Adaxial surface U-shaped, abaxial surface wide U-shaped. C.S. shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 120–141 × 111–136 µm, exine 1.00–2.59 µm thick, intine 5.00–10.67 µm thick, P/E ratio 1.02, prolate-spheroidal, inaperturate with verrucate sculpturing.

Seed morphology and anatomy

Seeds ovoid, 5.33–7.31 × 5.97–8.50 mm, non-non-arillate, smooth, black. Seed shape contorted by tight packing in fruits, seed body flat at micropyle and chalazal region, rarely notched at the centre of chalazal region, hilar rim prominent. Micropylar region conical, micropylar plug 2.51–3.33 mm diameter at top, operculum apical.

Outer surface colliculate, sparsely arranged connected to each other with reticulate tissues, cells irregularly-polygonal; periclinal wall convex, smooth; anticlinal wall shallow, straight to wavy, smooth to slightly-folded, unevenly thickened.

Seed coat 245.29–315.98 µm thick, 30–38-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 12.62–13.78 µm thick, 1-layered, cells U-shaped; tegmen 2.41–4.83 µm thick, 2-layered, cells elongate, spongy; aleurone or inner endosperm layer 7.51–8.23 µm thick. Micropylar mesotestal proliferation 758.04–934.34 µm thick; micropylar collar 1347.23–1450.33 µm long, straight. Chalazal chamber 1.10–1.50 × 2.70–3.60 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 689.31–751.03 µm thick. Chalazal mucro and chalazal chamber column absent. Embryo base bulbous.

Distribution*:* India (Peninsular India), Myanmar, Thailand and Vietnam.

Voucher specimens: **INDIA, Kerala:** Malappuram District, Calicut University Botanical Garden (Cultivated), Near West Gate, 15 September 2012, *A. Joe & M. Sabu 130896* (CALI); Malappuram District, Calicut University Botanical Garden (Cultivated), Near West Gate, 18 July 2013, *A. Joe & M.Sabu 121683* (CALI); Kozhikode District, Kakkayam, 14 July 2018, *V.S. Hareesh 143995* (CALI).

Key to the species of the genus *Musa* in India

1. Adaxial and abaxial hypodermis one-layered.. **2**
1. Adaxial hypodermis 2, 3, or 4-layered **5**
2. Adaxial hypodermal cells above the larger vascular bundles irregular……. .. ..***M. cylindrica***
2. Adaxial hypodermal cells above the larger vascular bundles hexagonal.. .. .. **3**
3. Adaxial hypodermal cells above larger vascular bundle broader than high .. .. ***M. rubra***
3. Adaxial hypodermal cells above larger vascular bundle isodiametric....... .**4**
4. Seed body tapering at micropylar region .... ***M. sikkimensis***
4. Seed body not tapering at micropylar region ....***M. velutina***
5. Hypodermal cells 4-layered adaxially .... ***M. sabuana***
5. Hypodermal cells 2 or 3-layered adaxially **6**
6. Adaxial hypodermal cells 2-layered **7**
6. Adaxial hypodermal cells 3-layered **17**
7. Larger vascular bundle of lamina elliptic ....***M. nagensium***
7. Larger vascular bundle of lamina ovate, ventricose, ovate-ventricose or obovate-ventricose… **8**
8. Larger vascular bundle of lamina ventricose .... ***M. thomsonii***
8. Larger vascular bundle of lamina ovate, ovate-ventricose or obovate-ventricose….. .**9**

9. Attachment of larger vascular bundles of lamina on both adaxial and abaxial hypodermis.. ***M. markkuana***

9. Attachment larger vascular bundles of lamina on adaxial hypodermis only ……... **10**

10. Smaller vascular bundles suspended in the mesophyll or rarely attached to abaxial hypodermis .... ***M. ornata***

10. Smaller vascular bundles attached to adaxial or abaxial hypodermis…… … **11**

11. Seeds ellipsoid in shape .... ***M. ochracea***

11. Seeds oblate in shape **12**

12. Inner periclinal wall of seed surface deeply folded .... ***M. mannii***

12. Inner periclinal wall of seed surface with multi-angular silica body........ **13**

13. Outer sculpturing of seed reticulate-foveate .... ***M. pradhanii***

13. Outer sculpturing of seed alveolate, reticulate or slightly reticulate-colliculate **14**

14. Pollen sculpturing verrucate .... ***M. itinerans***

14. Pollen sculpturing rugulate **15**

15. Inner and outer anticlinal wall of seed surface shallow; outer periclinal wall convex... ***M. argentii***

15. Inner and outer anticlinal wall of seed surface raised; outer periclinal wall concave **16**

16. Seed outer sculpturing alveolate .... ***M. aurantiaca***

16. Seed outer sculpturing reticulate...***M. acuminata***

17. Seed shape sub-globose **18**

17. Seed shape oblate **19**

18. Chalazal chamber column in seeds prominent .... ***M. balbisiana***

18. Chalazal chamber column in seeds absent ....***M. cheesmanii***

19. Pollen with verrucate sculpturing .... ***M. markkui***

19. Pollen with rugulate sculpturing **20**

20. Seed coat thickness 735 µm and above .... ***M. puspanjaliae***

20. Seed coat thickness 178–290 µm **21**

21. Adaxial guard cells smaller than abaxial cells ....***M. chunii***

21. Adaxial guard cells larger than abaxial cells **22**

22. Larger vascular bundle of lamina obovate .... ***M. flaviflora***

22. Larger vascular bundle of lamina ovate **23**

23. Adaxial costal cells polygonal in shape; intercostals cells irregularly polygonal... ***M. arunachalensis***

23. Adaxial costal cells rectangular in shape; intercostals cells rectangular…… .. .. ***M. kattuvazhana***

1. *Musa acuminata* Colla**,** Mem. Reale Accad. Sci. Torino 25: 394. 1820.

(Fig. 10, 11)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 1–2.5 m tall, cylindrical. Leaves arranged terminally; petioles 30–65 cm long, moderate to abundantly glaucous, green or yellow green. Inflorescence horizontal, then bending downwards; female and male bud lanceolate, convolute; bracts and flowers inserted separately on the axis; bracts reflexed, revolute before falling, faintly glaucous, brownish-purple to pinkish-purple with or without yellow-green lines, adaxially, red-purple to pale yellow abaxially; flowers arranged in two rows. Infructescence lax with 3–7 hands; fingers pedicellate, pointed upwards, straight or curved, slightly ridged, pointed at apex without floral relicts, glabrous, green, greenish yellow or pale yellow to yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 9.31–11.08 × 6.71–27.47 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 7.64–18.8 × 12.96–43.88 µm, rectangular, broader than high, cell wall straight to wavy. Abaxial costal cells 8.32–11.71 × 9.75–32.97 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous; inter-costal cells 8–14 × 10.61–37.83 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 21.13–23.14 µm long, abaxial guard cells 17.96–20.31 µm long. Adaxial stomatal index 0.00–2.20, abaxial stomatal index 7.54–12.37.

C.S. of lamina: 235–327 µm thick. Epidermis: adaxial epidermal cells 6–9 × 6–19 µm, rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle. Epidermis: abaxial epidermal cells 5–8 × 10–24 µm, hexagonal, papillose, 1-layered. Hypodermis: adaxial hypodermal cells 26–52 × 32–88 µm, rectangular, isodiametric to broader than high, 2-layered upto both sides of the 4th smaller vascular bundles, and further 1-layered, cells uniform in size and shape adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 7–18 × 8–19 µm, irregular, broader than high; abaxial hypodermal cells 5–9 × 10–22 µm, rectangular, broader than high, 2-layered. Mesophyll 135–177 µm thick, divided in to 2-layered palisade and 4 or 5-layered parenchymatous septa, traversed by chlorenchymatous cells; palisade 63–90 µm thick, cells 37–45 × 5–7 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 65–98 µm thick, cells 10–30 × 28–70 µm, irregularly-shaped, sinuous, chlorenchymatous. Larger vascular bundle 245–260 × 151–174 µm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 55–60 × 139–146 µm, 5 or 6-layered, cells thick-walled with smaller lumen; abaxial bundle sheath 17–22 × 73–84 µm, 2 or 3-layered, cells thick-walled with smaller lumen; protoxylem 1–3; metaxylem 43–50 µm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 38–43 × 50–58 µm, 6–9-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial hypodermis, rarely attached to both, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shaped, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial surface U-shaped, abaxial surface U-shaped. Abaxial epidermal cells rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; hypodermal cells isodiametric to broader than high, 1-layered, sclerenchymatous, cells thick-walled with smaller lumen, followed by 2 or 3-layered collenchymatous cells and further large parenchymatous ground tissue. Air canals larger with one arc of 25–30 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of numerous small vascular bundles situated between air canal and abaxial tissues, vascular bundles with well developed fibrous sheaths pectinating with fibrous strands; Arc III consists of small vascular bundles and numerous fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 96–102 × 95–136 μm, exine 0.02–2.12 μm thick, intine 3.33–5.14 μm thick, P/E ratio 1.01, prolate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 2.69–4.56 × 4.06–6.29 mm, non-non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, flat at chalazal region, hilar rim

inconspicous. Micropylar region conical, micropylar plug 1.30–1.91 mm diameter at top, operculum apical.

Outer surface reticulate, cells irregularly-polygonal; periclinal wall slightly concave or slightly concave with centre tubercle, warty; anticlinal wall raised, straight, smooth to finely-folded, unevenly thickened. Inner surface reticulate, prominently raised, straight, smooth to slightly-folded, unevenly thickened; periclinal wall slightly concave with multi-angular silica body at centre, warty; anticlinal wall prominently raised, straight, smooth to folded, unevenly thickened.

Seed coat 206.58–277.36 µm thick, 10–25-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 15.20–16.77 µm thick, 1-layered, cells U-shaped; tegmen 16.67–18.80 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 12.54–13.64 µm thick. Micropylar mesotestal proliferation 342.78–444.29 µm thick; micropylar collar 639.17–730.17 µm long, straight. Chalazal chamber 0.70–0.90 × 2.00–2.35 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 527.70–589.90 µm thick. Chalazal mucro absent, chalazal chamber column intermediate. Embryo base bulbous.

Distribution*:* China, India (Northeastern states), Java, Malaya, Myanmar and Thailand.

Voucher specimens: **INDIA, Arunachal Pradesh:** East Siang District, Pasighat, near Mebo, Siluk, 17 May 2016, *V.S. Hareesh 149311* (CALI); Jaintia Hills, Way to Dawki from Jowai (between Amlarem & Dawki), 31 May 2011, *A. Joe & P.E. Sreejith 116174* (CALI).

2. *Musa argentii* Gogoi & Borah, Edinburgh J. Bot. 71(2): 182. 2014.

(Fig. 12, 13)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 1.5–2.5 m tall, cylindrical, slender. Leaves arranged terminally, intermediate; petiole 50–120 cm long, glabrous, green or dark pinkish-red. Inflorescence pendulous; female and male bud lanceolate, convolute; bracts and flowers inserted separately on the axis; bracts non-revolute, glabrous, pink adaxially, glabrous, pinkish-red abaxially; flowers arranged in two rows. Infructescence compact with 5–11 hands; fingers pedicellate, straight or curved, slightly ridged, glabrous; pedicel 1–1.2 cm long, acute to truncate at apex without floral relicts, glabrous, greenish-pink.

Vegetative anatomy

Epidermis: Adaxial costal cells 10.79–17.85 × 19.83–27.08 µm, polygonal, isodiametric to broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded; inter-costal cells 10.58–22.24 × 20.17–57.32 µm, irregularly-polygonal, broader than high, cell wall straight to folded or wavy. Abaxial costal cells 10.41–12.19 × 18.32–37.12 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall sinuous; inter-costal cells 8.76–15.89 × 24.56–57.14 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall sinuous.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 27.05–29.84 µm long, abaxial guard cells 24.41–26.03 µm long. Adaxial stomatal index 0.00–2.85, abaxial stomatal index 5.40–14.06.

C.S. of lamina: 330–410 μm thick. Epidermis: adaxial epidermal cells 6–11 × 10–17 μm, hexagonal, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–8 × 8–21 μm, hexagonal, papillose, broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 23–63 × 27–72 μm, hexagonal, broader than high, 2-layered upto both sides of the 3rd or 4th smaller vascular bundles, and further 1-layered, cell length reduced in length adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 7–14 × 17–24 μm, hexagonal, broader than high; abaxial hypodermal cells 13–19 × 24–47 μm, rectangular, broader than high, 2-layered upto 3rd or 4th smaller vascular bundles, further and 1-layered; hypodermis below the larger vascular bundle 1-layered. Mesophyll 223–287 μm thick, divided in to 2-layered palisade and 5 or 6-layered parenchymatous septa or with air canal, traversed by few layers of chlorenchyma abaxially; palisade 82–124 μm thick, cells 38–47 × 9–12 μm, barrel-shaped, chlorenchymatous; parenchymatous septa 140–152 μm thick, cells 27–40 × 50–89 μm, broader than high. Larger vascular bundle 335–342 × 187–200 μm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2 or 3-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 85–112 × 150–158 μm, 5–7-layered, cells thick-walled with smaller lumen; abaxial bundle sheath 22–28 × 70–104 μm, 3-layered, cells thick-walled with smaller lumen; protoxylem 2 or 3; metaxylem 48–54 μm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 38–50 × 70–77 μm, 5–7-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped. Abaxial epidermal cells rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; hypodermal cells isodiametric to broader than high, 1 or 2-layered, sclerenchyma, cells thick-walled with smaller lumen, followed by 2 or 3-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 25–30 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in Y-shape; Arc II consists of numerous small vascular bundles situated between air canal and abaxial tissues, vascular bundles with well developed fibrous sheaths pectinating with fibrous strands; Arc III consists of comparatively fewer small vascular bundles and fibrous bundles situated adjacent to adaxial surface .

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 96–116 × 102–116 µm, exine 0.76–1.86 µm thick, intine 3.92–7.06 µm thick, P/E ratio 0.97, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 1.69–2.50 × 5.13–6.25 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body flat in micropyle, slightly taper in chalazal region, hilar rim

inconspicous. Micropylar region conical, micropylar plug 1.60–2.00 mm diameter at top, operculum apical.

Outer surface slightly reticulate-colliculate, cells irregularly-polygonal; periclinal wall convex, smooth; anticlinal wall shallow, straight, smooth to slightly-folded, unevenly thickened. Inner surface reticulate; periclinal wall slightly concave with multi-angular silica body at centre, smooth; anticlinal wall shallow, straight, sinuous, unevenly thickened.

Seed coat 163.31–240.45 µm thick, 18–21-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 5.78–6.22µm thick, 1-layered, cells U-shaped; tegmen 2.42–2.88µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 2.10–2.32 µm thick. Micropylar mesotestal proliferation 399.88–509.37 µm thick; micropylar collar 1003.91–1067.79 µm long, weakly curved. Chalazal chamber 0.70–0.88 × 2.25–2.58 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 423.25–477.52 µm thick. Chalazal mucro intermediate, chalazal chamber column absent. Embryo base bulbous.

Distribution*:* Endemic to Northeastern India (Arunachal Pradesh).

Voucher specimens*:* **INDIA, Arunachal Pradesh:** Namsai District, 5 km away from Wakro towards Namsai, 15 May 2017, *M. Sabu & V.S. Hareesh 149351* (CALI); Lower Dibang Valley District, Roing, Iduli, 04 July 2015, *A. Joe & V.S. Hareesh 121885* (CALI).

3. *Musa arunachalensis* A.Joe, Sreejith & M.Sabu, Phytotaxa 134(1): 50. 2013.

Musa kamengensis Gogoi & Hakkinen, Acta Phytotax. Geobot. 64(3): 149.2013.

(Fig. 14, 15)

Rhizomatous, stoloniferous, clump-forming, suckering herbs. Pseudostem 1–3 m tall, cylindrical. Leaves arranged terminaly; petioles 25–40 cm long, glabrous, green. Inflorescence erect, then bending, arch-shaped; female and male buds lanceolate, convolute, bracts and flowers inserted seperately on the axis; bracts glabrous, reddish-orange adaxially and yellow-orange abaxially, reflexed, deciduous; flowers arranged in a single row. Infructescence lax or compact, 2–6 hands; fingers pedicellate, pointed upwards, straight, prominently ridged, pointed at apex, glabrous, green, yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 12.16–17.45 × 18.55–35.60 µm, polygonal, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded; inter-costal cells 9.47–27.71 × 11.02–40.40 µm, irregularly-polygonal, isodiametric to broader than high, cell wall straight to folded. Abaxial costal cells 11.97–13.67 × 29.71–46.10 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall sinuous; inter-costal cells 12.41–19.73 × 16.80–49.25 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 27.54–30.62 μm long, abaxial guard cells 26.34–29.69 μm long. Adaxial stomatal index 0.00–0.51, abaxial stomatal index 3.33–10.37.

C.S. of lamina: 512–554 μm thick. Epidermis: adaxial epidermal cells 5–14 × 9–19 μm, rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 6–8 × 9–23 μm, papillose, irregularly-shaped, 1-layered. Hypodermis: adaxial hypodermal cells 42–65 × 33–55 μm, hexagonal, broader than high, 3-layered upto both sides of the 3rd smaller vascular bundles, and further 2-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, outer slightly larger than inner, 16–25 × 15.73–24, hexagonal, isodiametric; inner 15.34–20.64 × 11–22 μm, hexagonal, broader than high; abaxial hypodermis 9–13 × 14–38 μm, hexagonal, broader than high, 2-layered. Mesophyll 341–364 μm thick, divided in to 2-layered palisade and 7–10-layered parenchymatous septa or with air canal, occasionally traversed by few 2 or 3-layered clorenchyma below the vascular bundle; palisade 85–109 μm thick, cells 34–42 × 8–11 μm, barrel-shaped, chlorenchymatous; parenchymatous septa 75–99 μm thick, cells irregular. Larger vascular bundle 465–470 × 186–213 μm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 140–152 × 143–150 μm, 7 or 10-layered, cells thick-walled with smaller lumen; abaxial bundle sheath 80–120 × 67–83 μm, 2–4-layered, cells thick-walled with smaller lumen; protoxylem 1; metaxylem 76–87 μm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 40–63 × 60–67 μm, 12–18-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to both adaxial and abaxial or adaxial hypodermis only, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped. Abaxial epidermal cells rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; hypodermal cells isodiametric to broader than high, 1 or 2-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 2 or 3-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 24–28 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in wide V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands situated between air canal and abaxial tissues; Arc III consists of comparatively fewer small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals.

Pollen morphology

Pollen 112–122 × 105–123 µm, exine 0.87–2.10 µm thick, intine 4.30–10.98 µm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 3.39–4.30 × 4.50–7.00 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 2.00–2.45 mm diameter at top, operculum apical.

Outer surface slightly reticulate-colliculate, cells irregularly-polygonal; periclinal wall slightly concave, smooth; anticlinal wall shallow, straight, smooth, unevenly thickened. Inner surface reticulate; periclinal wall lightly concave, with multi-angular silica body at centre, smooth; anticlinal wall prominently raised, straight, smooth to folded, unevenly thickened.

Seed coat 247.62–290.48 µm thick, 28–32-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 12.83–13.75 µm thick, 1-layered, cells U-shaped; tegmen 20.76–22.29 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 11.61–12.07µm thick. Micropylar mesotestal proliferation 463.86–558.48 µm thick; micropylar collar 908.57–990.95 µm long, straight. Chalazal chamber 0.65–0.85 × 2.88–3.33 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 527.70–589.90 µm thick. Chalazal mucro present, chalazal chamber column intermediate. Embryo base bulbous.

***Distribution**:* Endemic to Northeastern India (Arunachal Pradesh).

***Voucher specimens**:* **INDIA, Arunachal Pradesh:** West Kameng district, Durga Mandir, 30 June 2015, *A. Joe & V.S. Hareesh 121843* (CALI); *ibid,* 30 May 2017, *V.S. Hareesh 152694* (CALI); Papum Pare District, way to Pareng from Sagalee, Apop, 27 May 2017, *V.S. Hareesh 152673* (CALI).

4. *Musa aurantiaca* G.Mann *ex* Baker, Ann. Bot. 7(26). 222. 1893.

Musa aurantiaca var. *homenborgohainiana* Gogoi, Nordic J. Bot. 32(6): 702. 2014.

Musa aurantiaca var. *jengingensis* Gogoi, Nordic J. Bot. 32(6): 702. 2014.

(Fig. 16, 17)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 0.7–2.5 m tall, slender, cylindrical. Leaves arranged terminaly; petiole 40–80 cm long, glabrous, green or green with red tinge. Inflorescence erect; female and male bud lanceolate, convolute or imbricate at apex, bracts and flowers inserted separately on the axis; bracts reflexed, revolute, deciduous, glabrous, bright orange on both sides; flowers arranged in a single row. Infructescence compact, hands 0–13; fingers pedicillate, straight, pointed upwards, minutely pointed at apex, green, greenish yellow or pale yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 15.46–19.30 × 22.87–34.53 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly wavy; inter-costal cells 12.55–20.82 × 21.31–55.42 µm, rectangular, broader than high, cell wall straight to folded or wavy. Abaxial costal cells 10.03–12.75 × 21.21–34.91 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous; inter-costal cells 11.73–17.96 × 20.16–52.31 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells

26.59–28.49 µm long, abaxial guard cells 23.56–26.00 µm long. Adaxial stomatal index 0.00–3.57, abaxial stomatal index 5.71–15.10.

C.S. of lamina: 258–315 µm thick. Epidermis: adaxial epidermal cells 8–13 × 12–22 µm, rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–10 × 8–28 µm, rectangular, isodiametric to broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 28–52 × 30–78 µm, rectangular, isodiametric to broader than high, 2-layered upto both sides of the 1st smaller vascular bundles, and further 1-layered, cells uniform in size and shape adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 20–31 × 10–19 µm, hexagonal, higher than broad; abaxial hypodermal cells 14–25 × 25–37 µm, rectangular, broader than high, 1-layered. Mesophyll 168–206 µm thick, divided in to 2-layered palisade and 6–8-layered parenchymatous septa, traversed by 2 or 3-layered chlorenchymatous cell near the vascular bundle abaxially; palisade 65–72 µm thick, cells 35–44 × 9–11 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 103–144 µm thick, cells 15–28 × 39–72 µm, rectangular. Larger vascular bundle 235–250 × 163–175 µm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2 or 3-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 55–79 × 98–107 µm, 5 or 6-layered, cells thick-walled with smaller lumen; abaxial bundle sheath 21–25 × 73–96 µm, 3 or 4-layered; protoxylem 1 or 2; metaxylem 32–35 µm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 60–84 × 58–61 µm, 8–13-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial hypodermis only, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shaped, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; abaxial epidermal cells rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; hypodermal cells isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 1 or 2-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 17–22 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in wide V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface wide V-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 100–119 × 112–118 µm, exine 2.50–4.30 µm thick, intine 8.12–13.50 µm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 2.69–4.56 × 4.06–6.29 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body flat at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 0.80–1.25 mm diameter at top, operculum apical.

Outer surface alveolate, cells irregularly-polygonal; periclinal wall slightly concave, smooth; anticlinal wall slightly raised, straight, smooth to slightly-folded, unevenly thickened. Inner surface reticulate; periclinal wall slightly concave, with multi-angular silica body at centre, smooth; anticlinal wall prominently raised, straight, smooth to folded, unevenly thickened.

Seed coat 129.29–184.63 µm thick, 22–25-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 5.64–6.19 µm thick, 1-layered, cells U-shaped; tegmen 2.04–2.25 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 1.26–1.54 µm thick. Micropylar mesotestal proliferation 186.03–244.07 µm thick; micropylar collar 583.98–667.14 µm long, straight. Chalazal chamber 0.65–0.75 × 2.10–2.40 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 317.08–348.85 µm thick. Chalazal mucro and chalazal chamber column absent. Embryo base bulbous.

Distribution: India (Assam, Arunachal Pradesh and Nagaland) and Tibet.

Voucher specimens: **INDIA, Arunachal Pradesh**: Upper Siang District, near Mariang, on the way to Jenging from Pasighat, 12 July 2015, *A. Joe & V.S. Hareesh 121980* (CALI); way to Jengging from Yinkiong, Karko, 20 May 2016, *V.S. Hareesh 149314* (CALI); Jengging, 20 May 2016, *V.S. Hareesh 149317* (CALI); Tirap District, Khonsa, Khetti Village, 31 May 2016, *V.S. Hareesh 149343* (CALI); Dibang Valley District, way to Anini from Hunli, Punli, 19 May 2017, *M. Sabu & V.S. Hareesh 152630* (CALI).

5. ***Musa balbisiana*** Colla, Mem. Reale Accad. Sci. Torino 25: 384. 1820

(Fig. 18, 19)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 3–4.5 m tall, cylindrical. Leaves arranged terminally, intermediate; petioles 30–65 cm long, slightly glaucous, green or yellow green to pale yellow. Inflorescence sub-horizontal; female and male bud lanceolate, convolute, rarely imbricate in male bud; bracts and flowers inserted separately on the axis; bracts reflexed before falling, non-revolute, faintly glaucous, pink-purple, adaxially, reddish-purple abaxially; flowers arranged in two rows. Infructescence compact with 3–10 hands; fingers pedicellate, pointed upwards straight or curved, prominently ridged, 4-angled, minutely pointed at apex without any floral relicts, slightly glaucous, green, yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 10.24–11.68 × 22.71–43.80 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 9.26–13.54 × 22.13–41.24 µm, rectangular, broader than high, cell wall straight to slightly wavy. Abaxial costal cells 10.13–19.25 × 22.94–40.09 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 13.52–17.84 × 24.17–54.21 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded or wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 24.39–26.73 µm long, abaxial guard cells 20.66–22.36 µm long. Adaxial stomatal index 0.00–1.96, abaxial stomatal index 5.88–14.28.

C.S. of lamina: 237–321 µm thick. Epidermis: adaxial epidermal cells 11–14 × 6–11 µm, rectangular, isodiametric to higher than broad, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–13 × 8–15 µm, papillose, irregularly-shaped, 1-layered. Hypodermis: adaxial hypodermal cells 17–29 × 30–60 µm, hexagonal, broader than high, 3-layered upto both sides of the 1st smaller vascular bundles, and further 2-layered, cells uniform in size and shape adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, upper larger than lower, 17–23 × 23–33 µm, hexagonal, broader than high; lower 9–12 × 11–22 µm, hexagonal, broader than high; abaxial hypodermal cells 9–13 × 15–44 µm, hexagonal, broader than high, 2-layered. Mesophyll 167–223 µm thick, divided in to 2 or 3-layered palisade and 7–9-layered parenchymatous septa or with air canal, traversed by 2–4-layered chlorenchymatous cell near the vascular bundle abaxially; palisade 94–101 µm thick, cells 28–43 × 7–8 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 94–101 µm thick, cells 10–18 × 28–51 µm, broader than high. Larger vascular bundle 250–257 × 150–156 µm, obovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 1 or 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 54–73 × 118–131 µm, 5 or 6-layered, cells thick-walled with smaller lumen; abaxial bundle sheath 15–22× 57–73 µm, 2 or 3-layered, , cells thick-walled with smaller lumen; protoxylem 1 or 2; metaxylem 29–46 µm in diameter, ellipsoid or circular, surrounded by smaller isodiametric parenchymatous cells; phloem 33–47 × 37–47 µm, 6–8-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to either adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wing nearly closed. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells hexagonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 4 or 5-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 25–30 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in wide Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 116–121 × 112–121 μm, exine 1.85–3.40 μm thick, intine 5.77–8.17 μm thick, P/E ratio 1.01, prolate-spheroidal, inaperturate with verrucate sculpturing.

Seed morphology and anatomy

Seeds sub-globose, 4.50–5.25 × 5.00–6.50 mm, non-arillate, verrucate, black, turned to dull black to brown when dry. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, curved at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.75–2.00 mm diameter at top, operculum apical.

Outer surface reticulate-foveate, cells irregularly-polygonal; periclinal wall prominently concave, warty; anticlinal wall raised, straight, smooth to slightly-folded, unevenly thickened. Inner surface reticulate-foveate; periclinal wall prominently concave, striate, striations warty; anticlinal wall prominently raised, straight, smooth to slightly-folded, unevenly thickened.

Seed coat 238.95–294.75µm thick, 24–29-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 8.84–9.94 µm thick, 1-layered, cells U-shaped; tegmen 5.30–8.79 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 7.68–8.58 µm thick. Micropylar mesotestal proliferation 531.81–633.24 µm thick; micropylar collar 962.14–1039.14 µm long, straight. Chalazal chamber 1.45–1.78 × 2.35–3.80 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 429.67–533.71 µm thick. Chalazal mucro absent, chalazal chamber column prominent. Embryo base bulbous.

Distribution: Widely distributed in South and South-East Asia. In India this taxon is common in Northeastern States and Eastern Ghats.

***Voucher specimens**:* **INDIA, Andhra Pradesh:** Arakku Valley, Mallidongur Hills, 11 December 2011, *A. Joe & P.E. Sreejith 130746* (CALI); **Odisha:** Kandhamal District, Guduguda, Thumudibandha, 07 October 2011, *A. Joe & P.E. Sreejith 130742* (CALI).

Key to the infraspecific taxa of *Musa balbisiana* in India

1. Pollen verrucate **2**

1. Pollen regulate **3**

2. Vascular bundle obovate.............................. ***M. balbisiana* var. *balbisiana***

2. Vascular bundle elliptic. .... ***M. balbisiana* var. *andamanica***

3. Adaxial hypodermal cells above larger vascular bundle 2-layered, larger vascular bundle elliptic, endotesta thickness below 10 µm **4**

3. Adaxial hypodermal cells above larger vascular bundle 1-layered, larger vascular bundle ventricose, endotesta thickness more than 10.01 µm …... ….. ....***M. balbisiana* var. *elavazhai***

4. Abaxial hypodermal cells rectangular, outer hypodermal cell above larger vascular bundle broader than high.............***M. balbisiana* var. *bheem-kola***

4. Abaxial hypodermal cells hexagonal, outer hypodermal cell above larger vascular bundle isodiametric..................... ***M. balbisiana* var. *sepa-athiya***

5.1. *Musa balbisiana* Colla var. ***andamanica*** D.B.Singh, Sreek., T.V.R.S.Sharma & A.K.Bandyop, Malayan Nat. J. 52(3–4): 157. 1998.

Musa paramjitiana L.J. Singh, Nordic J. Bot. 35: 77. 2017

(Fig. 20, 21)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 4–4.5 m tall, cylindrical, glaucous, dull green, greenish-black towards base and greenish towards apex. Leaves arranged terminally, intermediate; petiole 40–65 cm long, yellowish green, slightly glaucous. Inflorescence pendulous, then horizontal upto fruit bearing part; female bud lanceolate, imbricate; male bud lanceolate or top-shaped in advanced blooming, convolute or slightly imbricate at apex; bracts and flowers inserted separately on the axis; bracts open and reflexed before falling, non-revolute, glabrous, pink-purple adaxially, faintly glaucous, red-purple abaxially; flowers arranged in two rows. Infructescence compact with 3–10 hands; fingers pedicellate pointed upwards straight, prominently ridged, apex blunt without floral relicts, slightly glaucous, green, pale yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 8–14.26 × 32.55–50.25 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly wavy; inter-costal cells 7.44–12.52 × 32.73–54.99 µm, rectangular, broader than high, cell wall straight to folded or wavy. Abaxial costal cells 15.20–20.15 × 26.61–46.91 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 10.64–18.85 × 22.57–78.24 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 25.67–27.32 µm long, abaxial guard cells 21.02–22.63 µm long. Adaxial stomatal index 1.23–2.17, abaxial stomatal index 9.61–13.95.

C.S. of lamina: 313–365 µm thick. Epidermis: adaxial epidermal cells 9–15 × 7–11 µm, rectangular, isodiametric, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–13 × 6–23 µm, papillose, irregularly-shaped, 1-layered. Hypodermis: adaxial hypodermal cells 19–35 × 40–66 µm, hexagonal, broader than high, 2-layered upto both sides of the 5^{th} or 6^{th} smaller vascular bundles, and further 1-layered, cells uniform in size and shape adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, outer larger than inner; outer 10–13 × 18–41 µm, hexagonal, broader than high; inner 8–10 × 14–17 µm, hexagonal, broader than high; abaxial hypodermal cells 7–13 × 17–41 µm, hexagonal, broader than high, 2-layered. Mesophyll 208–277 µm thick, divided in to 2-layered palisade and 6 or 7-layered parenchymatous septa or with air canal, traversed by 2 or 3-layered chlorenchymatous cell near the vascular bundle abaxially; palisade 80–110 µm thick, cells 30–43 × 7–10 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 186–140 µm thick, cells 18–34 × 43–59 µm, broader than high. Larger vascular bundle 318–323 × 118–136 µm, elliptic, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 1-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 100–108 × 127–133 µm, 6 or 7-layered, cells thick-walled with smaller lumen; abaxial bundle sheath 22–26 × 80–86 µm, 2 or 3-layered, cells thick-walled with smaller lumen; protoxylem 1 or 2; metaxylem 45–53 µm in diameter, ellipsoid or circular, surrounded by smaller isodiametric parenchymatous cells; phloem 40–45 × 48–57 µm, 6–8-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open to nearly closed. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermis hexagonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 4 or 5-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 30–34 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 101–131 × 103–129 µm, exine 0.88–1.44 µm thick, intine 2.79–5.40 µm thick, P/E ratio 1.00 , spheroidal, inaperturate with psillate sculpturing.

Seed morphology and anatomy

Seeds sub-globose, 3.80–5.00 × 4.50–5.50 mm, non-arillate, verrucate, black, turned to dull black to brown when dry. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, curved at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.63–2.00 mm diameter at top, operculum apical.

Outer surface reticulate-foveate, cells irregularly-polygonal; periclinal wall slightly concave or concave, warty; anticlinal wall raised, straight, smooth to finely-folded, unevenly thickened. Inner surface reticulate-foveate;

periclinal wall prominently concave, striate, striations rugose; anticlinal wall prominently raised, straight, smooth to slightly-folded, unevenly thickened.

Seed coat 219.23–282.11 µm thick, 27–30-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 5.68–6.23 µm thick, 1-layered, cells U-shaped; tegmen 8.64–9.05 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 7.04–7.54 µm thick. Micropylar mesotestal proliferation 433.46–503.75 µm thick; micropylar collar 835.36–924.57 µm long, straight. Chalazal chamber 0.81–1.35 × 2.18–2.78 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 453.55–548.46 µm thick. Chalazal mucro absent, chalazal chamber column prominent. Embryo base bulbous.

Distribution*:* India (Andaman and Nicobar Islands and Tripura).

Note*:* Based on the present study, *Musa paramjitiana* synonimised under *Musa balbisiana* var. *andamanica* (Hareesh *et al.,* 2017a).

Voucher specimens*:* **INDIA, Andaman and Nicobar Islands:** Middle Andaman, Kausalya Nagar, 03.08.2017, *M. Sabu & V.S. Hareesh 152717* (CAL); North Andaman, near Shiv Mandir, 18 km from Mayabunder towards Diglipur, 04.08.2017, *M. Sabu & V.S. Hareesh 152728* (CALI); Diglipur, Krishnapuri, 04.08.2017, *M. Sabu & V.S. Hareesh 152738* (CALI); Lakshmipur, 04.08.2017, *M. Sabu & V.S. Hareesh 152743* (CALI); near Kali Mandir, 07.08.2017, *M. Sabu & V.S. Hareesh 152769* (CALI); Little Andaman, Ramakrishnapur, 09.08.2017, *M. Sabu & V.S. Hareesh 152778* (CALI); Tripura, South Tripura, Durgapur, left from Garjee, 22.05.2011, *A. Joe & Sreejith* 116152 (CALI).

5.2. *Musa balbisiana* Colla var. ***bheem-kola*** A.Joe & M.Sabu, Revis. Indian Musaceae 136. 2019.

(Fig. 22, 23)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 4.5–8.5 m tall, cylindrical, olive green with black patches, faintly glaucous towards apex. Leaves arranged terminally; petiole 35–45 cm long, glaucous pale green. Inflorescence sub-horizontal, atleast for the fruit bearing part; female and male bud lanceolate to intermediate, imbricate at apex, male bud top-shaped to ovoid in advanced blooming; flowers inserted separately on the axis; bracts open, reflexed before falling, non-revolute, glaucous, pinkish-purple, adaxially, glabrous, reddish-purple abaxially; flowers arranged in two rows. Infructescence compact with 8–10 hands; fingers pedicellate, pointed upwards, straight or curved, prominently ridged, faintly glaucous, prominently pointed at apex without floral relicts, green, pale yellow with brownish dry patches when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 9.31–11.64 × 34.67–53.31 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 4.92–10.64 × 27.86–50.85 µm, rectangular, broader than high, cell wall straight to slightly wavy. Abaxial costal cells 12.58–19.75 × 19.72–41.08 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 10.01–15.19 × 21.39–50.03 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 24.68–25.28 µm long, abaxial guard cells 19.23–23.32 µm long. Adaxial stomatal index 0.00–2.17, abaxial stomatal index 5.35–11.11.

C.S. of lamina: 300–368 µm thick. Epidermis: adaxial epidermal cells 5–12 × 6–11 µm, rectangular, 1-layered, covered with thick cuticle; abaxial epidermal cells 7–10 × 10–15 µm, papillose, irregularly-shaped, 1-layered. Hypodermis: adaxial hypodermal cells 24–34 × 33–58 µm, hexagonal, broader than high , 2-layered upto both sides of the 8^{th} or 9^{th} smaller vascular bundles, and further 1-layered, cells uniform in size and shape adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, upper larger than lower; upper 11–19 × 16–32 µm, hexagonal, broader than high ; lower 7–10 × 10–14 µm, hexagonal, broader than high; abaxial hypodermal cells 9–16 × 24–41 µm, rectangular, broader than high, 1-layered. Mesophyll 238–256 µm thick, divided in to 2-layered palisade and 8 or 9-layered parenchymatous septa or with air canal, traversed by 2–4-layered chlorenchymatous cell near the vascular bundle abaxially; palisade 89–96 µm thick, cells 34–44 × 6–8 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 148–158 µm thick, cells 18–23 × 39–62 µm, broader than high, lobed. Larger vascular bundle 289–299 × 129–135 µm, elliptic, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 104–110 × 97–102 µm, 8–10-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 28–32 × 75–82 µm, 3 or 4-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem 31–36 µm in diameter, ellipsoid, surrounded by smaller isodiametric parenchymatous cells; phloem 47–53 × 63–68 µm, 10–12-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers.

Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wing closed. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells hexagonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 4–6-layered collenchyma and further large parenchymatous ground tissue. Air canals larger with one arc of 30–35 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 109–119 × 106–121 µm, exine 0.89–2.61 µm thick, intine 3.45–7.66 µm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds sub-globose, 4.00–5.00 × 5.00–6.00 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, curved at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.75–2.25 mm diameter at top, operculum apical.

Outer surface reticulate-foveate, cells irregularly-polygonal; periclinal wall slightly concave or concave, warty; anticlinal wall raised, straight, smooth to finely-folded, unevenly thickened. Inner surface reticulate-foveate; periclinal wall prominently concave, striate, striations rugose; anticlinal wall prominently raised, straight, smooth to slightly-folded, unevenly thickened.

Seed coat 247.36–286.83 µm thick, 23–27-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 6.25–6.84 µm thick, 1-layered, cells U-shaped; tegmen 8.22–8.77 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 7.96–9.29 µm thick. Micropylar mesotestal proliferation 447.90–533.65 µm thick; micropylar collar 1023.03–1093.25 µm long, straight. Chalazal chamber 1.00–1.58 × 2.40–2.85 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 562.29–629.26 µm thick. Chalazal mucro absent, chalazal chamber column prominent. Embryo base bulbous.

Distribution: India (Assam).

Voucher specimens: **INDIA, Assam:** Tinsukia, 10 August 2011, *A. Joe & P.E. Sreejith 130708* (CALI).

5.3 ***Musa balbisiana*** Colla var. ***elavazhai*** A.Joe, Sreejith & M.Sabu, Phytotaxa 175(2): 113. 2014.

(Fig. 24, 25)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 5–7 m tall, cylindrical, glaucous green. Leaves arranged terminally, intermediate; petioles 50–65 cm long, glabrous, yellowish-green, pendulous, then horizontal upto fruit bearing part; female and male bud lanceolate, imbricate at apex; bracts and flowers inserted separately on the axis; bracts open, reflexed before falling, non-revolute, dark purple to purplish pink, faintly glaucous adaxially, purplish red, glabrous, abaxially; flowers arranged in two rows. Infructescence lax with 4–7; fingers pedicellate, pointed upwards, curved, prominently ridged, extensively pointed at apex with or without floral relicts, green, slightly glaucous, yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 9.41–16.98 × 17.08–33.79 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 7.33–13.63 × 12.31–36.13 µm, rectangular, broader than high, cell wall straight to folded or slightly wavy. Abaxial costal cells 15.13–19.95 × 27.78–47.64 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 9.27–13.25 × 18.68–48.31 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded or wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells

24.32–26.95 µm long, abaxial guard cells 20.53–21.16 µm long. Adaxial stomatal index 0.00–1.69, abaxial stomatal index 9.88–12.50.

C.S. of lamina: 243–352 µm thick. Epidermis: adaxial epidermal cells 8–14 × 5–11 µm, rectangular, isodiametric, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–13 × 8–15 µm, papillose, irregularly-shaped, 1-layered. Hypodermis: adaxial hypodermal cells 27–50 × 29–72 µm, hexagonal, broader than high , 3-layered upto both sides of the 1st smaller vascular bundles, and further 2-layered, cells uniform in size and shape adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 39–43 × 19–25 µm, hexagonal, broader than high; abaxial hypodermal cells 10–20 × 24–52 µm, hexagonal, broader than high, 1-layered. Mesophyll 162–180 µm thick, divided in to 2 or 3-layered palisade and 5–7-layered parenchymatous septa or with air canal, traversed by 1 or 2-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 64–89 µm thick, cells 35–40 × 8–10 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 94–111 µm thick, cells 8–22 × 35–41 µm, broader than high. Larger vascular bundle 249–270 × 135–148 µm, ventricose, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 1 or 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 92–95 × 90–105 µm, 5–7-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 21–32 × 65–80 µm, 2 or 3-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem 36–43 µm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 35–38 × 28–35 µm, 6 or 7-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to both adaxial and abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wing closed. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells hexagonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 1 or 2-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 30–35 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 88–103 × 89–103 µm, exine 1.59–2.59 µm thick, intine 6.75–9.99 µm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds sub-globose, 4.50–5.50 × 4.75–6.00 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, curved at chalazal region, hilar rim

inconspicous. Micropylar region conical, micropylar plug 1.60–2.25 mm diameter at top, operculum apical.

Outer surface reticulate, cells irregularly-polygonal; periclinal wall prominently concave, warty; anticlinal wall raised, straight, smooth, unevenly thickened. Inner surface reticulate-foveate; periclinal wall prominently concave, smooth to rugose; anticlinal wall raised, straight, smooth, unevenly thickened.

Seed coat 249.67–298.75µm thick, 28–31-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 10.54–12.07 µm thick, 1-layered, cells U-shaped; tegmen 12.80–14.35 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 12.42–13.74 µm thick. Micropylar mesotestal proliferation 455.51–543.63 µm thick; micropylar collar 1002.02–1102.13 µm long, straight to weakly curved. Chalazal chamber 1.16–1.45 × 2.00–2.30 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 541.44–585.95 µm thick. Chalazal mucro absent, chalazal chamber column prominent. Embryo base bulbous.

Distribution: Kerala and Karnataka.

Voucher specimens:**INDIA, Kerala:** Kozhikode District, Anniehall road, near railway station, behind PVS Hospital (cultivated), 26 November 2012, *P.E. Sreejith & M.Sabu 123220* (CALI); Malappuram District, Calicut University Botanical Garden (cultivated), 30 August 2013, *M. Sabu & A. Joe 130779* (CALI).

5.4. *Musa balbisiana* Colla var**. *sepa-athiya*,** Borthakur & Tanti, Bangladesh J. Plant Taxon. 23(1): 75. 2016.

(Fig. 26, 27)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 3.5–5.25 m high, cylindrical, yellow-green or green, slightly glaucous towards apex. Leaves arranged as terminal tuft at apex; petiole slightly glaucous. Inflorescence sub-horizontal. Female bud lanceolate to intermediate, imbricate at apex bracts and flowers inserted separately on the axis, pink base or pink-purple. Male bud ovoid, imbricate at apex, bracts adaxially pink-purple with yellow apex, glaucous; flowers arranged in two rows. Infructescence compact, with 7–16 hands; fingers straight or curved, angled, faintly glaucous, apex broadly pointed, green, yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 6.27–12.06 × 17.40–44.11 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 5.35–12.19 × 20.21–40.66 µm, rectangular, broader than high, cell wall straight to slightly wavy. Abaxial costal cells 10.11–16.11 × 22.54–31.14 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 9.75–14.52 × 8.98–31.14 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded or wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 25.60–26.82 µm long, abaxial guard cells 17.83–19.72 µm long. Adaxial stomatal index 0.00–3.37, abaxial stomatal index 6.49–9.17.

C.S. of lamina: 261–382 µm thick. Epidermis: adaxial epidermal cells 8–14 × 6–13 µm, rectangular, isodiametric, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–21 × 4–12 µm, papillose, irregularly-shaped, 1-layered. Hypodermis: adaxial hypodermal cells 30–51 × 43–61 µm, hexagonal, broader than high, 2 or 3-layered upto both sides of the 4th or 5th smaller vascular bundles, and further 2-layered, cells uniform in size and shape adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, upper smaller than lower, 22–35 × 23–40 µm, hexagonal, isodiametric, lower 28–42 × 19–23 µm, hexagonal, higher than broad; abaxial hypodermal cells 16–38 µm, hexagonal, broader than high, 1-layered. Mesophyll 193–214 µm thick, divided in to 2 or 3-layered palisade and 6–8-layered parenchymatous septa or with air canal, traversed by 3 or 4-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 78–124 µm thick, cells 33–42 × 9–11 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 94–101 µm thick, cells 10–18 × 12–28 µm, broader than high, lobed. Larger vascular bundle 272–284 × 135–142 µm, elliptic, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 1 or 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 83–88 × 106–138 µm, 6–9-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 33–35× 71–80 µm, 3–6-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem 35–47 µm in diameter, ellipsoid or circular, surrounded by smaller isodiametric parenchymatous cells; phloem 31–37 × 55–64 µm, 7–10-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wing closed. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells hexagonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 1–3-layered collenchymatous cells and further large parenchymatous ground tissue. Air canals larger with one arc of 28–34 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in narrow Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 97–111 × 97–108 μm, exine 1.60–3.70 μm thick, intine 2.38–3.92 μm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds sub-globose, 3.50–4.35 × 4.90–6.25 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, curved at chalazal region, hilar rim

inconspicous. Micropylar region conical, micropylar plug 1.70–2.25 mm diameter at top, operculum apical.

Outer surface reticulate, cells irregularly-polygonal; periclinal wall prominently concave, warty; anticlinal wall raised, straight, smooth, unevenly thickened. Inner surface reticulate-foveate; periclinal wall prominently concave, striate, striations rugose; anticlinal wall prominently raised, straight, smooth to slightly-folded, unevenly thickened.

Seed coat 198.92–255.13 µm thick, 24–29-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 4.70–5.54 µm thick, 1-layered, cells U-shaped; tegmen 4.54–4.97 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 4.50–4.98 µm thick. Micropylar mesotestal proliferation 347.44–473.97 µm thick; micropylar collar 801.43–896.08 µm long, straight. Chalazal chamber 0.80–1.10 × 1.75–2.10 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 413.87–486.98 µm thick. Chalazal mucro absent, chalazal chamber column intermediate to prominent. Embryo base bulbous.

Voucher specimens:**INDIA, Meghalaya:** Khasi Hills, Mahadev Village, Lower Cherapunjee, 28 May 2011, *A. Joe & P.E. Sreejith 116172* (CALI).

Distribution: India (Assam and Meghalaya).

6. *Musa cheesmanii* N.W.Simmonds, Kew Bull. 11(3): 479. 1957.

(Fig. 28, 29)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 3–6.5 m tall, cylindrical, black, upper portion green, glaucous. Leaves arranged terminally, intermediate; petiole 40–55 cm long, greenish yellow to purple, Inflorescence pendulous; female and male bud lanceolate, imbricate at apex; bracts and flowers inserted separately on the axis; bracts non-revolute, male bracts reflexed before falling, dark violet, sometimes pale yellowish green, faintly glaucous, adaxially, red purple or pale orange abaxially; flowers arranged in two rows. Infructescence lax with 3–14 hands; fingers pedicellate, pointed upwards, curved, angled, glaucous, minutely pointed at apex without any floral relicts, dull green in mature.

Vegetative anatomy

Epidermis: Adaxial costal cells 9.06–11.06 × 12.99–35.29 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 8.09–14.68 × 13.15–41.25 µm, rectangular, broader than high, cell wall straight to slightly wavy. Abaxial costal cells 10.31–12.85 × 16.29–35.23 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly wavy; inter-costal cells 8.89–12.30 × 12.33–38.02 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded or wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 18.5–19.73 µm long, abaxial guard cells 20.86–22.17 µm long. Adaxial stomatal index 0.00–1.35, abaxial stomatal index 4.22–6.77.

C.S. of lamina: 398–453 µm thick. Epidermis: adaxial epidermal cells 6–13 × 7–11 µm, rectangular, isodiametric, 1-layered, covered with thick cuticle; abaxial epidermal cells 7–9 × 7–10 µm, rectangular, isodiametric, 1-layered. Hypodermis: adaxial hypodermal cells 11–36 × 18–48 µm, hexagonal, isodiametric to broader than high, 3-layered upto both sides of the 2nd or 3rd smaller vascular bundles, and further 2-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, upper slightly smaller than lower, 10–16 × 23–28 µm, hexagonal, broader than high, lower 12–14 × 10–14 µm, hexagonal, isodiametric; abaxial hypodermal cells 7–11 × 18–36 µm, hexagonal, broader than high, 2-layered. Mesophyll 245–297 µm thick, divided in to 2-layered palisade and 6 or 7-layered parenchymatous septa or with air canal, traversed by 2 or 3-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 85–90 µm thick, cells 39–55 × 9–11 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 88–92 µm thick, cells 8–19 × 21–26 µm, irregular. Larger vascular bundle 373–386 × 189–194 µm, elliptic, attached to both adaxial and abaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 1 or 2-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 68–76 × 80–88 µm, 5 or 6-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 21–29 × 72–94 µm, 2 or 3-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem 43–57 µm in diameter, ellipsoid, surrounded by smaller isodiametric parenchymatous cells; phloem 52–56 × 48–63 µm, 8–10-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wing closed. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells hexagonal, isodiametric to broader than high, 1 or 2-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 5–6-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 29–36 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in narrow Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 101–117 × 100–119 µm, exine 2.01–3.15 µm thick, intine 3.22–6.76 µm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds sub-globose, 5.50–7.00 × 8.00–11.00 mm, non-arillate, verrucate, black, turn to dull black when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, flat at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 3.00–5.75 mm diameter at top, operculum apical.

Outer surface alveolate, cells irregularly-polygonal; periclinal wall flat to slightly concave, foveate; anticlinal wall raised, straight, smooth, unevenly thickened. Inner surface reticulate-foveate; periclinal wall prominently concave, striate to rugose; anticlinal wall prominently raised, straight, smooth to slightly-folded, unevenly thickened.

Seed coat 520.46–630.91 µm thick, 38–45-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 7.14–7.59 µm thick, 1-layered, cells U-shaped; tegmen 4.29–4.81 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 6.08–6.47 µm thick. Micropylar mesotestal proliferation 342.78–444.29 µm thick; micropylar collar 932.46–1085.26 µm long, straight. Chalazal chamber 1.50–1.75 × 5.50–5.85 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 551.59–657.42 µm thick. Chalazal mucro and chalazal chamber column absent. Embryo base bulbous.

Distribution: Endemic to Northeastern India (Arunachal Pradesh, Assam, Manipur and Nagaland).

Voucher specimens: **INDIA, Arunachal Pradesh:** Changlang District, Kanubari Reserve Forest, 10 August 2011, *A. Joe & P.E. Sreejith 130705* (CALI); East Siang District, near Pasighat, Ruksin, 22 May 2016, *V.S. Hareesh 149326* (CALI); West Kameng District, way to Bomdilla rom Bhalukpong, near Ziro point, Ruksin, 30 May 2017, *V.S. Hareesh 152700* (CALI).

7. ***Musa chunii*** Hakkinen, J. Syst. Evol.47(1): 87. 2009.

(Fig. 30, 31)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 1–2 m tall, cylindrical, pale green. Leaves arranged terminally, intermediate;

petioles 30–45 cm long, glabrous, pale green. Inflorescence pendulous; female and male buds lanceolate, convolute; bracts and flowers inserted separately on the axis; bracts pale purple on both surfaces, faintly glaucous adaxially, glabrous abaxially; flowers arranged in a single row. Infructescence lax with 5 hands; fingers pedicellate, straight or slighty curved, slightly ridged, blunt at apex with floral relicts, glabrous, pale green, yellow when mature.

Vegetative anatomy

Epidermis: Adaxial costal cells 10.25–14.23 × 10.38–29.71 µm, rectangular, isodiametric to broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 7.48–19.05 × 11.32–35.45 µm, irregularly-polygonal, broader than high, cell wall straight to folded or slightly wavy. Abaxial costal cells 9.28–14.68 × 23.19–41.38 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 13.71–23.31 × 22.05–49.14 µm, irregularly-polygonal, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 25.02–27.21 µm long, abaxial guard cells 29.53–31.50 µm long. Adaxial stomatal index 0.00–2.04, abaxial stomatal index 6.21–12.50.

C.S. of lamina: 315–673 µm thick. Epidermis: adaxial epidermal cells 14–16 × 10–14 µm, rectangular, isodiametric, 1-layered, covered with thick cuticle; abaxial epidermal cells 9–14 × 11–27 µm, papillose, isodiametric to broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 84–144 × 61–101 μm, hexagonal, higher than broad, 3-layered upto both sides of the 2nd or 3rd smaller vascular bundles, followed by 2-layers up to 5th vascular bundle and further 1-layered, cell length reduced in size and shape adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, upper larger than lower; outer 77–105 × 26–38 μm, polygonal, broader than high; lower 38–53 × 19–24 μm, polygonal, broader than high; abaxial hypodermal cells 17–21 × 26–54 μm, rectangular, broader than high, 1-layered, some times, an additional layer arises below the larger vascular bundle. Mesophyll 218–307 μm thick, divided in to 2-layered palisade and 6 or 7-layered parenchymatous septa or with air canal, traversed by 2 or 3-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 66–90 μm thick, cells 25–29 × 8–10 μm, barrel-shaped, chlorenchymatous; parenchymatous septa 142–188 μm thick, cells 19–41 × 37–66 μm, broader than high. Larger vascular bundle 443–443 × 248–261 μm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2 or 3-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 100–125 × 148–164 μm, 5–7-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 24–26 × 75–112 μm, 3-layered, thick-walled cells with smaller lumen; protoxylem 1; metaxylem 48–66 μm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 50–58 × 90–119 μm, 6–8-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wing closed. Abaxial epidermal cells rectangular, isodiametric, 1-layered, covered with thick cuticle; hypodermal cells rectangular, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 1 or 2-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 23–28 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 67–87 × 66–89 µm, exine 0.71–1.13 µm thick, intine 2.50–4.19 µm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 3.00–3.75 × 4.00–5.75 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body flat at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.50–2.00 mm diameter at top, operculum apical.

Outer surface reticulate-foveate, cells irregularly-polygonal; periclinal wall slightly concave, smooth; anticlinal wall raised, straight, smooth to sinuous, uniformly thickened. Inner surface reticulate-foveate; periclinal wall concave, deeply folded, smooth; anticlinal wall shallow, straight, slightly-folded, unevenly thickened.

Seed coat 178.16–277.89 µm thick, 26–30-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 4.86–7.35 µm thick, 1-layered, cells U-shaped; tegmen 8.50–11.00 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 6.25–7.35 µm thick. Micropylar mesotestal proliferation 318.44–420.92 µm thick; micropylar collar 505.22–597.52 µm long, straight. Chalazal chamber 0.63–0.0.80 × 2.30–3.00 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 458.81–548.71 µm thick. Chalazal mucro present, chalazal chamber column intermediate. Embryo base bulbous.

Distribution: China, India (Arunachal Pradesh) and Myanmar.

Voucher specimens: **INDIA, Arunachal Pradesh:** Lohit District Salangham, way to Tidding from Tezu, near Salangham village, 08 July 2015, *A. Joe & V.S. Hareesh 121961* (CALI); Tidding, 14 May 2016, *V.S. Hareesh 149306* (CALI); Anjaw District, way to Walong from Hayuliang, Komba Village, 12 June 2016, *V.S. Hareesh 143788* (CALI).

8. ***Musa cylindrica*** A.Joe, Sreejith & M.Sabu, Phytotaxa 172(2): 138. 2014.

(Fig. 32, 33)

Rhizomatous, stoloniferous, suckering, clump forming-herbs. Pseudostem 2–3.3 m tall, cylindrical, pale green, minutely glaucous towards apex. Leaves arranged terminally, intermediate; petiole 70–82 cm long, faintly glaucous. Inflorescence first pendulous, then slightly horizontal; female bud cylindrical male bud lanceolate, imbricate; bracts and flowers inserted separately on the axis; bracts revolute before falling, faintly brown-purple glaucous adaxially, cream abaxially; flowers arranged in two rows. Infructescence compact with 5–7 hands; fingers pedicellate, pointed upwards, elongated, straight or slightly curved, minutely pointed at apex, green, yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 11.63–15.45 × 27.69–59.46 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly wavy; inter-costal cells 10.39–23.82 × 22.99–57.66 µm, rectangular, broader than high, cell wall straight to slightly wavy. Abaxial costal cells 10.23–14.38 × 16.19–44.52 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to wavy; inter-costal cells 8.85–18.72 × 14.03–61.31 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded or wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 22.93–25.62 µm long, abaxial guard cells 22.48–24.04 µm long. Adaxial stomatal index 1.93–3.70, abaxial stomatal index 2.63–11.18.

C.S. of lamina: 240–280 µm thick. Epidermis: adaxial epidermal cells 6–14 × 10–21 µm, rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–11 × 7–24 µm, rectangular, isodiametric to broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 47–68 × 43–73 µm, rectangular, isodiametric, 1-layered, cell length slightly reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 12–24 × 12–31 µm, irregular, broader than high; abaxial hypodermal cells 16–31 × 25–49 µm, rectangular, broader than high, 1-layered. Mesophyll 140–196 µm thick, divided in to 2-layered palisade and 4 or 5-layered parenchymatous septa or with air canal, traversed by 1 or 2-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 51–78 µm thick, cells 25–36 × 7–9 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 88–106 µm thick, cells 14–19 × 29–51 µm, broader than high. Larger vascular bundle 218–225 × 158–165 µm, ovate to ventricose, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 45–50 × 89–98 µm, 5 or 6-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 22–25× 57–63 µm, 2 or 3-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem 32–35 µm in diameter, ellipsoid or circular, surrounded by smaller isodiametric parenchymatous cells; phloem 38–42 × 34–37 µm, 7–9-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present. Oil glands present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells hexagonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 1 or 2-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 18–22 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 96–110 × 94–111 µm, exine 1.25–2.43 µm thick, intine 2.53–6.88 µm thick, P/E ratio 0.98, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 2.60–3.00 × 4.98–6.40 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body flat at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.40–2.00 mm diameter at top, operculum apical.

Outer surface alveolate, cells irregularly-polygonal; periclinal wall slightly concave, smooth to slightly warty; anticlinal wall slightly raised, straight, smooth, uniformly thickened. Inner surface reticulate; periclinal wall concave, smooth to slightly warty; anticlinal wall prominently raised, straight, smooth to folded, uniformly thickened.

Seed coat 200.88–258.28 µm thick, 18–25-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 14.50–15.75 µm thick, 1-layered, cells U-shaped; tegmen 15.85–18.11 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 8.77–10.16 µm thick. Micropylar mesotestal proliferation 281.30–375.53 µm thick; micropylar collar 607.01–699.89 µm long, straight. Chalazal chamber 0.80–1.00 × 1.15–2.15 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 449.11–451.90 µm thick. Chalazal mucro and chalazal chamber column absent. Embryo base bulbous.

Distribution: Endemic to India (Meghalaya)

Voucher specimen: **INDIA, Meghalaya:** Jaintia Hill District, Umkiang, Jamsara, 2 June 2011, *A. Joe & P.E. Sreejith 116176* (CALI).

9. *Musa flaviflora* N.W.Simmonds, Kew Bull., 11(3): 471. 1956.

(Fig. 34, 35)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 1.5–2.5 m tall, cylindrical, green, glaucous. Leaves arranged terminally, intermediate; petioles 40–55 cm long, glaucous, green. Inflorescence first erect, then horizontal; female buds lanceolate, convolute, minutely imbricate at apex; male buds top-shaped or convolute, imbricate at apex; bracts and flowers inserted separately on the axis; bracts moderately grooved, reflexed and revolute before falling, reddish-pink, minutely glaucous, adaxially cream with pink tinge; flowers arranged in two rows. Infructescence lax with 5–8 hands; fingers pedicellate, pointed upwards, straight, slightly ridged, minutely pointed at apex without floral relicts, glabrous, green, yellow when mature.

Vegetative anatomy

Epidermis: Adaxial costal cells 7.28–18.33 × 19.62–32.86 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded; inter-costal cells 12.12–23.28 × 14.55–40.73 µm, irregularly-polygonal, broader than high, cell wall straight to folded or slightly wavy. Abaxial costal cells 10.38–19.49 × 20.33–45.49 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous; inter-costal cells 11.01–16.56 × 17.08–50.27 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 30.16–31.55 µm long, abaxial guard cells 23.49–26.51 µm long. Adaxial stomatal index 1.40–3.03, abaxial stomatal index 3.44–8.05.

C.S. of lamina: 380–440 µm thick. Epidermis: adaxial epidermal cells 7–11 × 11–22 µm, haxagonal, broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–11 × 9–32 µm, rectangular, papillose, 1-layered. Hypodermis: adaxial hypodermal cells 40–63 × 19–72 µm, hexagonal, broader than high, 3-layered upto both sides of the 2nd smaller vascular bundles, and further 2-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 22–37 × 11–24 µm, hexagonal, broader than high; abaxial hypodermal cells 13–21 × 18–53 µm, rectangular, broader than high, 2-layered. Mesophyll 240–279 µm thick, divided in to 2-layered palisade and 6–8-layered parenchymatous septa or with air canal, traversed by 4 or 5-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 73–79 µm thick, cells 38–46 × 9–11 µm, barrel-shaped, chlorenchymatous;

parenchymatous septa 175–201 µm thick, cells 19–52 × 50–131 µm, broader than high. Larger vascular bundle 345–357 × 213–220 µm, obovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2 or 3-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 83–105 × 178–200 µm, 5–8-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 30–37 × 90–104 µm, 3–5-layered, thick-walled cells with smaller lumen; protoxylem 3 or 4; metaxylem 50–54 µm in diameter, ellipsoid or circular, surrounded by smaller isodiametric parenchymatous cells; phloem 73–90 × 61–75 µm, 10–13-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells hexagonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 5–7-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 30–37 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the

differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 102–117 × 103–118 µm, exine 1.00–2.10 µm thick, intine 2.37–3.24 µm thick, P/E ratio 0.98, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 3.50–4.00 × 6.00–6.75 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body flat at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.75–2.00 mm diameter at top, operculum apical.

Outer surface areolate, cells irregularly-polygonal; periclinal wall slightly convex, smooth; anticlinal wall shallow, straight to wavy, smooth to slightly-folded, unevenly thickened. Inner surface colliculate; periclinal wall concave, slightly-folded, smooth; anticlinal wall shallow, straight to wavy, smooth to folded, unevenly thickened.

Seed coat 186.24–233.39 µm thick, 21–25-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 13.03–14.62 µm thick, 1-layered, cells U-shaped; tegmen 17.00–19.93 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 10.24–10.77 µm thick. Micropylar mesotestal proliferation 318.64–411.19 µm thick; micropylar collar 734.79–796.49 µm long, straight.

Chalazal chamber 0.75–0.95 × 2.50–2.65 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 531.21–583.67 µm thick. Chalazal mucro absent, chalazal chamber column intermediate. Embryo base bulbous.

Distribution: Endemic to Northeastern India (Assam, Nagaland and Meghalaya)

Voucher specimens: **INDIA. Arunachal Pradesh:** Namsai District, 3 km away from Wakro towards Namsai, 15 May 2017, *M. Sabu & V.S. Hareesh 149352* (CALI); **Nagaland:** Nagutomi, 20 August 2011. *A. Joe & P.E. Sreejith 130727* (CALI).

10. *Musa itinerans* Cheesman, *Kew Bull.* 4 (1): 23. 1949.

(Fig. 36, 37)

Rhizomatous, stoloniferous, suckering, non-clump forming herbs, spreading by running rhizomes. Pseudostem 3–5.5 m tall, cylindrical, yellowish green or reddish brown. Leaves arranged terminally, intermediate; petioles 60–70 cm long, pale green or yellowish green. Inflorescence pendulous, then nearly horizontal; female and male bud lanceolate, convolute, male bud ovoid in advanced blooming; bracts and flowers inserted separately on the axis; bracts reflexed and revolute before falling, glabrous, dark maroon with yellow striations or yellow margins towards apex adaxially, cream to yellowish cream or yellow abaxially; flowers arranged in two rows. Infructescence lax with 3–6 hands, pointed upwards; fingers pedicellate, straight, slightly ridged, minutely pointed at apex, glabrous, pale green, green when mature.

Vegetative anatomy

Epidermis: Adaxial costal cells 6.72–13.07 × 18.55–63.29 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly wavy; inter-costal cells 7.61–14.42 × 15.19–64.16 µm, rectangular, broader than high, cell wall straight to wavy. Abaxial costal cells 12.74–17.75 × 10.97–33.74 µm, rectangular, isodiametric to broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous; inter-costal cells 9.76–17.78 × 12.64–60.63 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, normal or slightly deeper than other epidermal cells; adaxial guard cells 21.62–23.57 µm long, abaxial guard cells 21.27–23.50 µm long. Adaxial stomatal index 0.00–2.43, abaxial stomatal index 4.76–11.90.

C.S. of lamina: 272–382 µm thick. Epidermis: adaxial epidermal cells 7–13 × 6–13 µm, rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–8 × 8–20 µm, rectangular, broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 28–46 × 32–82 µm, hexagonal, broader than high, 2-layered upto both sides of the 4th smaller vascular bundles, and further 1-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 14–19 × 12–20 µm, hexagonal, isodiametric; abaxial hypodermal cells 8–13 × 13–36 µm, hexagonal, broader than high, 1-layered. Mesophyll 197–276 µm thick, divided in to 2-layered palisade and 5–7-layered parenchymatous septa or with air canal, traversed by 3 or 4-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 32–81 µm thick, cells 27–35 × 6–8 µm, barrel-shaped, chlorenchymatous;

parenchymatous septa 145–159 µm thick, cells 13–35 × 38–57 µm, broader than high . Larger vascular bundle 320–330 × 195–208 µm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 1 or 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 89–96 × 135–143 µm, 5–7-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 27–35 × 97–105 µm, 4 or 5-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem, 40–45 µm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 38–51 × 63–69 µm, 11–14-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to both adaxial and abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells hexagonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 2–4-layered collenchyma and further large parenchymatous ground tissue. Air canals larger with one arc of 26–31 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the

differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 96–106 × 99–108 µm, exine 1.40–2.56 µm thick, intine 4.43–8.93 µm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with verrucate sculpturing.

Seed morphology and anatomy

Seeds oblate, 3.20–4.80 × 4.76–8.35 mm, non-arillate, verrucate, dull black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, flat at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.40–2.50 mm diameter at top, operculum apical.

Outer surface alveolate, cells irregularly-polygonal; periclinal wall Slightly concave, smooth; anticlinal wall slightly raised, straight, smooth, unevenly thickened. Inner surface reticulate; periclinal wall slightly concave with multi-angular silica body at centre, smooth; anticlinal wall shallow to slightly raised, straight, sinuous, unevenly thickened.

Seed coat 325.00–372.17 µm thick, 28–31-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 10.27–11.94 µm thick, 1-layered, cells U-shaped; tegmen 18.29–22.85 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 7.62–9.28 µm thick. Micropylar mesotestal proliferation 461.29–556.39 µm thick; micropylar collar 767.30–851.47 µm long, straight.

Chalazal chamber 0.90–1.15 × 2.60–3.00 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 834.25–880.41 μm thick. Chalazal mucro absent, chalazal chamber column prominent. Embryo base bulbous.

***Distribution**:* China, India (Arunachal Pradesh, Manipur and Nagaland), Myanmar and Thailand.

Voucher specimens: **INDIA, Arunachal Pradesh:** Lower Dibang Valley District, on the way to Iduli from Roing, 04 July 2015, *A. Joe & V.S. Hareesh 121884* (CALI); Anjaw District, way to Walong from Hayuliang, Yasang, 13 June 2016, *V.S. Hareesh 143799* (CALI); Lohit Disrict, Tidding, 14 May 2016, *V.S. Hareesh 149308* (CALI); **Nagaland,** near Tinunsang, Siponsang Village, 27 May 2016, *V.S. Hareesh 149340* (CALI).

11. *Musa kattuvazhana* K.C.Jacob,Madras Bananas Monogr. 129. 1952.

Musa banksii F. Muell.var. *singampatti* T.G. Nayar, Indian J. Hort. 9: 14. 1952 (cf. Häkkinen & Vare, 2008).

Musa acuminata subsp. *burmannica* N.W. Simmonds, Kew Bull.11: 468. 1957. (cf. Häkkinen & Väre, 2008).

(Fig. 38, 39)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 1.5–4 m tall, cylindrical, pale green or greenish-yellow or yellow with reddish-brown patches. Leaves arranged terminally, intermediate; petioles 20–40 cm long, pale yellow to yellowish green, glabrous. Inflorescence pendulous, then sub-horizontal; female and male bud lanceolate, imbricate at apex; bracts reflexed, revolute before falling, dark purplish-violet, slightly glaucous adaxially, blood red abaxially. Infructescence compact with 3–10 hands; fingers pointed upwards, straight or curved, slightly ridged, pointed at apex without floral relicts, glabrous, green, pale yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 10.32–17.41 × 12.63–34.93 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly wavy; inter-costal cells 7.66–17.14 × 16.08–38.34 µm, rectangular, broader than high, cell wall straight to wavy. Abaxial costal cells 9.78–13.21 × 12.77–32.58 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous; inter-costal cells 8.34–17.86 × 8.75–58.02 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, slightly deeper than other epidermal cells; adaxial guard cells 23.62–25.31 µm long, abaxial guard cells 21.98–23.32 µm long. Adaxial stomatal index 2.04–2.43, abaxial stomatal index 4.47–9.42.

C.S. of lamina: 512–596 µm thick. Epidermis: adaxial epidermal cells 8–12 × 9–15 µm, rectangular, isodiametric, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–8 × 9–15 µm, rectangular, broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 49–52 × 49–86 µm, rectangular, isodiametric to broader than high, 3-layered upto both sides of the 2nd smaller vascular bundles and further followed by 2-layers, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, outer larger than inner, outer

14–18 × 27–39 µm, hexagonal, broader than high; inner 9–13 × 12–22 µm; hexagonal, brader than high; abaxial hypodermis 16–24 × 23–60 µm, rectangular, broader than high, 1-layered. Mesophyll 422–446 µm thick, divided in to 2-layered palisade and 5 or 6-layered parenchymatous septa or with air canal; palisade 62–84 µm thick, cells 26–29 × 6–8 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 340–367 µm thick, cells 20–29 × 33–71 µm, broader than high. Larger vascular bundle 520–526 × 243–251 µm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 1 or 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 145–158 × 138–145 µm, 14–17-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 22–31 × 89–103 µm, 2–4-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem, 45–50 µm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 60–67 × 66–73 µm, 9–12-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to both adaxial and abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells hexagonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 1–3-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 28–34 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 84–101 × 88–103 µm, exine 1.18–2.75 µm thick, intine 3.82–5.92 µm thick, P/E ratio 0.98, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 3.75–5.00 × 6.75–8.00 mm, non-arillate, verrucate, black, turned to dull black or brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, flat at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.75–2.50 mm diameter at top, operculum apical.

Seed coat 191.82–244.18 µm thick. Micropylar mesotestal proliferation 409.73–492.73 µm thick; micropylar collar 769.27–837.36 µm long, straight. Chalazal chamber 0.60–1.00 × 2.00–3.35 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 548.54–677.18 µm thick. Chalazal mucro absent, chalazal chamber column prominent. Embryo base bulbous.

Distribution: India (Kerala, Tamil Nadu and Karnataka and North & South Andaman Islands), Myanmar and Thailand.

Voucher specimens: **INDIA, Andaman and Nicobar Islands:** North Andaman, Diglipur, 04 August 2017, *M. Sabu & V.S. Hareesh 152739* (CALI); Diglipur, Saddle Peak foot-hill, 06 August 2017, *M. Sabu & V.S. Hareesh 152760* (CALI); **Kerala**, Idukki district, Vaguvarai, 09 April 2016, *V.S. Hareesh* 143936 (CALI).

12. *Musa mannii* H.Wendl. *ex* Baker, in Hook.f., Fl. Brit. India 6: 263. 1892, Ann. Bot. 7: 222. 1893.

(Fig. 40, 41)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 0.8–1 m tall, cylindrical, pale green with reddish brown patches. Leaves arranged terminally, drooping; petioles 40–45 cm long, pale green or with pale to deep pink patches, margin wrinkled, brown. Inflorescence pendulous or horizontal; female and male bud lanceolate, convolute; bracts and flowers inserted separately on the axis; bracts reflexed before falling, pale pink on both surface, adaxially puberulent, abaxially glabrous; flowers arranged in a single row. Infructescence lax with 3 or 4 hands; fingers pedicellate, straight, faintly ridged, slightly pointed at apex without floral relicts, glabrous, pale green, yellowish-green when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 14.72– 21.32× 15.00–54.73 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 14.54–21.29 × 23.82–62.38 µm, irregularly- polygonal, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded or wavy. Abaxial costal cells 11.72–22.78 × 17.95–63.94 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 10.64–22.73 × 17.95–63.92 µm, irregular, broader than high, cell wall straight to wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 31.22–32.58 µm long, abaxial guard cells 28.64–34.5 µm long. Adaxial stomatal index 0.00–0.85, abaxial stomatal index 3.22–9.15.

C.S. of lamina: 280–339 µm thick. Epidermis: adaxial epidermal cells 5–12 × 8–25 µm, rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 6–13 × 14–16 µm, rectangular, papillose, 1-layered. Hypodermis: adaxial hypodermal cells 40–58 × 48–80 µm, hexagonal, broader than high, 2-layered upto both sides of the 3rd smaller vascular bundles, and further 1-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 9–18 × 8–17 µm, hexagonal, higher than broad; abaxial hypodermal cells 10–15 × 27–48 µm, rectangular, broader than high, 1-layered. Mesophyll 128–190 µm thick, divided in to 2 or 3-layered palisade and 5 or 6-layered parenchymatous septa or with air canal, traversed by 4 or 5-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 62–79 µm thick, cells 27–31 × 7–9 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 120–135 µm thick, cells 15–24 × 36–111 µm, broader than high, irregularly lobed. Larger vascular bundle 266–278 × 157–168 µm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 3-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 79–95 × 95–108 µm, 2 or 3-layered, cells thin-walled sclerenchyma with larger lumen, followed by 3 or 4-layered, thick-walled with smaller lumen; abaxial bundle sheath 20–25 × 100–109 µm, 2 or 3-layered, thick-walled cells with smaller lumen; protoxylem 3 or 5; metaxylem 37–45 µm in diameter, ellipsoid or circular, surrounded by smaller isodiametric parenchymatous cells; phloem 40–46 × 66–78 µm, 5–7-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial surface U-shaped, abaxial surface wide U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 1–3-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 18–24 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 101–114 × 97–111 µm, exine 1.69–3.88 µm thick, intine 2.70–4.55 µm thick, P/E ratio 1.01, prolate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 3.25–3.75 × 5.00–6.00 mm, non-arillate, verrucate, dull black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body flat at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.50–2.00 mm diameter at top, operculum apical.

Outer surface reticulate-foveate, cells irregularly-polygonal; periclinal wall concave, smooth; anticlinal wall shallow, straight, smooth to slightly-folded, unevenly thickened. Inner surface reticulate-foveate; periclinal wall concave, deeply-folded, smooth; anticlinal wall shallow, straight, smooth to folded, unevenly thickened.

Seed coat 201.31–247.57 µm thick, 23–26-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 6.52–7.58 µm thick, 1-layered, cells U-shaped; tegmen 7.89–9.25 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 3.00–4.66 µm thick. Micropylar mesotestal proliferation 317.85–408.78 µm thick; micropylar collar 603.91–677.36 µm long, straight to weakly curved. Chalazal chamber 0.65–0.75 × 1.90–2.10 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation

253.64–373.83 μm thick. Chalazal mucro and chalazal chamber column absent. Embryo base bulbous.

Distribution: Endemic to Northeatern India (Arunachal Pradesh).

Voucher specimens: **INDIA, Arunachal Pradesh,** Changlang District, way to Changlang from Tinsukia, near Namdang check, 24 May 2016, *V.S. Hareesh 149332* (CALI); 9 mile, 16 August 2011, *A. Joe* & *P.E. Sreejith 130712* (CALI).

13. *Musa markkuana* (M.Sabu, A.Joe & Sreejith) Hareesh, A.Joe & M.Sabu Phytotaxa 303(3): 283. 2017.

Musa velutina H.Wendl. & Drude subsp. *markkuana* M.Sabu *et. al.* in Phytotaxa 92: 50 (2013)

(Fig. 42, 43)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem cylindrical, 0.7–1.7 m tall, slender, pale green to pale green with pale purple patches. Leaves arranged terminally, intermediate; petioles 50–70 cm long, glabrous, pale brownish-pink, margins scarious. Inflorescence erect; female and male buds lanceolate, convolute; bracts and flowers inserted separately on the axis; bracts open or reflexed and revolute before falling, pink to deep pink on both sides, minutely puberulent to glabrous adaxially, glabrous abaxially; flowers in a single row. Infructescence compact with 4–6 hands; fingers pedicellate, straight, prominently ridged, blunt at apex with or without floral relicts, glabrous, deep pink, pale pink when mature. Immature fruit peel colour maroon, becoming light maroon or pink when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 11.12–14.54 × 18.94–37.67 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly wavy; inter-costal cells 9.61–19.60 × 21.27–63.49 µm, rectangular, broader than high, cell wall straight to folded or slightly wavy. Abaxial costal cells 12.89–19.45 × 18.43–28.14 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy; inter-coastal cells 10.39–18.42 × 13.65–49.59 µm, irregular, broader than high, cell wall wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 30.00–31.97 µm long, abaxial guard cells 23.85–25.18 µm long. Adaxial stomatal index 0.00–2.85, abaxial stomatal index 6.00–10.60.

C.S. of lamina: 247–282 µm thick. Epidermis: adaxial epidermal cells 8–16 × 13–20 µm, rectangular, isodiametric to broader than long, 1-layered, covered with thick cuticle; abaxial epidermal cells 6–12 × 8–27 µm, rectangular, broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 21–37 × 24–63 µm, hexagonal, broader than high, 2-layered upto both sides of the 1^{st} smaller vascular bundles, and further 1-layered, cell length reduced djacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 15–18 × 11–18 µm, hexagonal, isodiametric; abaxial hypodermal cells 13–21 × 12–46 µm, rectangular, broader than high, 1-layered. Mesophyll 184–210 µm thick, divided into 2-layered palisade and 5 or 6-layered parenchymatous septa or with air canal, traversed by 3–6-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 73–88 µm thick, cells 36–45 × 10–12 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 96–105 µm thick, cells 13–32 × 44–85 µm, broader than high. Larger vascular bundle 230–257 × 138–145 µm, ovate to ventricose, attached to both adaxial and abaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 65–69 × 97–105 µm, 4 or 5-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 23–28× 56–72 µm, 2 or 3-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem 29–33 µm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 39–44 × 34–38 µm, 5–6-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 1 or 2-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 1–3-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 19–25 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the

differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 96–119 × 99–120 µm, exine 2.14–3.86 µm thick, intine 3.27–6.50 µm thick, P/E ratio 0.98, oblate-spheroidal, inaperturate with verrucate sculpturing.

Seed morphology and anatomy

Seeds oblate, 2.50–3.00 × 5.00–6.00 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body flat at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.50–2.00 mm diameter at top, operculum apical.

Outer surface reticulate-foveate, cells polygonal; periclinal wall concave, smooth; anticlinal wall raised, straight, smooth to slightly-sinuous, unevenly thickened. Inner surface reticulate; periclinal wall concave with multi-angular silica body at centre, smooth; anticlinal wall prominently raised, straight, smooth to folded, unevenly thickened.

Seed coat 149.39–259.81 µm thick, 24–27-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 7.63–8.10 µm thick, 1-layered, cells U-shaped; tegmen 9.47–10.08 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 3.83–4.60 µm thick. Micropylar mesotestal proliferation 286.73–393.27 µm thick; micropylar collar 607.47–693.26 µm long, straight to weakly curved. Chalazal chamber 0.35–0.55 × 2.10–2.40 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 309.72–398.41 μm thick. Chalazal mucro and chalazal chamber column absent. Embryo base bulbous.

Distribution: India (Arunachal Pradesh and Nagaland) and Myanmar.

Voucher specimens: **INDIA, Arunachal Pradesh:** West Kameng district, way to Bomdilla from Balukpong, Durga Mandir, 30 June 2015, *A. Joe & V.S. Hareesh 121845* (CALI); *ibid* 30 May 2017, *V.S. Hareesh 152695* (CALI); East Siang District, Pasighat, near Mebo, Siluk, 17 May 2016, *V.S. Hareesh 149311* (CALI).

Notes: Initially, *M. markkuana* was described as a subspecies of *M. velutina* H.Wendl. & Drude (Sabu *et al.,* 2013) eventhough the taxa shows distinct differences in its morphology with its most similar congener, *M. velutina* in multiple charactes such as the basal hand of the inflorescence with female flowers (*vs*. bisexual flowers), glabrous ovary (*vs*. hairy), glabrous fruits that do not split at maturity (*vs*. hairy schizocarpic), *etc*. Subsequently, Hareesh *et al.,* (2017b) reinstated the taxonomy based on the differences in vegetative and reproductive anatomy and palynology.

14. *Musa markkui* Gogoi & Borah, Gard. Bull. Singapore 65(1): 20. 2013.

(Fig. 44, 45)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 1–3.5 m tall, cylindrical, pale-green with reddish-brown patches. Leaves arranged terminally, intermediate; petioles 40–80 cm long, pale green with pink coloration, petiole wings wrinkled with scarious margin. Inflorescence erect, then pendulous, again erect, the sub-horizontal; female and male buds lanceolate, convolute; bracts and flowers arranged separately on the axis; bracts reflexed, revolute before falling, pale pink to pink or pale orange adaxially, pale pink or pale orange with pink striations abaxially; flowers arranged in a single row. Infructescence compact with 5–8 hands; fingers pedicellate, pointed upwards, straight, ridged, glabrous, faintly pointed at apex without floral relicts, pale green to green, yellow with brownish-red small patches when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 11.97–16.54 × 13.30–30.61 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 11.52–22.56 × 17.41–48.52 µm, irregularly-polygonal, broader than high, cell wall straight to folded. Abaxial costal cells 12.87–17.62 × 28.18–40.01 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 7.40–19.82 × 23.86–73.04 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded or wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 30.08–31.25 µm long, abaxial guard cells 29.64–32.02 µm long. Adaxial stomatal index 0.00–2.50, abaxial stomatal index 5.00–10.00.

C.S. of lamina: 383–495 µm thick. Epidermis: adaxial epidermal cells 9–18 × 11–21 µm, rectangular, isodiametric, 1-layered, covered with thick cuticle; abaxial epidermal cells 8–12 × 7–25 µm, papillose, broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 50–113 × 40–47 µm, hexagonal, higher than broad, 3-layered upto both sides of the 1st or 2nd

smaller vascular bundles, and further 2-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, sub-equal, 38–55 × 14–17 µm, polygonal, broader than high; abaxial hypodermal cells 16–22 × 37–46 µm, rectangular, broader than high, 2-layered. Mesophyll 208–297 µm thick, divided in to 2-layered palisade and 7–9-layered parenchymatous septa or with air canal, traversed by 2 or 3-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 92–101 µm thick, cells 38–42 × 8–11 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 114–165 µm thick, cells 23–32 × 34–80 µm, broader than high. Larger vascular bundle 360–368 × 205–211 µm, ventricose, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2 or 3-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 60–68 × 125–131 µm, 4 or 5-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 40–42× 72–75 µm, 4-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem 47–52 µm in diameter, ellipsoid or circular, surrounded by smaller isodiametric parenchymatous cells; phloem 55–57 × 60–63 µm, 10–12-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals are absent.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, isodiametric, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 2-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 1 or 2-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 20–26 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 112–119 × 112–119 µm, exine 4.06–12.79 µm thick, intine 3.68–12.06 µm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with verrucate sculpturing.

Seed morphology and anatomy

Seeds oblate, 2.50–3.50 × 4.38–5.82 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body flat at micropyle, weakly taper at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.30–1.65 mm diameter at top, operculum apical.

Outer surface colliculate, cells irregularly-polygonal; periclinal wall convex, smooth; anticlinal wall shallow, straight, smooth, unevenly thickened. Inner surface colliculate; periclinal wall convex with multi-angular silica body at centre, smooth; anticlinal wall shallow, straight, smooth, unevenly thickened.

Seed coat 141.44–182.14 µm thick, 26–30-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 6.40–7.83 µm thick, 1-layered, cells U-shaped; tegmen 7.73–9.01 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 8.30–8.75 µm thick. Micropylar mesotestal proliferation 324.28–448.93 µm thick; micropylar collar 520.14–607.49 µm long, straight. Chalazal chamber 0.70–0.85 × 2.15–2.25 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 558.24–603.54 µm thick. Chalazal mucro present, chalazal chamber column prominent. Embryo base bulbous.

Distribution: Endemic to Northeastern India (Arunachal Pradesh and Nagaland).

Voucher specimens: **INDIA. Arunachal Pradesh:** Lohit District, way to Tidding from Tezu, 12 kms from Tohangam view point, before Salangham village, 08 July 2015, *A. Joe & V.S. Hareesh 121954* (CALI); Tidding, 14 May 2016, *V.S. Hareesh 149304* (CALI); Lower Dibang Valley District, way to Mayodia from Roing, Tiwari Gaon, 06 May 2016, *V.S. Hareesh 143744* (CALI); 9 km behind Mayodia towards Anini from Roing, 06 May 2016, *V.S. Hareesh 143756* (CALI); 36 km behind Riyali from towards Anini from Roing, 06 May 2016, *V.S. Hareesh 143764* (CALI); Namsai District, near Namsai, 15 May 2017, *M. Sabu & V.S. Hareesh 149355* (CALI); Dibang Valley District, way to Anini from Hunli, Punli, 19 May 2017, *M. Sabu & V.S. Hareesh 152625* (CALI).

15. *Musa nagensium* Prain, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 73(1): 21. 1904.

(Fig. 46, 47)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 3.5–7 m tall, cylindrical, glaucous, olive green to brownish-red or black. Leaves arranged terminally, drooping; petioles 40–55 cm long, slender, yellowish-green, glaucous. Inflorescence horizontal then pendulous; female and male buds lanceolate or cylindrical, prominently imbricate; bracts and flowers inserted separately on the axis; bracts open, non-revolute before falling, glaucous, yellowish-orange with brick-red coloration and sometimes pale greenish-brown towards the apex adaxially, pale orange to orange abaxially; flowers arranged in two rows; Infructescence lax with 4–8 hands; fingers pedicellate, pointed downwards, straight, prominently angular, slightly pointed at apex, without floral relicts, glaucous, pale green to green, dark green when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 7.13–10.53 × 32.36–42.88 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly wavy; inter-costal cells 6.46–11.97 × 18.82–74.38 µm, rectangular, broader than high, cell wall straight to slightly wavy. Abaxial costal cells 8.78–13.13 × 13.70–29.05 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 8.27–15.54 × 12.96–71.34 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall slightly-folded to slightly wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 17.17–19.83 µm long, abaxial guard cells 22.82–23.89 µm long. Adaxial stomatal index 0.00–2.43, abaxial stomatal index 7.31–11.76.

C.S. of lamina: 201–300 µm thick. Epidermis: adaxial epidermal cells 6–10 × 6–13 µm, rectangular, isodiametric, 1-layered, covered with thick cuticle; abaxial epidermal cells 7–11 × 7–18 µm, rectangular, broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 25–34 × 20–74 µm, hexagonal, broader than high, 2-layered upto both sides of the 5th smaller vascular bundles, and further 1-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, 9–14 × 10–19 µm, hexagonal, isodiametric to broader than high; abaxial hypodermal cells 6–14 × 12–33 µm, rectangular, broader than high, 1-layered. Mesophyll 165–202 µm thick, divided in to 2-layered palisade and 4 or 5-layered parenchymatous septa or with air canal, traversed by chlorenchymatous cells near the vascular bundles abaxially; palisade 85–107 µm thick, cells 36–50 × 8–11 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 80–188 µm thick, cells 10–15 × 29–58 µm, broader than high. Larger vascular bundle 218–330 × 125–133 µm, elliptic, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 1 or 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 71–80 × 105–111 µm, 4 or 5-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 18–21 × 57–69 µm, 2 or 3-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem, 39–45 µm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 25–33 × 42–49 µm, 5–7-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to both adaxial and abaxia hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wing completely closed. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 5–8-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 23–27 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 89–105 × 85–106 µm, exine 2.27–4.59 µm thick, intine 2.46–12.76 µm thick, P/E ratio 1.00, spheroidal, inaperturate with verrucate sculpturing.

Seed morphology and anatomy

Seeds oblate, 6.42–7.50 × 8.00–12.00 mm, non-arillate, smooth to verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, flat at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 3.50–6.50 mm diameter at top, operculum apical.

Outer surface reticulate-foveate, cells irregularly-polygonal; periclinal wall concave, smooth to folded; anticlinal wall raised, straight, smooth, unevenly thickened. Inner surface reticulate; periclinal wall concave, warty; anticlinal wall prominently raised, straight, smooth to sinuous, unevenly thickened.

Seed coat 550.91–596.32 µm thick, 28–35-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 10.39–12.44 µm thick, 1-layered, cells U-shaped; tegmen 10.12–12.59 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 21.67–23.09 µm thick. Micropylar mesotestal proliferation 1350.67–1460.53 µm thick; micropylar collar 1705.48–1780.20 µm long, straight. Chalazal chamber 0.95–1.25 × 6.10–6.70 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 1330.90–1424.75 µm thick. Chalazal mucro and chalazal chamber column absent. Embryo base bulbous.

Distribution: China, India (Arunachal Pradesh and Nagaland), Myanmar and Thailand.

Voucher specimens**: INDIA, Arunachal Pradesh:** Lohit District, way to Tidding from Tezu, 4 kms from Tohangam view point, 08 July 2015, *A. Joe & V.S. Hareesh 121946* (CALI); Anjaw District, way to Walong from Hayuliang, Yasang, 13 June 2016, *V.S. Hareesh 143800* (CALI); Changlang District, way to Changlang from Tinsukia, near Namdang check gate, 24 May 2016, *V.S. Hareesh 149335* (CALI).

16. *Musa ochracea* K.Sheph., *Kew Bull.* 17(3): 461. 1964.

(Fig. 48, 49)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 1.5–3m tall, cylindrical, ochreous yellow. Leaves arranged terminally, intermediate; petioles 60–85 cm long, greenish yellow to yellow, glabrous, petiolar wings margin broad dry-wrinkled, scarious. Inflorescence horizontal, peduncle densely puberulent; female bud lanceolate, convolute; male bud lanceolate to top-shaped in advanced blooming, convolute; bracts and flowers inserted separately on the axis; bracts revolute before falling, ochreous yellowish-green with purple striations adaxially, cream to brown purple abaxially; flowers arranged in two rows. Infructescence compact with 5–7 hands, pointed upwards; fingers pedicellate, curvd, slightly pointed at apex, glabrous except minutely puberulent base, green.

Vegetative anatomy

Epidermis: Adaxial costal cells 11.01–17.13 × 17.42–45.75 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 9.78–19.22 × 14.57–43.41 µm, rectangular, broader than high, cell wall straight to slightly-folded. Abaxial costal cells 9.8–14.21 × 14.14–31.79 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous; inter-costal cells 10.06–17.25 × 15.75–60.31 µm, irregularly-polygonal, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells

24.28–26.47 µm long, abaxial guard cells 20.97–23.63 µm long. Adaxial stomatal index 0.00–5.26, abaxial stomatal index 11.76–14.72.

C.S. of lamina: 307–418 µm thick. Epidermis: adaxial epidermal cells 8–16 × 6–18 µm, rectangular, isodiametric, 1-layered, covered with thick cuticle; abaxial epidermal cells 6–8 × 8–14 µm, rectangular, broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 17–49 × 19–70 µm, hexagonal, broader than high, 2-layered upto both sides of the 3rd smaller vascular bundles, and further 1-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, rarely two, 5–14 × 11–27 µm, hexagonal, broader than high; abaxial hypodermal cells 9–12 × 12–34 µm, rectangular, broader than high, 1-layered. Mesophyll 198–298 µm thick, divided in to 2 or 3-layered palisade and 6 or 7-layered parenchymatous septa or with air canal, traversed by 1 or 2-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 50–81 µm thick, cells 27–52 × 7–11 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 135–185 µm thick, cells 24–39 × 34–107 µm, broader than high. Larger vascular bundle 264–345 × 181–204 µm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2 or 3-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 56–65 × 109–164 µm, 5 or 6-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 23–35 × 80–94 µm, 4 or 5-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem, 54–57 µm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 42–48 × 54–69 µm, 6–8-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to both adaxial and abaxia hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 1 or 2-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 26–30 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 100–124 × 102–129 µm, exine 7.74–12.10 µm thick, intine 3.10–15.57 µm thick, P/E ratio 0.98, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds ellipsoid, 2.50–4.00 × 3.16–4.00 mm, non-arillate, smooth, black, turn to dull black when dried. Seeds shape not contorted by tight packing in fruits, seed body flat at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.00–1.50 mm diameter at top, operculum apical.

Outer surface reticulate-foveate, cells irregularly-polygonal; periclinal wall concave, smooth; anticlinal wall shallow, straight, smooth, unevenly thickened. Inner surface reticulate; periclinal wall concave, with multi-angular silica body at centre, smooth; anticlinal wall prominently raised, straight, smooth to folded, unevenly thickened.

Seed coat 166.71–198.19 µm thick, 26–32-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 8.88–9.21 µm thick, 1-layered, cells U-shaped; tegmen 16.07–17.69 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 10.67–12.17 µm thick. Micropylar mesotestal proliferation 313.71–424.76 µm thick; micropylar collar 518.14–589.23 µm long, straight. Chalazal chamber 0.65–0.75 × 1.35–1.50 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 330.43–401.48 µm thick. Chalazal mucro absent, chalazal chamber column intermediate. Embryo base bulbous.

Distribution: India (Manipur, Mizoram and Tripura).

Voucher specimens: **INDIA, Manipur:** Tamenglong District, Tupul, 9 kms before Noney from Imphal, 12 December 2012, *A. Joe & Ashfak 121668* (CALI); **Mizoram:** Mamit District, 2 km from Lengpui to Mamit, 372 m, 14 March 2012, *A. Joe & P.E. Sreejith 130815* (CALI).

17. *Musa ornata* Roxb.,Hort. Bengal. 19. 1814. *nomen nud.*, Fl. Ind., ed. Carey & Wall., 2: 488. 1824. *descry*.

(Fig. 50, 51)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 1–2.5 m tall, glaucous, pale green. Leaves arranged terminally, erect to intermediate; petioles 24–55 cm long, glaucous, margins smooth. Inflorescence erect, peduncle glabrous; female and male bud lanceolate, convolute; bracts and flowers inserted separately on the axis; bracts reflexed, revolute before falling, faintly glaucous lilac with yellow apex adaxially, pale lilac with cream towards the base; flowers arranged in a single row. Infructescence compact with 3–6 hands; fingers pedicellate, pointed upwards, slightly ridged, glabrous, pale gerrn to green, greenish-yellow or pale yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 10.53–16.52 × 12.53–33.97 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 11.01–22.47 × 11.23–43.42 µm, rectangular, broader than high, cell wall straight to folded. Abaxial costal cells 8.98–16.22 × 9.20–37.03 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly wavy; inter-costal cells 7.27–16.29 × 14.68–39.16 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells

21.55–22.27 µm long, abaxial guard cells 20.83–22.91 µm long. Adaxial stomatal index 0.00–0.45, abaxial stomatal index 8.33–10.52.

C.S. of lamina: 227–304 µm thick. Epidermis: adaxial epidermal cells 6–17 × 10–20 µm, rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 6–13 × 8–25 µm, rectangular, isodiametric to broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 22–49 × 25–69 µm, rectanguular, broader than high, 2-layered upto both sides of the 3rd or 4th smaller vascular bundles, and further 1-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 7–10 × 10–20 µm, hexagonal, broader than high; abaxial hypodermis 10–16 × 19–43 µm, rectangular, broader than high, 1-layered. Mesophyll 153–208 µm thick, divided in to 2-layered palisade and 4 or 5-layered parenchymatous septa without air canal, traversed by thick-layered chlorenchymatous cells abaxially; palisade 72–92 µm thick, cells 32–45 × 6–9 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 70–94 µm thick, cells 15–20 × 25–46 µm, broader than high, completely chlorenchymatous. Larger vascular bundle 230–236 × 150–159 µm, obovate to ventricose, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 1 or 2-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 58–68 × 118–137 µm, 4 or 5-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 13–19 × 74–89 µm, 1 or 2-layered, thick-walled cells with smaller lumen; protoxylem 1, rarely 2; metaxylem 33–46 µm in diameter, circular to ellipsoid, surrounded by smaller isodiametric parenchymatous cells; phloem 38–42 × 48–52 µm, 6–8-layered, parenchymatous, thin-walled. Smaller vascular bundles mostly suspended in the mesophyll or connected to abaxial hypodermis followed or rarely both, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 1 or 2-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 3 or 4-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 22–28 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 112–119 × 115–117 µm, exine 3.00–3.25 µm thick, intine 12.24 – 15.97 µm thick, P/E ratio 0.98, oblate-spheroidal, inaperturate with regulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 3.40–4.00 × 5.54–6.00 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 0.90–1.75 mm diameter at top, operculum apical.

Outer surface areolate, cells irregularly-polygonal; periclinal wall slightly concave, rugose; anticlinal wall slightly raised, straight, smooth, unevenly thickened. Inner surface reticulate; periclinal wall concave with multi-angular silica body at centre, rugose; anticlinal wall prominently raised, straight, smooth to folded, unevenly thickened.

Seed coat 184.74–216.09 µm thick, 19–24-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 9.30–10.86 µm thick, 1-layered, cells U-shaped; tegmen 16.89–19.09 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 10.86–12.50 µm thick. Micropylar mesotestal proliferation 311.79–424.60 µm thick; micropylar collar 638.95–735.99 µm long, straight. Chalazal chamber 0.10–1.15 × 2.10–2.35 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 371.72–442.80 µm thick. Chalazal mucro present, chalazal chamber column intermediate. Embryo base bulbous.

Distribution*:* Bangladesh, India (Andara Pradesh, Mizoram and Odisha) and Myanmar.

Voucher specimens*:* **INDIA, Mizoram:** Lengpui dist., 5km from Lengpui to Buchali bridge, 15.03.2012, *A. Joe & P.E. Sreejith* (CALI).

18. ***Musa pradhanii*** A.Joe & M.Sabu, Revis. Indian Musaceae 212. 2019.

(Fig. 52, 53)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 2–2.5 m high, cylindrical, green or greenish-yellow, glaucous towards apex.Leaves arranged terminally, intermediate; petioles 30–53 cm long, pale green or greenish-yellow. Inflorescence sub-horizontal, peduncle, puberulent, green or green or with with purple colouration, then changes to green; female and male bud lanceolate, convolute; bracts and flowers inserted separately on the axis; bracts pinkish-purple on both surface, faintly glaucous adaxially, revolute before falling; male bract reflexed, revolute before falling; flowers arranged in two rows. Infructescence lax with 4–6 hands, fingers pedicellate, pointed upwards, straight or curved, prominently angled, glabrous, slightly pointed at apex, green.

Vegetative anatomy

Epidermis: Adaxial costal cells 14.12–17.14 × 22.46–59.72 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 11.74–23.11 × 12.85–63.45 µm, rectangular, broader than high, cell wall straight to folded. Abaxial costal cells 9.11–16.86 × 10.97–19.39 µm, rectangular, isodiametric to broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 9.31–18.16 × 10.91–56.22 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells

22.59–26.35 µm long, abaxial guard cells 22.19–25.15 µm long. Adaxial stomatal index 0.00–2.63, abaxial stomatal index 4.87–16.66.

C.S. of lamina: 275–338 µm thick. Epidermis: adaxial epidermal cells 6–15 × 8–17 µm, hexagonal, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–7 × 8–20 µm, rectangular, isodiametric to broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 27–57 × 26–54 µm, hexagonal, broader than high, 2-layered upto both sides of the 1st smaller vascular bundles, and further 1-layered, cell length uniform adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 10–16 × 11–18 µm, hexagonal, isodiametric; abaxial hypodermal cells 7–16 × 15–36 µm, broader than high, rectangular, 1-layered. Mesophyll 175–215 µm thick, divided in to 2-layered palisade and 5–7-layered parenchymatous septa or with air canal, traversed by 1–3-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 56–71 µm thick, cells 30–37 × 7–10 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 113–135 µm thick, cells 14–29 × 25–59 µm, broader than high. Larger vascular bundle 277–285 × 175–183 µm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 99–105 × 88–92 µm, 8–11-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 12–18 × 66–71 µm, 2 or 3-layered, thick-walled cells with smaller lumen; protoxylem 1; metaxylem, 42–47 µm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 47–52 × 56–62 µm, 9–12-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to both adaxial and abaxia hypodermis, sub-equal in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 1 or 2-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 21–26 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 110–135 × 112–133 µm, exine 2.24–4.64 µm thick, intine 3.98–6.2 µm thick, P/E ratio 0.96, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 3.50–5.00 × 5.50–7.67 mm, non-arillate, verrucate, dull black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, flat at chalazal region, hilar rim

inconspicous. Micropylar region conical, micropylar plug 1.30–1.65 mm diameter at top, operculum apical.

Outer surface reticulate-foveate, cells irregularly-polygonal; periclinal wall slightly concave, smooth; anticlinal wall raised, straight, smooth to slightly folded, unevenly thickened. Inner surface colliculate; periclinal wall convex concave with multi-angular silica body, smooth; anticlinal wall prominently raised, straight, smooth to folded, unevenly thickened.

Seed coat 287.59–354.63 µm thick, 22–27-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 9.36–10.24 µm thick, 1-layered, cells U-shaped; tegmen 6.50–7.01 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 7.38–8.19 µm thick. Micropylar mesotestal proliferation 530.64–640.14 µm thick; micropylar collar 900.45–988.23 µm long, straight. Chalazal chamber 0.65–1.00 × 1.95–3.30 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 824.35–907.96 µm thick. Chalazal mucro absent, chalazal chamber column prominent. Embryo base bulbous.

Distribution*:* India (West Bengal).

Voucher specimens*:* **INDIA**, **West Bengal:** Kalimpong, Everest Nursery area (cultivated, originally collected from Darjeeling), 21 April 2013, *M. Sabu 130769* (CALI).

19. *Musa puspanjaliae* Gogoi & Hakkinen, Nordic J. Bot. 31(4): 473. 2013.

(Fig. 54, 55)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 7.5–9m high, glaucous, green to dark green with greenish-black. Leaves arranged terminally, intermediate; petioles 30–45 cm long, faintly glaucous, green. Inflorescence pendulous, peduncle, glabrous to pubescent; female bud lanceolate, imbricate, bracts glaucous, pale greenish-yellow adaxially, pale pink to purple abaxially; male bud ovoid, imbricate, bracts non-revolute yellowish-green or purple axaxially, faintly glaucous, yellow to pink abaxially glabrous; bracts and flowers attached separately on the axis; flowers arranged in two rows. Inflorescence compact with 5–10 hands; fingers straight, prominently 3-angled, slightly pointed at apex without floral relicts, glaucous, glabrous, pale green.

Vegetative anatomy

Epidermis: Adaxial costal cells 12.65–14.23 × 8.67–24.59 µm, rectangular, isodiametric to broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 8.74–15.73 × 9.08–23.92 µm, rectangular, broader than high, cell wall straight to folded. Abaxial costal cells 12.19–18.13 × 14.20–44.91 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 7.75–15.92 × 8.32–42.54 µm, irregularly-polygonal, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded or wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 18.64–19.61 µm long, abaxial guard cells 20.69–21.95 µm long. Adaxial stomatal index 0.00–0.49, abaxial stomatal index 1.53–7.69.

C.S. of lamina: 392–469 µm thick. Epidermis: adaxial epidermal cells 13–17 × 7–14 µm, rectangular, broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 7–9 × 8–16 µm, rectangular, broader than high

, 1-layered. Hypodermis: adaxial hypodermal cells 25–54 × 38–80 µm, hexagonal, broader than high, 3-layered upto both sides of the 8^{th} or 11^{th} smaller vascular bundles, and further 2-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, upper smaller than lower; upper 17–19 × 17–27 µm, hexagonal, broader than high; lower 33–37 × 9–17 µm, polygonal, broader than high; abaxial hypodermal cells 10–15 × 34–39 µm, rectangular, broader than high, 2-layered up to 2^{nd} smaller vascular bundle, and 1-layered. Mesophyll 260–288 µm thick, divided in to 2-layered palisade and 6 or 7-layered parenchymatous septa or with air canal, traversed by scattered chlorenchymatous cells abaxially; palisade 80–100 µm thick, cells 24–39 × 5–8 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 172–181 µm thick, cells 25–37 × 35–50 µm, broader than high. Larger vascular bundle 356–365 × 193–205 µm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 3-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 85–90 × 93–98 µm, 5 or 6-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 26–32 × 103–109 µm, 3-layered, thick-walled cells with smaller lumen; protoxylem 2–4; metaxylem 45–49 µm in diameter, ellipsoid or circular, surrounded by smaller isodiametric parenchymatous cells; phloem 60–65 × 73–78 µm, 8–12-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wing closed. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 2-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 1–3-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 30–35 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 120–140 × 124–136 μm, exine 2.51–5.38 μm thick, intine 4.53–7.81 μm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 6.50–7.90 × 8.00–15.00 mm, non-arillate, smooth-verrucate, black, turn to dull black when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, flat at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 4.25–6.00 mm diameter at top, operculum apical.

Outer surface reticulate, cells irregularly-polygonal; periclinal wall concave, smooth to finely-folded; anticlinal wall prominently raised, straight, smooth to slightly-folded, unevenly thickened. Inner surface reticulate; periclinal wall concave with multi-angular silica body at centre, smooth to rugose; anticlinal wall raised, straight, smooth to slightly-sinuous,, unevenly thickened.

Seed coat 735.04–810.82 µm thick, 50–58-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 11.41–12.52 µm thick, 1-layered, cells U-shaped; tegmen 9.36–9.94 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 2.39–3.23 µm thick. Micropylar mesotestal proliferation 1284.22–1378.07 µm thick; micropylar collar 1306.23–1397.79 µm long, straight. Chalazal chamber 1.15–1.20 × 4.80–5.20 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 1474.68–1559.63 µm thick. Chalazal mucro absent, chalazal chamber column prominent. Embryo base bulbous.

Distribution: Endemic to Northeastern India (Arunachal Pradesh).

Voucher specimens: **INDIA, Arunachal Pradesh:** Lohit District, Tezu, Tohangam, near Tohangam view point, 08 July 2015, *A. Joe & V.S. Hareesh 121941* (CALI); on the way to Salangham, 08 July 2015, *A. Joe & V.S. Hareesh 121969* (CALI);on the way to Salangham, 08 July 2015, *A. Joe & V.S. Hareesh 121970* (CALI); Tidding, 14 May 2016, *V.S. Hareesh 149310* (CALI); 25 km ahead to Salangam from Thohangam, 15 May 2017, *M. Sabu & V.S. Hareesh 149381* (CALI); Dibang Valley District, 8 km from Anini towards Mipi, 08 May 2016, *V.S. Hareesh 143778* (CALI).

20. *Musa rubra* Wall. ex Kurz., J. Agric. Soc. Ind. 14: 301. 1867.

(Fig. 56, 57)

Rhizomatous stoloniferous, suckering, clump-forming herbs. Pseudostem 30–250 cm tall cylindrical, pale green with black or dark reddish-brown patches. Leaves arranged terminally, erect; petiole 20–40 cm long, margin scarious, blackish-brown. Inflorescence erect, peduncle densely puberulent; female and male bud lanceolate, imbricate at apex, male bud top-shaped in advanced stage; bracts and flowers inserted separately on the axis; bracts reflexed, revolute before falling, non-revolute in female bract, red to brick red on both surfaces, faintly glaucous adaxially; flowers arranged in two rows. Infructescence compact with 4–6; fingers pedicellate, straight, prominently ridged, slightly pointed at apex without floral relicts, glabrous, pale green to green, yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 12.85–18.34 × 20.12–32.97 µm, rectangular, broader than high, with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly wavy; inter-costal cells 10.64–15.97 × 27.55–63.55 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to wavy. Abaxial costal cells 12.54–13.73 × 20.71–33.64 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy; inter-costal cells 9.12–22.57 × 24.82–78.03 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells broader, parelle or slightly deeper than other epidermal cells;

adaxial guard cells 28.51–33.38 μm long, abaxial guard cells 25.82–27.81 μm long. Adaxial stomatal index 0.00–2.77, abaxial stomatal index 3.03–12.21.

C.S. of lamina: 279–342 μm thick. Epidermis: adaxial epidermal cells 9–14 × 8–22 μm, rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–8 × 7–21 μm, rectamgular, isodiametric to broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 40–75 × 63–93 μm, rectangular, broader than high, 1-layered, cells uniform in size and shape adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 9–13 × 10–15 μm, hexagonal, isodiametric to broader than high; abaxial hypodermal cells 10–12 × 31–50 μm, rectangular, broader than high, 1-layered. Mesophyll 215–257 μm thick, divided in to 2-layered palisade and 4–6-layered parenchymatous septa or with air canal, traversed by thick 2 or 3-layered chlorenchymatous cells abaxially; palisade 65–71 μm thick, cells 32–38 × 8–11 μm, barrel-shaped, chlorenchymatous; parenchymatous septa 120–167 μm thick, cells 25–36 × 65–102 μm, broader than high. Larger vascular bundle 283–290 × 163–179 μm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2 or 3-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 65–70 × 95–111 μm, 4–6-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 13–18 × 63–76 μm, 2-layered, thick-walled cells with smaller lumen; protoxylem 1; metaxylem 35–39 μm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 57–62 × 50–57 μm, 7 or 8-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present. Oil glands present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 1 or 2-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 15–21 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 73–94 × 77–93 μm, exine 1.69–2.96 μm thick, intine 2.43–5.50 μm thick, P/E ratio 0.97, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds ellipsoid, 4.25–5.00 × 5.40–6.25 mm, non-arillate, smooth, black. Seeds shape not contorted by tight packing in fruits, seed body slightly flat at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.34–1.85 mm diameter at top, operculum apical.

Outer surface reticulate-areolate, cells irregularly-polygonal; periclinal wall slightly convex, smooth; anticlinal wall shallow, straight, smooth, unevenly thickened. Inner surface reticulate; periclinal wall concave with multi-angular silica body at centre, smooth; anticlinal wall prominently raised, straight, smooth to folded, unevenly thickened.

Seed coat 158.57–221.33 µm thick, 19–24-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 7.24–8.36 µm thick, 1-layered, cells U-shaped; tegmen 16.03–18.15 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 6.55–8.27 µm thick. Micropylar mesotestal proliferation 272.53–372.39 µm thick; micropylar collar 721.55–793.49 µm long, straight. Chalazal chamber 0.60–0.80 × 2.15–2.68 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 377.92–452.34 µm thick. Chalazal mucro absent, chalazal chamber column prominent. Embryo base bulbous.

Distribution*:* India (Manipur and Mizoram), Myanmar and Thailand.

Voucher specimens: **INDIA, Manipur:** Churchandpur District, Chongpi, way to Samti, 10 December 2012, *A. Joe & Ashfak 121655* (CALI); Tamenglong District, way to Silchar from Imphal, Noney, 12 December 2012, *A. Joe & Ashfak 121658* (CALI).

21. *Musa sabuana* K.Prasad, A.Joe, Bheem. & B.R.P.Rao, Indian J. Forest. 36(1): 151. 2013.

Musa indandamanensis L.J. Singh, Taiwania 59: 27. 2014

(Fig. 58, 59)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 5–9 m tall, cylindrical, pale to dark green or greenish-yellow with reddish brown patches. Leaves arranged terminally in a spiral manner, intermediate. Petioles 50–70 cm long, glaucous. Inflorescence sub-horizontal, peduncle glabrous, pale green to dark green; femal bud cylindrical, imbricate at apex, bracts adaxially glaucous, green to greenish-purple on both surface; male bud lanceolate, imbricate at apex, bracts open, non-revolute, green to pale green, pale green with pale purplish patches, adaxially brown purple with green striations and green tip, glabrous, abaxially with greenish-white, pale greenish-brown or dark pink; bracts and flowers inserted separately on the axis; flowers arranged in two rows. Infructescence compact with 8–13 hands; fingers pedicellate, pointed upwards curved, glabrous, faintly ridged, bottle-necked at apex with or without floral relicts, pale green to dark green, yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 8.12–13.12 × 16.78–31.6 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 6.02–13.56 × 11.75–43.52 µm, irregularly-polygonal, broader than high, cell wall straight to folded. Abaxial costal cells 11.42–13.55 × 12.97–27.14 µm, polygonal, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 8.76–14.45 × 12.81–60.52 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to folded or slightly wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 25.91–26.83 µm long, abaxial guard cells 23.93–25.49 µm long. Adaxial stomatal index 0.00–1.51, abaxial stomatal index 1.09–11.76.

C.S. of lamina: 438–514 µm thick. Epidermis: adaxial epidermal cells 5–10 × 8–16 µm, rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–9 × 7–18 µm, papillose, irregularly-shaped, 1-layered. Hypodermis: adaxial hypodermal cells 27–77 × 47–80 µm, rectangular, isodiametric to broader than high, 4-layered, upto either side of 4th smaller vascular bundle, followed by 3-layers upto 8th or 9th bundles and further 2-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 2-layered, isodiametric, 9–15 × 17–23 µm, hexagonal, broader than high; abaxial hypodermis 7–18 × 10–38 µm, rectangular, broader than high, 2-layered. Mesophyll 533–556 µm thick, divided in to 2-layered palisade and 10 or 12-layered parenchymatous septa or with air canal, traversed by 1 or 2-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 112–119 µm thick, cells 73–78 × 15–18 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 220–228 µm thick, cells 23–27 × 51–107 µm, broader than high . Larger vascular bundle 435–448 × 192–201 µm, obovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2 or 3-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 163–176 × 180–195 µm, 8–15-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 52–69 ×

67–81 µm, 5 or 6-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem 46–60 µm in diameter, ellipsoid, surrounded by smaller isodiametric parenchymatous cells; phloem 46–64 × 40–65 µm, 8–10-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 2 or 3-layers of collenchyma, and further large parenchymatous ground tissue; chlorechyma are distributed in both the side, obvious adaxially. Air canals larger with one arc of 25–29 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 103–115 × 101–115 µm, exine 1.09–2.72 µm thick, intine 2.77–4.31 µm thick, P/E ratio 1.01, prolate-spheroidal, inaperturate with verrucate sculpturing.

Seed morphology and anatomy

Seeds oblate, 3.25–3.85 × 5.00–6..25 mm, non-arillate, verrucate, black, turned to dull black or brown when dry. Seed shape contorted by tight packing in fruits, seed body flat at micropyle, weakly taper at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.75–2.25 mm diameter at top, operculum apical.

Outer surface reticulate, cells irregularly-polygonal; periclinal wall concave, smooth; anticlinal wall raised, straight, smooth, unevenly thickened. Inner surface prominently raised, straight, smooth, unevenly thickened; periclinal wall prominently concave, with multiangular silica body at centre, smooth; anticlinal wall prominently raised, straight, smooth to folded, unevenly thickened.

Seed coat 183.92–228.86 µm thick, 22–26-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 15.00–17.56 µm thick, 1-layered, cells U-shaped; tegmen 22.70–23.96 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 12.31–14.04 µm thick. Micropylar mesotestal proliferation 350.74–420.93 µm; micropylar collar 657.37–768.85 µm long, straight to weakly curved. Chalazal chamber 0.60–0.65 × 2.52–2.95 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 513.91–584.47 µm thick. Chalazal mucro absent, chalazal chamber column intermediate. Embryo base bulbous.

Distribution: Endemic to Andaman and Nicobar Islands, India.

***Note**:* Based on the present study, *Musa indanadamaneisi* synonimised under *Musa sabuana* (Hareesh *et al.,* 2017a).

Voucher specimens: **INDIA. Andaman Islands**: Little Andaman Islands, Ramakrishnapur, 09 August 2017, *M. Sabu & V.S. Hareesh 152776* (CALI); Krishna Nalah, 09 August 2017, *M. Sabu & V.S. Hareesh 152779* (CALI); Nicobar Islands, Great Nicobar Island, Campbell Bay, Vijayanagar, 17 August 2017. *V.S. Hareesh 152785* (CALI); Laxmi Nagar, 17 August 2017, *V.S. Hareesh 152786* (CALI); 1 km away from Laxmi Nagar towards Indira Point, 17.08.2017, *V.S. Hareesh 152787* (CALI); 1 km away from Great Nicobar Biosphere Reserve check gate, 18 August 2017, *V.S. Hareesh 152789* (CALI).

22. *Musa sikkimensis* Kurz., J. Agric. Hort. Soc. India. 5: 164. 1878.

(Fig. 60, 61)

Rhizomatous stoloniferous, suckering, clump-forming herbs. Pseudostem 5–8 m tall, cylindrical, dark reddish-black or green with dark reddish-black blotches. Leaves arranged terminally, intermediate; petioles 35–60 cm long, glaucous, green, petiole margins dry wrinkled, scarious. Inflorescence horizontal, peduncle, green, puberulent; female and male bud ovate-oblong, imbricate, reflexed and revolute before falling; bracts and flowers inserted separately on the axis; bracts faintly glaucous, dark violet-purple with yellow apex adaxially, reddish-purple abaxially; flowers arranged in two rows. Infructescence lax with 4–7 hands; fingers pedicellate, pointed upwards, curved, prominently angled, slightly pointed or truncate at apex, glabrous, green.

Vegetative anatomy

Epidermis: Adaxial costal cells 12.12–18.73 × 19.45–61.09 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 10.31–20.44 × 13.78–62.43 µm, rectangular, broader than high, cell wall straight to folded. Abaxial costal cells 8.94–15.65 × 11.57–18.68 µm, rectangular, isodiametric to broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight; inter-costal cells 8.28–17.37 × 11.00–59.17 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 21.46–25.94 µm long, abaxial guard cells 22.31–24.35 µm long. Adaxial stomatal index 0.00–2.62, abaxial stomatal index 5.87–15.59.

C.S. of lamina: 253–305 µm thick. Epidermis: adaxial epidermal cells 5–12 × 9–12 µm, rectangular, isodiametric, 1-layered, covered with thick cuticle; abaxial epidermal cells 5–7 × 6–20 µm, rectangular, isodiametric to broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 30–42 × 39–86 µm, rectangular, broader than high, 1-layered, cell length reduced adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 5–11 × 10–19 µm, hexagonal, isodiametric; abaxial hypodermal cells 9–14 × 19–59 µm, rectangular, broader than high, 2-layered up to 1st smaller vascular bundle, and 1-layered. Mesophyll 203–248 µm thick, divided in to 2-layered palisade and 8–10-layered parenchymatous septa or with air canal, traversed by 1 or 2-layered chlorenchymatous cells near the vascular bundles abaxially; palisade 45–54 µm thick, cells 22–29 × 7–9 µm, barrel-shaped, chlorenchymatous; parenchymatous septa 140–162 μm thick, cells 11–25 × 25–54 μm, broader than high. Larger vascular bundle 285–298 × 190–197 μm, ovate to ventricose, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2 or 3-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 58–74 × 93–118 μm, 7–9-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 20–38 × 66–87 μm, 3 or 4-layered, thick-walled cells with smaller lumen; protoxylem 3 or 4; metaxylem 35–42 μm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 47–56 × 50–58 μm, 7–13-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present. Oil glands present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with smaller lumen, followed by 1 or 2-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 20–25 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in Y-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the

differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 135–185 × 140–180 µm, exine 3.55–8.00 µm thick, intine 6.03–10.13 µm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 4.85–6.00 × 6.00–10.5 mm, non-arillate, smooth-verrucate, dull-black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, flat at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 2.35–3.25 mm diameter at top, operculum apical.

Outer surface reticulate, cells irregularly-polygonal; periclinal wall concave with tubercle at centre, smooth to slightly-folded; anticlinal wall raised, straight, smooth to slightly-folded, unevenly thickened. Inner surface reticulate; periclinal wall concave with multi-angular silica body at centre, smooth; anticlinal wall raised, straight, smooth to slightly-folded, unevenly thickened.

Seed coat 445.69–511.11 µm thick, 29–37-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 12.67–13.63 µm thick, 1-layered, cells U-shaped; tegmen 29.43–32.12 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 13.45–14.73 µm thick. Micropylar mesotestal proliferation

948.58–1060.40 µm; micropylar collar 901.85–964.19 µm long, straight. Chalazal chamber 0.80–1.01 × 3.50–3.65 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 1369.88–1435.20 µm thick. Chalazal mucro absent, chalazal chamber column prominent. Embryo base bulbous.

***Distribution**:* Bhutan, India (Arunachal Pradesh, Manipur, Mizoram, Sikkim and West Bengal), Nepal and Sikkim.

Voucher specimens: **INDIA: Arunachal Pradesh:** West Kameng District, Sessa village, 30 June 2015, *A. Joe & V.S. Hareesh 121847* (CALI); West Kameng District, Sessa village, behind primary school, 01 July 2015, *A.Joe & V.S. Hareesh 121868* (CALI); Tirap District, Laju, 31 May 2016, *V.S. Hareesh 149343* (CALI); Papum Pare District, near Pareng 27 May 2017, *V.S. Hareesh 152690* (CALI).

Key to the infraspecific taxa of *Musa sikkimensis* in India

1. Seed outer and inner surface sculpturing reticulate; inner anticlinal wall raised; inner periclinal wall concave with multi-angular silica body at centre .... ***M. sikkimensis* var. *sikkimensis***
1. Seed outer surface sculpturing alveolate; inner surface reticulate-foveate; inner anticlinal wall shallow; inner periclinal wall concave, deeply folded….. ***M. sikkimensis* var. *simmondsii***

22.1. *Musa sikkimensis* Kurz var. ***simmondsii*** A. Joe & M. Sabu, Webbia, 2016.

(Fig. 62 A, B, 63)

Stoloniferous, rhizomatous, suckering, clump forming herbs. Pseudostem 4–7 m tall, cylindrical, greenish-yellow with red pigmentation, faintly glaucous towards apex. Leaves arranged terminally, intermediate; petioles 32–50 cm long, glaucous, green to pale greenish-yellow, margins scarious, wrinkled. Inflorescence pendulous, peduncle green, puberulous; male bud ovate-oblong, convolute; bracts and flowers inserted separately on the axis; bracts closely arranged, revolute before falling, faintly glaucous, dark violet-purple with yellow apex adaxially, red-purple with yellow apex abaxially; flowers arranged in two rows. Infructescence compact with 2–3 hands; fingers pedicellate, pedicel fused at base, straight, pointed upwards, nearly rounded without ridges, slightly pointed at apex without floral relicts, glabrous, green.

Pollen morphology

Pollen 138–161 × 135–159 μm, exine 3.18–8.17 μm thick, intine 6.17–10.10 μm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 4.85–6.00 × 6.00–10.50 mm, non-arillate, smooth-verrucate, dull black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 2.75–3.50 mm diameter at top, operculum apical.

Outer surface alveolate, cells irregularly-polygonal; periclinal wall concave or with faintly tubercle at centre, smooth; anticlinal wall slightly raised, straight to slightly wavy, smooth, unevenly thickened. Inner surface reticulate-foveate; periclinal wall concave, deeply folded, smooth; anticlinal wall shallow, straight to slightly wavy, smooth to slightly-folded, unevenly thickened.

Seed coat 418.22–459.95 µm thick, 33–39-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 9.82–15.31 µm thick, 1-layered, cells U-shaped; tegmen 28.16–31.02 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 10.90–13.70 µm thick. Micropylar mesotestal proliferation 970.00–1016.52 µm thick; micropylar collar 1114.80–1198.13 µm long, straight. Chalazal chamber 0.90–1.05 × 4.90–5.20 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 1293.06–1358.74 µm thick. Chalazal mucro present, chalazal chamber column intermediate. Embryo base bulbous.

Distribution: India: Manipur.

Voucher specimens: **INDIA**, **Manipur:** Churchandpur District, Tuilumzang, way to Samti, 10 December 2012, *A. Joe & Ashfak 121650* (CALI).

23. ***Musa thomsonii*** (King *ex* Baker) A.M.Cowan & Cowan, Trees North Bengal, 135. 1929.

(Fig. 64, 65)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 4–5 m tall, cylindrical, pale green with reddish-brown patches, glaucous towards the apex. Leaves arranged terminally, intermediate; petioles 46–50 cm long, faintly glaucous, petiole margins blackish-brown, scarious. Inflorescence horizontal, peduncle, glabrous dark green; female buds lanceolate, imbricate; male bud lanceolate to ovate or intermediate to top shaped at advanced blooming, convolute; bracts and flowers inserted separately on the axis; bracts reflexed, revolute before falling, faintly glaucous, purplish-brown with yellow streaks adaxially, cream to creamy yellow abaxially; flowers arranged in two rows. Infructescence lax with 8–12 hands; fingers pedicellate, pointed upwards straight or curved, prominently ridged, pointed at apex without any floral relicts, glabrous, pale green to green, yellow when ripen.

Vegetative anatomy

Epidermis: Adaxial costal cells 9.07–13.21 × 24.73–51.43 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly-folded; inter-costal cells 9.08–18.96 × 18.34–71.25 µm, rectangular, broader than high, cell wall straight to folded. Abaxial costal cells 8.34–14.26 × 17.18–35.80 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous; inter-costal cells 7.10–17.73 × 29.07–71.69 µm, irregular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy to sinuous.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells sub-equal, deeper than other epidermal cells; adaxial guard cells 27.55–30.52 µm long, abaxial guard cells 24.65–27.08 µm long. Adaxial stomatal index 0.66–0.73, abaxial stomatal index 8.07–11.45.

C.S. of lamina: 298–364 µm thick. Epidermis: adaxial epidermal cells 7–17 × 6–16 µm, hexagonal, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 6–11 × 9–27 µm, rectangular, broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 12–28 × 33–54 µm, rectangular, broader than high, 2-layered upto both sides of the 4^{th} or 5^{th} smaller vascular bundles, and further 1-layered, cells uniform in size and shape adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 7–13 × 10–26 µm, irregular; abaxial hypodermal cells 13–28 × 22–52 µm, rectangular, broader than high, 2-layered except larger and smaller vascular bundles. Mesophyll 190–252 μm thick, divided in to 2-layered palisade and 4-layered parenchymatous septa or with air canal, traversed by 2 or 3-layered chlorenchymatous cells below the vascular bundles; palisade 80–92 μm thick, cells 39–44 × 9–11 μm, barrel-shaped, chlorenchymatous; parenchymatous septa 107–140 μm thick, cells 26–51 × 47–94 μm, broader than high. Larger vascular bundle 300–315 × 189–231 μm, ventricose, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2 or 3-layered, circular, parenchymatous bundle sheath followed by inner thin-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 65–70 × 161–173 μm, 5–7-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 19–24 × 76–86 μm, 2 or 3-layered, thick-walled cells with smaller lumen; protoxylem 2–4; metaxylem 40–43 μm in diameter, circular, surrounded by smaller isodiametric parenchymatous cells; phloem 46–54 × 56–63 μm, 7–10-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial hypodermis in the mesophyll, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermal cells polygonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 1 or 2-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 27–32 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 91–113 × 93–115 µm, exine 1.98–3.45 µm thick, intine 3.26–5.19 µm thick, P/E ratio 0.99, oblate-spheroidal, inaperturate with verrucate sculpturing.

Seed morphology and anatomy

Seeds oblate, 3.00–4.00 × 4.83–6.23 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.25–1.75 mm diameter at top, operculum apical.

Outer surface reticulate, cells irregularly-polygonal; periclinal wall concave, smooth; anticlinal wall raised, straight to slightly wavy, smooth to sinuous, unevenly thickened. Inner surface reticulate; periclinal wall concave with multi-angular silica body at centre, rugose; anticlinal wall prominently raised, straight to slightly wavy, smooth to folded, unevenly thickened.

Seed coat 191.77–266.09 µm thick, 24–28-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 14.32–15.55 µm thick, 1-layered, cells U-shaped; tegmen 23.53–25.45 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 50–8.53 µm thick. Micropylar mesotestal proliferation 297.18–406.59 µm thick; micropylar collar 593.86–640.90 µm long, straight. Chalazal chamber 0.80–1.98 × 2.35–2.85 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 501.72–590.90 µm thick. Chalazal mucro present, chalazal chamber column absent. Embryo base bulbous.

Distribution*:*India (Sikkim, Meghalaya and Mizoram).

Voucher specimens: **INDIA. Mizoram:** Darlawn District, N24°02.621′ E092°58.694′; 141 m, 17 March 2012, *A. Joe & P.E. Sreejith 130821* (CALI); **Meghalaya:** West Garo Hills, Tura Peak, 02 June 2017, *V.S. Hareesh 152706* (CALI).

24. *Musa velutina* H.Wendl. & Drude, Gartenflora 24: 65, t. 823. 1875.

(Fig. 66, 67)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 45–180 cm tall, cylindrical, pale green or creamy green to pale purplish, with brown or reddish-brown blotches. Leaves arranged terminally, intermediate to drooping; petioles 15–55 cm long, green, margins scarious with dry appearance. Inflorescence erect, peduncle pubescent, cream or creamy-pink to deep pink or red; female buds lanceolate, convolute; female and male; bracts and flowers inserted separately on the axis; bracts reflexed, revolute before falling, female bract pubescent, pale pink adaxially, pink or reddish-pink abaxially; male bratcs glabrous, adaxially pale pink, pink or reddish-pink abaxially; flowers arranged in a single row. Infructescence compact with 3–6 hands; fingers pointed upwards, straight, prominently ridged, blunt at apex with or without floral relicts, densely pubescent, pink or red, peel splits open when ripen, exposing pulp and seeds.

Vegetative anatomy

Epidermis: Adaxial costal cells 10.38–12.46 × 15.34–39.61 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall straight to slightly wavy; inter-costal cells 8.37–20.55 × 20.41–62.87 µm, rectangular, broader than high, cell wall straight to folded or slightly wavy. Abaxial costal cells 11.36–18.95 × 17.22–26.78 µm, rectangular, broader than high with their longer axis perpendicular to the longitudinal vein, cell wall wavy; inter-coastal cells 11.69–19.38 × 12.21–50.57 µm, irregular, broader than high, cell wall wavy.

Stomata: Distributed in the inter-costal region, frequent in abaxial epidermis than adaxial, tetracytic; terminal subsidiary cells short, non-papillose; lateral subsidiary cells narrow, deeper than other epidermal cells; adaxial guard cells 29.95–32.02 µm long, abaxial guard cells 23.65–25.08 µm long. Adaxial stomatal index 0.00–2.65, abaxial stomatal index 5.59–9.97.

C.S. of lamina: 310–322 µm thick. Epidermis: adaxial epidermal cells 8–14 × 11–18 µm, rectangular, isodiametric to broader than high, 1-layered, covered with thick cuticle; abaxial epidermal cells 6–8 × 9–27 µm, rectangular, broader than high, 1-layered. Hypodermis: adaxial hypodermal cells 25–48 × 38–64 µm, hexagonal, broader than high, 1-layered, cells uniform in size and shape adjacent to smaller vascular bundles; adaxial hypodermal cells (above the larger vascular bundle) 1-layered, 10–12 × 13–14 µm, hexagonal, isodiametric; abaxial hypodermal cells 13–20 × 28–46 µm, rectangular, broader than high, 1-layered. Mesophyll 176–267 μm thick, divided in to 2-layered palisade and 6 or 7-layered parenchymatous septa or with air canal; palisade 62–72 μm thick, cells 33–42 × 7–10 μm, barrel-shaped, chlorenchymatous; parenchymatous septa 157–181 μm thick, cells 16–43 × 36–73 μm, irregular. Larger vascular bundle 266–272 × 187–194 μm, ovate, attached to the adaxial hypodermis with sclerenchymatous bundle sheath, surrounded by outer 2 or 3-layered, circular, parenchymatous bundle sheath followed by inner thick-walled sclerenchymatous bundle sheath with larger lumen; adaxial bundle sheath 58–65 × 56–60 μm, 5 or 6-layered, thick-walled cells with smaller lumen; abaxial bundle sheath 20–23× 54–66 μm, 2–3-layered, thick-walled cells with smaller lumen; protoxylem 1 or 2; metaxylem 39–56 μm in diameter, ellipsoid, surrounded by smaller isodiametric parenchymatous cells; phloem 46–56 × 45–51 μm, 6–8-layered, parenchymatous, thin-walled. Smaller vascular bundles connected to adaxial or abaxial hypodermis, variable in cellular shape and numbers. Calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present.

C.S. of petiole: Adaxial and abaxial surface U-shaped; petiolar wings open. Abaxial epidermal cells rectangular, broader than high, 1-layered, covered with thick cuticle; hypodermis polygonal, isodiametric to broader than high, 1-layered, sclerenchymatous thick-walled cells with larger lumen, followed by 2 or 3-layered collenchyma, and further large parenchymatous ground tissue. Air canals larger with one arc of 20–25 lacunae. Bundle arcs I, II and III are present; arc I of larger vascular bundles situated adaxial to and pectinating with air canal, arranged in V-shape; Arc II consists of intermediate sized vascular bundles with well developed fibrous sheaths pectinating with fibrous strands, situated between air canal and abaxial tissues; Arc III consists of comparatively fewer, small vascular bundles and fibrous bundles situated adjacent to adaxial surface.

C.S. of mid rib: Adaxial surface wide U-shaped, abaxial surface U-shaped. C.S shows similar anatomical features, as that of the petiole, except for the differences in the lesser number of air canals and proportions of the vascular bundle size.

In addition, petiole and midrib exhibit numerous chlorenchymatous cells on adaxial and few on the abaxial side, and calcium oxalate crystals throughout.

Pollen morphology

Pollen 80–104 × 85–107 µm, exine 1.59–2.72 µm thick, intine 3.37–7.32 µm thick, P/E ratio 0.96, oblate-spheroidal, inaperturate with rugulate sculpturing.

Seed morphology and anatomy

Seeds oblate, 2.75–3.25 × 4.35–6.25 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly flat at micropyle and chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.40–1.90 mm diameter at top, operculum apical.

Outer surface reticulate, cells irregularly-polygonal; periclinal wall concave or rarely with faintly tubercle at centre, smooth; anticlinal wall slightly raised, straight, smooth, unevenly thickened. Inner surface reticulate; periclinal wall concave with multi-angular silica body at centre, smooth to rugose; anticlinal wall prominently raised, straight, smooth to folded, unevenly thickened.

Seed coat 171.65–196.19 µm thick, 25–30-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 5.47–7.19 µm thick, 1-layered, cells U-shaped; tegmen 8.52–9.82 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 6.69–7.95 µm thick. Micropylar mesotestal proliferation 268.53–393.56 µm thick; micropylar collar 566.80–622.63 µm long, straight to weakly curved. Chalazal chamber 0.45–0.65 × 2.40–2.85 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 239.29–308.31 µm thick. Chalazal mucro absent, chalazal chamber column intermediate. Embryo base bulbous.

Distribution: India (Arunachal Pradesh, Assam, Meghalaya and Nagaland) and Myanmar.

Voucher specimens:**INDIA, Arunachal Pradesh:** Lower Dibang Valley,On the way to Iduli from Roing, 04 July 2015, *A. Joe & Hareesh V.S. 121880* (CALI); **Assam:** Tinsukia District, near Thermal Gate, Makum Road, 08 August 2011, *A.Joe & Sreejith 130702* (CALI).

Key to the infraspecific taxa of *Musa velutina* in India

1. Inner anticlinal wall prominently raised; thickness of tegmen less than 9.99 µm ....***M. velutina var. velutina***
1 Inner anticlinal wall shallow to raised, thickness of tegmen more than 9.99 µm…...***M. velutina var. variegata***

24.1. *Musa velutina* H.Wendl. & Drudevar. ***variegata*** A.Joe, M.Sabu & Sreejith, Pl. Syst. Evol. 300(1): 13. 2014.

(Fig. 62 C, D, 68)

Rhizomatous, stoloniferous, suckering, clump-forming herbs. Pseudostem 60–70 cm tall, cylindrical, pale green. Leaves arranged terminally, intermediate; petiole 18–24 cm long, pale pink. Inflorescence erect, peduncle whitish-pink, densely pubescent; female and male bud lanceolate, convolute; bracts and flowers inserted separately on the axis; bracts revolute before falling, dark red with whitish-pink striations on both side, densely pubescent with white hairs towards the apex of adaxial surface; flowers arranged in single row. Infructescnce compact with 3–4 fruits per hand; fingers pedicellate, pointed upwards, pubescent, angled or round, truncate at apex without floral relicts, pink to red, pink or red when ripen.

Pollen morphology

Pollen 81–106 × 83–109 µm, exine 1.63–2.67 µm thick, intine 3.50–6.45 µm thick, P/E ratio 0.97, oblate-spheroidal, inaperturate with rugulate sculpturing

Seed morphology and anatomy

Seeds oblate, 2.05–3.00 × 4.20–5.63 mm, non-arillate, verrucate, black, turn to brown when dried. Seed shape contorted by tight packing in fruits, seed body slightly taper at micropyle, flat at chalazal region, hilar rim inconspicous. Micropylar region conical, micropylar plug 1.30–1.75 mm diameter at top, operculum apical.

Outer surface reticulate, cells irregularly-polygonal; periclinal wall concave, smooth; anticlinal wall raised, straight, smooth, unevenly thickened. Inner surface reticulate; periclinal wall concave with multi-angular silica body at centre, smooth to rugose; anticlinal wall raised or shallow, straight, smooth to folded, unevenly thickened.

Seed coat 162.60–195.43 µm thick, 25–28-layered; exotesta with multi-angular crystalline silica bodies; mesotesta composed of pitted sclerotic cells; endotesta 4.94–6.69 µm thick, 1-layered, cells U-shaped; tegmen 9.70–13.13 µm thick, 2-layered, cells elongated, spongy; aleurone or inner endosperm layer 7.08–7.64 µm thick. Micropylar mesotestal proliferation 277.99–330.04 µm thick; micropylar collar 526.99–584.79 µm long, straight.

Chalazal chamber 0.40–0.50 × 2.40–2.55 mm, chalazal pigment gap discoid, endotestal gap absent, chalazal mesotestal proliferation 228.31–283.70 µm thick. Chalazal mucro absent, chalazal chamber column absent. Embryo base bulbous.

***Distribution**:* Endemic to Northeastern India (Assam).

Voucher specimen: Assam: Tinsukia District, Makum road, Thermal Gate, alt. 146 m, 08 August 2011, *Alfred Joe & P.E. Sreejith 130701* (CALI).

Chapter 6

DISCUSSION

DISCUSSION

COMPARATIVE VEGETATIVE ANATOMY

Epidermis

Epidermis of *Ensete* and *Musa* are uniformly single-layered, covered with cuticle without epidermal hairs. The cross sections of all taxa show that anticlinal outer cell wall is thick when compared to the inner cell wall. In surface view, all taxa show differences in their costal and inter-costal cell shapes and anticlinal wall nature in both surfaces. Costal cells are arranged in a regular manner in all taxa, whereas inter-costal cells as regular or irregularly arranged. Two types of adaxial costal cells *viz.* polygonal in *E. glaucum*, *E. superbum, M. argentii* and *M. arunachalensis* (Fig. 69 A, B, D, E) and rectangular in rest of the studied taxa, are observed. Abaxial costal cells are rectangular in shape in all *Musa* taxa where as they are polygonal in *Ensete.* The nature of adaxial anticlinal wall varies from straight, straight to folded or straight to wavy; but it does not have any importance in the delimitation of taxa. However, the anticlinal wall nature of the abaxial costal cells has great importance and four different types are observed in Indian Musaceae (straight, straight to folded, sinuous or wavy to sinuous). In which, sinuous or wavy to sinuous type is present in *M. acuminata, M. argentii, M. arunachalensis, M. aurantiaca, M. flaviflora, M. itinerans, M. kattuvazhana, M. ochracea* and *M. thomsonii* (Fig. 70 C, D, E, F, O, P, Q, V, C1), the remaining taxa show either straight or straight to folded types. The nature of anticlinal cell wall observed matches with the result of Tomlinson (1969), except that of *M. rubra* (mentioned as *M. laterita*) in which we got slightly wavy type of anticlinal cell against the sinuous type in Tomlinson's report.

Inter-costal cell shape of adaxial epidermis varies from irregularly polygonal to rectangular. Irregularly-polygonal type is observed in *E. glaucum, E. superbum, M. argentii, M. arunachalensis, M. aurantiaca, M. chunii, M. flaviflora, M. mannii, M. markkui* and *M. sabuana* (Fig. 69 A, B, D, E, F, M, O, R, T, A1), and rest of the taxa show rectangular shaped cells. In majority of the taxa, adaxial inter-costal cell shape is irregular, except irregularly-polygonal shaped cells found in *E. glaucum, E. superbum, M. chunii, M. nagensium, M. ochracea* and *M. puspanjaliae* (Fig. 69 A, M, U, V, Y). Anticlinal cell wall varies from straight to wavy, straight to folded, wavy or wavy to sinuous in Musaceae. Within Musaceae sinuous or wavy to sinuous type is present in *M. acuminata, M. arunachalensis, M. flaviflora, M. itinerans, M. kattuvazhana, M. ochracea, M. pradhanii* and *M. thomsonii* (Fig. 69 C, E, O, P, Q, V, X, C1). The rest of the taxa have either straight to wavy or straight to folded cell wall, but this character is not a stable one. However, the shape of the adaxial and abaxial costal and inter-costal cells and the sinuous nature of anticlinal walls are constant and have great importance in taxonomy.

In cross section, abaxial epidermal cells are papillose in *M. acuminata, M. argentii, M. arunachalensis, M. balbisiana* as well as in all the studied infraspecific taxa, *viz., M. chunii, M. flaviflora, M. mannii, M. markkui* and *M. sabuana,* whereas, other species show either broader than high or higher than broad rectangular cells. These results also support Tomlinson (1969); who mentioned *M. balbisiana* and *M. flaviflora* as species with papillose abaxial epidermis (Table 1).

Stomata

Numerous stomata are seen in the abaxial surface whereas, they are less frequent in the adaxial surface and are aligned in the inter-costal region. Tetracytic stomata are observed in all taxa studied. Terminal subsidiary cells are short, non-papillose, whereas lateral cells are narrower. In all taxa, stomata are aligned slightly deeper than the other epidermal cells. Stomatal index has no significance in taxonomy. It varies according to the habitat in which they grow (shade to open areas). The guard cells are mostly 24–33 µm long in adaxial surface, and 23–30 µm long in abaxial surface. In most of the species, adaxial guard cells are longer than abaxial, but in taxa such as *M. cheesmanii, M. chunii, M. mannii, M. markkui, M. nagensium* and *M. puspanjaliae,* adaxial cells are smaller than abaxial. *Musa itinerans, M. ornata* and *M. pradhanii* possess stomata of sub-equal in length in both the surfaces (Table 2, 3).

C.S. of lamina

Thickness of lamina varies from one taxon to another and it provides sufficient data for species delimitation (Skutch, 1927; Tomlinson, 1969; Triplett & Kirchoff, 1991). All taxa with erect inflorescence (*M. aurantiaca, M. mannii, M. markkuana, M. ornata, M. rubra* and *M. velutina* var. *velutina*) have lamina thickness less than 320 µm (above smaller vascular bundles). Some species with pendulous inflorescence such as *M. cylindrica* and *M. nagensium* also have lamina thickness less than 320 µm. Rest of the taxa have lamina thickness above 320 µm and these those are intermediate sized sub-horizontal to pendulous tall inflorescence bearing plants. Differences in the lamina thickness between the smaller and larger vascular bundle is found to be least in *M. balbisiana var. bheem-kola* (about 16 µm) (Fig. 71 I) and the most in *M. balbisiana var. sepa-athiya* (about 63 µm) (Fig. 71 I) (Table 3).

Hypodermis

Hypodermis is considered as one of the most important parts with major taxonomic importance. Adaxial hypodermal cell layers vary from 1–4, while abaxial layers are either 1 or 2. One-layered adaxial hypodermis is seen in *M. cylindrica, M. rubra, M. sikkimensis* and *M. velutina* (Fig. 71 N, Z, B1, D1). Two-layered in *E. superbum. M. acuminata, M. argentii, M. aurantiaca, M. balbisiana* var. *andamanica, M. balbisiana* var. *bheem-kola, M. itinerans, M. mannii, M. markkuana, M. nagensium, M. ochracea, M. ornata, M. pradhanii* and *M. thomsonii* (Fig. 71 B, C, D, F, H, I, P, R, S, U, V, W, X, C1). *Ensete glaucum, M. arunachalensis, M. balbisiana var. elavazhai, M. cheesmanii, M. chunii, M. flaviflora, M. kattuvazhana, M. markkui* and *M. puspanjaliae* (Fig. 71 A, E, J, L, M, O, Q, T, Y) are characterised by three-layers of hypodermal cells. *Musa balbisiana* var. *sepa-athiya* possesses both 2 and 3-layers of hypodermal cells. *Musa sabuana* (Fig. 71 A1) is unique from other Indian taxa having 4-layered hypodermis. Abaxial hypodermis is 1-layered in most of the taxa, however, species such as *E. glaucum, M. acuminata, M. argentii, M. arunachalensis, M. balbisiana var. balbisiana, M. balbisiana var. andamanica, M. cheesmanii, M. flaviflora, M. markkui, M. puspanjaliae* and *M. sabuana* (Fig. 73 A, C, D, E, G, H, L, O, T, Y, A1; 73 A, C, D, E, G, H, L, O, T, Y, A1) are characterised by 2-layers.

In Musaceae, both adaxial and abaxial hypodermal cells are hexagonal in surface view and rectangular or hexagonal in cross section. In cross section, adaxial hypodermis consists of both hexagonal as well as rectangular cells. Though hexagonal type is the prominent cell shape, species such as *M. acuminata, M. aurantiaca, M. cylindrica, M. rubra, M. sikkimensis* var. *sikkimensis, M. thomsonii* and *M. velutina* var. *velutina* (Fig. 71 C, F, N, Z, B1, C1, D1) have rectangular cells. Abaxial hypodermal cells are hexagonal in *E. glaucum, E. superbum, M. arunachalensis, M. balbisiana* var. *balbisiana, M. balbisiana* var. *andamanica, M. balbisiana* var. *elavazhai, M. balbisiana* var. *sepa-athiya, M. cheesmanii* and *M. itinerans* (Fig. 71 A, B, E, G, H, J, K, L, P) whereas other taxa show rectangular shaped cells.

Hypodermal cell above the larger vascular bundle

Hypodermis above the larger vascular bundles is either 1 or 2-layered and the cell shape also varies. One-layered hypodermis is observed in about half of the taxa studied *viz., M. acuminata, M. argentii, M. aurantiaca, M. balbisiana var. elavazhai, M. cylindrica, M. flaviflora, M. itinerans, M. mannii, M. markkuana, M. ornata, M. pradhanii, M. rubra, M. sikkimensis, M. thomsonii* and *M. velutina var. velutina* (Fig. 72 C, D, F, J, N, O, P, R, S, W, X, Z, B1, C1, D). These species exhibit polygonal, hexagonal or irregularly shaped hypodermal cells. Irregularly shaped cells are seen in *M. acuminata, M. cylindrica* and *M. thomsonii* (Fig. 72 C, N, C1). Hexagonal or isodiametric cells are the characteristics of *M. itinerans, M. markkuana, M. pradhanii* and *M. sikkimensis* var. *sikkimensis* (Fig. 72 P, S, X, B1). Hexagonal, higher than broader cells, is the key character of *M. aurantiaca* and *M. mannii* (Fig. 72 F, R), and the remaining taxa exhibit hexagonal, broader than high hypodermal cells.

Ensete glaucum, E. superbum, M. arunachalensis, M. balbisiana var. *balbisiana, M. balbisiana* var. *andamanica, M. balbisiana* var. *bheem-kola, M. balbisiana* var. *sepa-athiya, M. cheesmanii, M. chunii, M. kattuvazhana, M. markkui, M. nagensium, M. ornata, M. puspanjaliae* and *M. sabuana* (Fig. 72 A, B, E, G, H, I, K, L, M, Q, T, U, W, Y, A1) possess 2-layered hypodermis above larger vascular bundles. Hypodermal cells in both the layers are isodiametric in *M. markkui, M. nagensium* and *M. sabuana* (Fig. 72 T, U, A1), while others have non-isodiametric cells. *Musa nagensium* and *M. sabuana* exhibit hexagonal, broader than high hypodermal cells, where as *M. markkui* has polygonal, broader than high cells. Taxa with non-isodiametric cells exhibit differences in the proportion of the cell size. Outer layers have larger cells than inner layers in *E. glaucum, E. superbum, M. arunachalensis, M. balbisiana var. balbisiana, M. balbisiana var. bheem-kola, M. cheesmanii,* *M. chunii, M. kattuvazhana* and *M. ochracea* (Fig. 72 A, B, E, G, I, L, M, Q, V), where as in the remaining taxa outer layers have smaller cells and inner layers have larger cells.

Hypodermal cells in both outer and inner layers also show significant differences in their shapes. Outer and inner cells are polygonal, higher than broad in *E. glaucum* and polygonal broader than high in *M. chunii.* The outer cells of *E. superbum, M. balbisiana var. balbisiana, M. balbisiana var. andamanica, M. balbisiana var. bheem-kola, M. balbisiana var. elavazhai, M. cheesmanii, M. kattuvazhana, M. ochracea, M. puspanjaliae,* are hexagonal, broader than high, where as hexagonal isodiametric shaped cells are seen in *M. arunachalensis* and *M. balbisiana var. sepa-athiya.* Inner hypodermis with hexagonal, isodiametric cells are seen in *E. superbum* and *M. cheesmanii,* where as the remaining taxa such as *M. arunachalensis, M. balbisiana var. balbisiana, M. balbisiana var. andamanica, M. balbisiana var. bheem-kola, M. balbisiana var. sepa-athiya, M. kattuvazhana* and *M. ochracea* with non-isodiametric cell layers exhibit hexagonal, broader than high cells (Table 4).

In all studied taxa, mesophyll is divided in to 2 or 3-layered palisade and paranchymatous transverse septa or with air canals, or with sparsely chlorenchymatous cells on abaxial side. Anticlinal cell wall of the parenchymatous septum varies from straight, folded to wavy or sinuous. The exception is *M. ornata that* consists of thick layered mesophyll without transverse septa or air canal. This supports the results of Tomlinson (1969).

In most of the species, larger vascular bundles are attached to the adaxial hypodermis only, where as in *E. superbum, M. cheesmanii, M. markkuana* and *M. velutina var. velutina* (Fig. 74 B, L, S, D1) the attachments are seen on both the hypodermis. One exception is *E. glaucum,* where the attachment is either adaxial or on both the hypodermis. Shape of the larger vascular bundles varies from elliptic (*M. balbisiana var. andamanica, M.*

balbisiana var. bheem-kola, M. balbisiana var. sepa-athiya, M. cheesmanii and *M. nagensium*) (Fig. 74 G, I, K, L, U), obovate (*M. balbisiana var. balbisiana, M. flaviflora* and *M. sabuana*) (Fig. 74 G, O, A1), ovate (*M. acuminata, M. argentii, M. arunachalensis, M. aurantiaca, M. chunii, M. itinerans, M. kattuvazhana, M. mannii, M. ochracea, M. pradhanii, M. puspanjaliae, M. rubra* and *M. velutina* var. *velutina*) (Fig. 74 C, D, E, F, M, P, Q, R, V, X, Y, Z, D1), ventricose (*M. balbisiana var. elavazhai, M. markkui* and *M. thomsonii*) (Fig. 74 J, T, C1), ovate to ventricose (*M. cylindrica, M. markkuana* and *M. sikkimensis* var. *sikkimensis*) (Fig. 74 N, S, B1) and obovate to ventricose in *M. ornata* (Fig. 74 W). Smaller vascular bundles are connected to either adaxial or abaxial or both the hypodermis, in all the species. Exceptions are seen in *M. ornata,* where the bundles are suspended in the palisade without any connection to the hypodermis (rarely few bundles are connected to adaxial hypodermis) (Table 5).

In all the species, adaxial bundle strand is composed of sclerenchymatous thick walled cells with smaller lumen followed by thick walled cells with larger lumen, where as in *M. mannii* (Fig. 72 R), bundle sheath is composed of thin-walled sclerenchyma with larger lumen, followed by thick-walled cells with smaller lumen.

Cellular inclusions such as calcium oxalate crystals of various shapes such as rod-shape, prismatic or rhombohedral are present throughout the lamina, in all taxa.

Table 1. Epidermal cell characters

Sl no	Name of taxa	Costal cell				Inter-costal cell			
		Adaxial		Abaxial		Adaxial		Abaxial	
		Shape	Cell wall nature	Shape	Cell wall nature	Shape	Cell wall nature	Shape	Cell wall nature
1	*Ensete glaucum*	Polygonal	Straight to folded	Polygonal	Straight to folded	Irregularly-polygonal	Straight to folded	Irregularly-polygonal	Straight to folded or wavy
2	*E. superbum*	Polygonal	Straight to folded	Polygonal	Straight to slightly folded	Irregularly-polygonal	Straight to folded or wavy	Irregularly-polygonal	Straight to folded or wavy
3	*Musa acuminata*	Rectangular	Straight	Rectangular	Wavy to sinuous	Rectangular	Straight to wavy	Irregular	Wavy to sinuous
4	*M. argentii*	Polygonal	Straight to folded	Rectangular	Sinuous	Irregularly-polygonal	Straight to folded or wavy	Irregular	Sinuous
5	*M. arunachalensis*	Polygonal	Straight to folded	Rectangular	Sinuous	Irregularly-polygonal	Straight to folded	Irregular	Sinuous
6	*M. aurantiaca*	Rectangular	Straight to slightly wavy	Rectangular	Sinuous	Irregularly-polygonal	Straight to folded or wavy	Irregular	Wavy
7	*M. balbisiana*	Rectangular	Straight	Rectangular	Straight to slightly folded	Rectangular	Straight to slightly wavy	Irregular	Straight to folded or wavy
8	*M. balbisiana var. andamanica*	Rectangular	Straight to slightly wavy	Rectangular	Straight to slightly folded	Rectangular	Straight to folded or wavy	Irregular	Straight to wavy
9	*M. balbisiana var. bheem-kola*	Rectangular	Straight	Rectangular	Straight to slightly folded	Rectangular	Straight to slightly folded	Irregular	Straight to folded
10	*M. balbisiana var. elavazhai*	Rectangular	Straight	Rectangular	Straight to slightly folded	Rectangular	Straight to folded or slightly wavy	Irregular	Straight to folded or wavy
11	*M. balbisiana var. sepa-athiya*	Rectangular	Straight	Rectangular	Straight	Rectangular	Straight to slightly wavy	Irregular	Straight to slightly folded or wavy
12	*M. cheesmanii*	Rectangular	Straight	Rectangular	Straight to slightly wavy	Rectangular	Straight to slightly wavy	Irregular	Straight to folded or wavy
13	*M. chunii*	Rectangular	Straight to slightly folded	Rectangular	Straight to slightly folded	Irregularly-polygonal	Straight to folded or slightly wavy	Irregularly-polygonal	Straight to wavy
14	*M. cylindrica*	Rectangular	Straight to slightly wavy	Rectangular	Straight to wavy	Rectangular	Straight to slightly wavy	Irregular	Straight to folded or wavy

15	*M. flaviflora*	Rectangular	Straight to folded	Rectangular	Wavy to sinuous	Irregularly-polygonal	Straight to folded or slightly wavy	Irregular	Wavy to sinuous
16	*M. itinerans*	Rectangular	Straight to slightly wavy	Rectangular	Wavy to sinuous	Rectangular	Straight to wavy	Irregular	Wavy to sinuous
17	*M. kattuvazhana*	Rectangular	Straight to slightly wavy	Rectangular	Wavy to sinuous	Rectangular	Straight to wavy	Rectangular	Wavy to sinuous
18	*M. mannii*	Rectangular	Straight	Rectangular	Straight to slightly folded	Irregularly-polygonal	Straight to folded or slightly wavy	Irregular	Straight to wavy
19	*M. markkuana*	Rectangular	Straight to slightly wavy	Rectangular	Wavy	Rectangular	Straight to folded or slightly wavy	Irregular	Wavy
20	*M. markkui*	Rectangular	Straight to slightly folded	Rectangular	Straight to slightly folded	Irregularly-polygonal	Straight to folded	Irregular	Straight to slightly folded or wavy
21	*M. nagensium*	Rectangular	Straight to slightly wavy	Rectangular	Straight to slightly wavy	Rectangular	Straight to slightly wavy	Irregular	Slightly folded to slightly wavy
22	*M. ochracea*	Rectangular	Straight to slightly folded	Rectangular	Wavy to sinuous	Rectangular	Straight to slightly folded	Irregularly-polygonal	Wavy to sinuous
23	*M. ornata*	Rectangular	Straight to slightly folded	Rectangular	Straight to slightly wavy	Rectangular	Straight to folded	Irregular	Straight to wavy
24	*M. pradhanii*	Rectangular	Straight to slightly folded	Rectangular	Straight	Rectangular	Straight to folded	Irregular	Wavy to sinuous
25	*M. puspanjaliae*	Rectangular	Straight	Rectangular	Straight	Rectangular	Straight to folded	Rectangular to Irregularly-polygonal	Straight to folded or wavy
26	*M. rubra*	Rectangular	Straight to slightly wavy	Rectangular	Wavy	Rectangular	Straight to wavy	Irregular	Wavy to sinuous
27	*M. sabuana*	Rectangular	Straight	Polygonal	Straight to slightly folded	Irregularly-polygonal	Straight to folded	Irregular	Slightly folded to slightly wavy
28	*M. sikkimensis*	Rectangular	Straight to slightly folded	Rectangular	Straight	Rectangular	Straight to folded	Irregular	Wavy to sinuous
29	*M. thomsonii*	Rectangular	Straight to slightly folded	Rectangular	Wavy to sinuous	Rectangular Irregularly-polygonal	Straight to folded	Irregular	Wavy to sinuous
30	*M. velutina*	Rectangular	Straight to slightly wavy	Rectangular	Wavy	Rectangular	Straight to folded or slightly wavy	Irregular	Wavy

Table 2. Guard cell length

Sl no	Name of taxa	Guard cell length (µm)	
		Adaxial	**Abaxial**
1	*Ensete glaucum*	28.15–31.58	25.47–28.05
2	*E. superbum*	30.35–34.60	25.38–29.36
3	*Musa acuminata*	21.13–23.14	17.96–20.31
4	*M. argentii*	27.51–29.84	24.41–26.03
5	*M. arunachalensis*	30.62–33.65	26.34–29.69
6	*M. aurantiaca*	26.59–28.49	23.56–26.00
7	*M. balbisiana var. balbisiana*	24.39–26.73	20.66–22.36
8	*M. balbisiana var. andamanica*	25.67–27.32	21.02–22.63
9	*M. balbisiana var. bheem-kola*	24.68–25.28	19.23–23.32
10	*M. balbisiana var. elavazhai*	24.32–26.95	20.53–21.16
11	*M. balbisiana var. sepa-athiya*	25.60–26.82	17.83–19.72
12	*M. cheesmanii*	18.50–19.73	20.86–22.17
13	*M. chunii*	25.02–27.21	29.53–31.50
14	*M. cylindrica*	22.93–25.62	22.48–24.04
15	*M. flaviflora*	30.1–31.55	23.49–26.51
16	*M. itinerans*	21.62–23.57	21.27–23.50
17	*M. kattuvazhana*	23.62–25.31	21.98-23.32
18	*M. mannii*	31.22–32.58	28.64–34.50
19	*M. markkuana*	30.00–31.97	23.85–25.18
20	*M. markkui*	30.08–31.25	29.64–32.02
21	*M. nagensium*	17.17–19.83	22.82–23.89
22	*M. ochracea*	24.28–26.47	20.97–23.63
23	*M. ornata*	21.55–22.27	20.83–22.91
24	*M. pradhanii*	22.59–26.35	22.19-25.15
25	*M. puspanjaliae*	18.64–19.61	20.69–21.95
26	*M. rubra*	28.51–33.38	25.82–27.81
27	*M. sabuana*	25.91–26.83	23.93–25.49
28	*M. sikkimensis*	21.46–25.94	22.31–24.35
29	*M. thomsonii*	27.55–30.52	24.65–27.08
30	*M. velutina*	29.95–32.02	23.65–25.08

Table 3. Lamina thickness and Stomatal Index

Sl no	Name of taxa	Lamina thickness above smaller VB's		Lamina thickness above larger VB's		Adaxial Stomatal index		Abaxial Stomatal index	
		Min–Max	Mean ± SE	Min–Max	Mean ± SE	Min–Max	Mean ± SE	Min–Max	Mean ± SE
1	*Ensete glaucum*	375.00–498.00	463.26 ± 8.29	480.00–510.00	497.60 ± 2.75	0.00–2.70	1.66 ± 0.50	2.63–6.86	4.84 ± 0.77
2	*E. superbum*	368.00–485.00	441.46 ± 12.00	478.00–508.00	492.40 ± 2.32	2.17–3.84	2.94 ± 0.34	6.89–10.60	8.50 ± 0.61
3	*Musa acuminata*	228.00–300.00	258.33 ± 5.81	292.00–327.00	311.40 ± 2.76	0.00–2.20	1.53 ± 0.39	7.54–12.37	9.52 ± 0.89
4	*M. argentii*	330.00–386.00	363.60 ± 4.71	389.00–410.00	401.66 ± 1.61	0.00–2.85	1.03 ± 0.48	5.40–14.06	10.19 ± 1.57
5	*M. arunachalensis*	512.00–529.00	548.33 ± 2.68	548.00–554.00	552.36 ± 1.28	0.00–0.51	0.28 ± 0.11	3.33–10.37	7.50 ± 1.25
6	*M. aurantiaca*	258.00–290.00	273.00 ± 2.62	294.00–315.00	305.00 ± 1.81	0.00–3.57	1.78 ± 0.71	5.71–15.10	10.17 ± 1.54
7	*M. balbisiana*	237.00–285.00	262.60 ± 4.19	290.00–321.00	308.86 ± 2.53	0.00–1.96	0.62 ± 0.35	5.88–14.28	10.11 ± 1.40
8	*M. balbisiana var. andamanica*	330.00–365.00	353.33 ± 2.63	381.00–402.00	393.86 ± 1.71	1.23–2.17	1.67 ± 0.20	9.69–13.95	11.89 ± 0.69
9	*M. balbisiana var. bheem–kola*	350.00–387.00	363.20 ± 2.80	364.00–388.00	379.93 ± 1.51	0–2.17	0.62 ± 0.42	5.35–11.11	8.96 ± 1.07
10	*M. balbisiana var. elavazhai*	243.00–318.00	285.06 ± 6.62	320.00–352.00	339.66 ± 2.57	0.00–1.69	0.81 ± 0.37	9.88–12.50	11.48 ± 0.50
11	*M. balbisiana var. sepa–athiya*	261.00–340.00	306.80 ± 6.30	350.00–382.00	369.73 ± 2.48	0.00–3.27	0.99 ± 0.62	6.49–9.17	7.96 ± 0.52
12	*M. cheesmanii*	398.00–453.00	428.80 ± 3.54	430.00–453.00	443.26 ± 2.12	0.00–1.35	0.33 ± 0.26	4.22–6.77	5.74 ± 0.52
13	*M. chunii*	554.00–634.00	612.67 ± 7.07	635.00–673.00	657.37 ± 3.37	0.00–2.04	0.65 ± 0.35	6.21–12.50	9.22 ± 1.22
14	*M. cylindrica*	240.00–265.00	255.06 ± 2.23	268.00–280.00	273.00 ± 1.05	1.93–3.70	2.82 ± 0.37	2.63–11.18	7.12 ± 1.90
15	*M. flaviflora*	380.00–418.00	395.60 ± 2.50	420.00–440.00	430.60 ± 1.62	1.40–3.03	2.52 ± 0.29	3.44–8.05	6.29 ± 0.85
16	*M. itinerans*	272.00–350.00	316.20 ± 6.89	356.00–382.00	372.06 ± 2.31	0.00–2.43	0.89 ± 0.47	4.76–11.90	8.96 ± 1.59
17	*M. kattuvazhana*	512.00–568.00	548.18 ± 6.80	570.00–596.00	581.60 ± 3.47	2.04–2.43	2.21 ± 0.07	4.47–9.42	7.33 ± 1.01
18	*M. mannii*	280.00–318.00	296.06 ± 3.26	320.00–339.00	329.93 ± 1.71	0.00–0.85	0.31 ± 0.19	3.22–9.15	6.67 ± 1.18
19	*M. markkuana*	274.00–263.00	254.66 ± 1.39	268.00–282.00	275.26 ± 1.25	0.00–2.85	1.50 ± 0.55	6.00–10.60	8.41 ± 0.92

20	*M. markkui*	383.00–488.00	447.60 ± 7.87	478.00–495.00	485.40 ± 1.62	0.00–2.50	1.08 ± 0.56	5.00–10.00	7.94 ± 0.85
21	*M. nagensium*	201.00–270.00	245.06 ± 5.70	275.00–300.00	288.93 ± 2.26	0.00–2.43	1.12 ± 0.47	7.31–11.76	9.97 ± 0.97
22	*M. ochracea*	307.00–381.00	350.86 ± 6.56	385.00–418.00	401.73 ± 2.90	0.00–5.26	1.86 ± 0.99	11.76–14.72	13.65 ± 0.52
23	*M. ornata*	227.00–273.00	257.53 ± 3.50	278.00–308.00	292.60 ± 2.30	0.00–0.45	0.17 ± 0.10	8.33–10.52	9.14 ± 0.36
24	*M. pradhanii*	275.00–321.00	303.13 ± 3.70	326.00–338.00	332.26 ± 1.04	0.00–2.63	0.77 ± 0.48	4.87–16.66	9.05 ± 2.06
25	*M. puspanjaliae*	392.00–465.00	426.46 ± 5.22	445.00–469.00	458.26 ± 1.92	0.00–0.49	0.19 ± 0.11	1.53–7.69	5.29 ± 1.17
26	*M. rubra*	279.00–319.00	298.60 ± 3.44	32.00–342.00	332.26 ± 1.85	0.00–2.77	1.63 ± 0.66	3.03–12.21	8.83 ± 1.82
27	*M. sabuana*	438.00–488.00	459.13 ± 6.44	489.00–514.00	503.93 ± 2.30	0.00–1.51	0.44 ± 0.30	1.09–11.76	5.95 ± 1.97
28	*M. sikkimensis*	253.00–301.00	282.60 ± 3.76	305.00–365.00	333.93 ± 4.44	0.00–2.62	0.81 ± 0.43	5.87–15.59	8.38 ±1.31
29	*M. thomsonii*	298.00–340.00	318.73 ± 4.03	345.00–364.00	354.60 ± 1.70	0.66–2.70	1.68 ± 0.37	8.07–11.45	10.44 ± 0.62
30	*M. velutina*	222.00–280.00	260.26 ± 4.06	286.00–319.00	303.46 ± 2.68	0.00–2.65	1.31 ± 0.41	8.75–11.76	10.74 ± 0.53

Table 4. Hypodermal cell characters of lamina

Sl no	Name of taxa	No. of layers		Shape		Adaxial hypodermis above larger VB			
		Adaxial	Abaxial	Adaxial	Abaxial	Layers		Outer cell shape	Inner cell shape
						No.	Isodiam-etric (+) /not (-)		
1	*Ensete glaucum*	3	2	Hexagonal	Hexagonal	2	-	Polygonal, higher than broad	Polygonal, higher than broad
2	*E. superbum*	2	1	Hexagonal	Hexagonal	2	-	Hexagonal, broader than high	Hexagonal, isodiametric
3	*Musa acuminata*	2	2	Rectangular	Rectangular	1	NA	Irregular, broader than high	NA
4	*M. argentii*	2	2	Hexagonal	Rectangular	1	NA	Hexagonal, broader than high	NA
5	*M. arunachalensis*	3	2	Hexagonal	Hexagonal	2	-	Hexagonal, isodiametric	Hexagonal, broader than high
6	*M. aurantiaca*	2	1	Rectangular	Rectangular	1	NA	Hexagonal, higher than broad	NA
7	*M. balbisiana*	3	2	Hexagonal	Hexagonal	2	-	Hexagonal, broader than high	Hexagonal, broader than high
8	*M. balbisiana var. andamanica*	2	2	Hexagonal	Hexagonal	2	-	Hexagonal, broader than high	Hexagonal, broader than high
9	*M. balbisiana var. bheem-kola*	2	1	Hexagonal	Rectangular	2	-	Hexagonal, broader than high	Hexagonal, broader than high
10	*M. balbisiana var. elavazhai*	3	1	Hexagonal	Hexagonal	1	NA	Hexagonal, broader than high	NA
11	*M. balbisiana var. sepa-athiya*	2	1	Hexagonal	Hexagonal	2	-	Hexagonal, isodiametric	Hexagonal, broader than high
12	*M. cheesmanii*	3	2	Hexagonal	Hexagonal	2	-	Hexagonal, broader than high	Hexagonal, isodiametric
13	*M. chunii*	3	1	Hexagonal	Rectangular	2	-	Polygonal, broader than high	Polygonal, broader than high
14	*M. cylindrica*	1	1	Rectangular	Rectangular	1	NA	Irregular, broader than high	NA
15	*M. flaviflora*	3	2	Hexagonal	Rectangular	1	NA	Hexagonal, broader than high	NA
16	*M. itinerans*	2	1	Hexagonal	Hexagonal	1	NA	Hexagonal, isodiametric	NA
17	*M. kattuvazhana*	3	1	Rectangular	Rectangular	2	-	Hexagonal, broader than high	Hexagonal, broader than high

18	*M. mannii*	2	1	Hexagonal	Rectangular	1	NA	Hexagonal, higher than broad	NA
19	*M. markkuana*	2	1	Hexagonal	Rectangular	1	NA	Hexagonal, isodiametric	NA
20	*M. markkui*	3	2	Hexagonal	Rectangular	2	+	Polygonal, broader than high	Polygonal, broader than high
21	*M. nagensium*	2	1	Hexagonal	Rectangular	2	+	Hexagonal, isodiametric to broader than high	Hexagonal, isodiametric to broader than high
22	*M. ochracea*	2 or 3	1 or 2	Hexagonal	Rectangular	1 or 2	-	Hexagonal, broader than high	Hexagonal, broader than high
23	*M. ornata*	2	1	Rectangular	Rectangular	1	NA	Hexagonal, broader than high	NA
24	*M. pradhanii*	2	1	Hexagonal	Rectangular	1	NA	Hexagonal, isodiametric	NA
25	*M. puspanjaliae*	3	2	Hexagonal	Rectangular	2	-	Hexagonal, broader than high	Polygonal, broader than high
26	*M. rubra*	1	1	Rectangular	Rectangular	1	NA	Hexagonal, broader than high	NA
27	*M. sabuana*	4	2	Rectangular	Rectangular	2	+	Hexagonal, broader than high	Hexagonal, broader than high
28	*M. sikkimensis*	1	1	Rectangular	Rectangular	1	NA	Hexagonal, isodiametric	NA
29	*M. thomsonii*	2	1	Rectangular	Rectangular	1	NA	Irregular	NA
30	*M. velutina*	1	1	Rectangular	Rectangular	1	NA	Hexagonal, isodiametric	NA

Table 5. Vascular bundle characters of lamina

Sl no	Name of taxa	Larger Vascular Bundle shape	Attachment of vascular bundles on hypodermis	
			Smaller	Larger
1	*Ensete glaucum*	Ventricose	Adaxial or abaxial	Adaxial or both
2	*E. superbum*	Ventricose	Adaxial and abaxial	Adaxial and abaxial
3	*Musa acuminata*	Ovate	Adaxial or rarely both	Adaxial
4	*M. argentii*	Ovate	Adaxial or abaxial	Adaxial
5	*M. arunachalensis*	Ovate	Adaxial or both	Adaxial
6	*M. aurantiaca*	Ovate	Adaxial	Adaxial
7	*M. balbisiana*	Obovate	Adaxial or abaxial	Adaxial
8	*M. balbisiana var. andamanica*	Elliptic	Adaxial or abaxial	Adaxial
9	*M. balbisiana var. bheem-kola*	Elliptic	Adaxial or abaxial	Adaxial
10	*M. balbisiana var. elavazhai*	Ventricose	Adaxial and abaxial	Adaxial
11	*M. balbisiana var. sepa-athiya*	Elliptic	Adaxial or abaxial	Adaxial
12	*M. cheesmanii*	Elliptic	Adaxial or abaxial	Adaxial and abaxial
13	*M. chunii*	Ovate	Adaxial or abaxial	Adaxial
14	*M. cylindrica*	Ovate to ventricose	Adaxial or abaxial	Adaxial
15	*M. flaviflora*	Obovate	Adaxial or abaxial	Adaxial
16	*M. itinerans*	Ovate	Adaxial and abaxial	Adaxial
17	*M. kattuvazhana*	Ovate	Adaxial and abaxial	Adaxial
18	*M. mannii*	Ovate	Adaxial	Adaxial
19	*M. markkuana*	Ovate to ventricose	Adaxial or abaxial	Adaxial and abaxial
20	*M. markkui*	Ventricose	Adaxial or abaxial	Adaxial
21	*M. nagensium*	Elliptic	Adaxial and abaxial	Adaxial
22	*M. ochracea*	Ovate	Adaxial and abaxial	Adaxial
23	*M. ornata*	Obovate to ventricose	Suspended or adaxial	Adaxial
24	*M. pradhanii*	Ovate	Both	Adaxial
25	*M. puspanjaliae*	Ovate	Adaxial or abaxial	Adaxial
26	*M. rubra*	Ovate	Adaxial or abaxial	Adaxial
27	*M. sabuana*	Obovate	Adaxial or abaxial	Adaxial
28	*M. sikkimensis*	Ovate to ventricose	Adaxial or abaxial	Adaxial
29	*M. thomsonii*	Ventricose	Adaxial	Adaxial
30	*M. velutina*	Ovate	Adaxial or abaxial	Adaxial and abaxial

C.S. of petiole and mid rib

In genus *Musa,* petiole in both adaxial and abaxial surface is U-shaped, whereas in *Ensete,* petiole exhibits wide U-shape in the abaxial portion. One of the peculiar characters observed in the petiole of *Musa* is the presence of close contact of the petiolar wings in certain taxa (*M. balbisiana* and its infraspecific taxa) (Fig. 75 G, H, I, J, K). They are completely overlapped in *M. cheesmanii* and *M. nagensium* (Fig. 75 L, U) and the rest of the studied taxa exhibit open petiolar wings. Midrib of all taxa of *Musa* studied possess U-shaped adaxial and abaxial surface. However, in *Ensete,* the midrib shows differences in their surface shape. In *E. glaucum,* adaxial surface is wide U-shaped and abaxial is U-shaped (Fig. 76 A), whereas *E. superbum* possesses U-shaped adaxial and wide U-shaped abaxial surface (Fig. 76 B).

Both petiole and midrib consist of Bundle arcs I, II and III; arc I of larger vascular bundles is situated adaxial to and pectinating with air canal, arranged in different shapes (U, V or Y-shaped); Arc II consists of numerous small vascular bundles situated between air canal and abaxial tissues and the vascular bundles are with well developed fibrous sheaths pectinating with fibrous stands; Arc III consists of small vascular bundles and numerous fibrous bundles. U-shaped arc I is the characteristic feature of *E. glaucum* and *E. superbum* (Fig. 75 A, B). While, *Musa* exhibit both V-shaped (*M. acuminata, M. arunachalensis, M. aurantiaca, M. balbisiana var. elavazhai, M. chunii, M. cylindrica, M. mannii, M. markkuana, M. markkui, M. nagensium, M. ornata, M. rubra, M. sabuana, M. thomsonii* and *M. velutina* var. *velutina*) (Fig. 75 C, E, F, J, M, N, R, S, T, U, W, Z, A1, C1, D1) and Y-shaped (*M. argentii, M. balbisiana var. balbisiana, M. balbisiana var. andamanica, M. balbisiana var. bheem-kola, M. balbisiana var. sepa-athiya, M. cheesmanii, M. flaviflora, M. itinerans, M. kattuvazhana, M. ochracea, M.*

pradhanii, M. puspanjaliae and *M. sikkimensis* var. *sikkimensis*) (Fig. 75 D, G, H, I, K, L, O, P, Q, V, X, Y, B1))arc I bundles.

Cellular constituents show similarities in their structure in both the petiole and midrib in all the studied taxa except for proportions of the vascular bundle size. All taxa studied exhibit isodiametric to broader than high, rectangular, 1-layered, adaxial epidermal cells, covered with thick cuticle; polygonal, broader than high, hypodermal cells, 1 or 4-layered sclerenchyma, followed by 2 or 5-layered collenchymatous cells and further large parenchymatous ground tissue. More sclerenchymatous cells are seen in adaxial epidermis than in the abaxial surface, whereas, more chlorenchymatous tissues are seen in abaxial and least in adaxial surface. Air chambers in petiole and midrib show differences in the number when the plants are collected form dry as well as from wet areas. Hence, number of the air chambers has no significance in taxonomy.

The above anatomical studies have revealed that anatomy of all vegetative parts combined would provide good characters for delimitation of species in vegetative stage. This is very important because many taxa are very difficult to assign species status even in flowering stage.

COMPARATIVE POLLEN MORPHOLOGY

According to Simmonds (1960), the pollen gains of *Musa* are smaller when compared to *Ensete*. The present study supports the former findings except that of *M. pradhanii, M. puspanjaliae, M, sikkimensis var. sikkimensis* and *M. sikkimensis* var. *simmondsii,* which show pollen size larger than the rest of the Indian taxa. Shape of the pollen grains varies from spheroidal to oblate-spheroidal or prolate-spheroidal. All taxa except *M. nagensium* and *M. balbisiana* var. *andamanica* possess either oblate-spheroidal or prolate-spheroidal pollen grains, whereas, the latter mentioned taxa have spheroidal pollen grains (Table 6).

The pollen grains of the family Musaceae are inaperturate, which supports the earlier reports (Stone *et al.,* 1979; Dahlgren *et al,* 1985; Fortescue & Turner, 2004). Indian taxa possess two types of sculpturing *viz.* rugulate and verrucate. However, there is inconsistency in the surface sculpturing patterns as reported in previous works when compared with the present results. Based on light microscopic studies, Simmonds (1960) reported warty sculpturing in *Ensete*, and granulate surface in *Musa*. Scanning Electron Microscopic studies of *Ensete* pollen from Thailand reported that, *E. glaucum* has verrucate and *E. superbum* with perforated sculpturing (Inta *et al.,* 2015). Our findings do not match with the former works and both species of *Ensete* resulted verrucate surface sculpturing. Along with *Ensete, Musa* taxa like *M. balbisiana, M. balbisiana* var. *bheem-kola, M. itinerans, M. sabuana* and *M. thomsonii* (Fig. 78 A, B, G, I, P, A1, D1; 79 A, B, G, I, P, A1, D1) also possess verrucate natured pollen grains and rest of the taxa consist of rugulate sculpturing (Table 7).

Earlier literature on Zingiberales (Kress *et al.,* 1978; Dahlgren & Clifford, 1982; Zavada, 1983; Dahlgren *et al.,* 1985) clearely indicated that, the members have exineless pollen grains. Subsequently, detailed pollen morphological studies on some of the sister families *viz.,* Zingiberaceae (Mangaly & Nair, 1990) and Musaceae (Fortescue & Turner, 2004) reported the presence of thick prominent exine to skinny exine. The present investigation revealed that, most of the taxa show thin/relatively negligible exine (<2 µm), however, thick exine (>2 µm) was present in taxa such as *M. aurantiaca*, *M. markkuana, M. nagensium, M. ornata, M. pradhanii, M. puspanjaliae, M. sikkimensis* var. *sikkimensis* and *M. sikkimensis* var.

simmondsii (Fig. 77 F, S, U, W, X, Y, B1, C1). In addition, prominent exine thickness was (7.74–12.10 µm) observed in *M. ochraceae* (Fig. 77 V). Intine thickness varies from 2.37–3.25 µm to 12.24–15.97 µm. *Musa ornata* and *M. ochracea* possess thick exine (more than 10 µm), whereas *M. aurantiaca, M. sikkimensis* and *M. sikkimensis* var. *simmondsii* show medium sized exine (5.00–10 µm), and rest of the species exhibit thin intine (below 5 µm) with the thinnest in *Musa flaviflora* (Fig. 77 O).

The characters of pollen grains are not enough for species delimitation and to develop a key. However, some strong characters possessed by a few taxa are useful in identification of taxa.

Table 6. Pollen size

Sl no	Name of taxa	Polar length (P) (µm)		Equatorial length (E) (µm)		P/E ratio		Exine thickness (µm)		Intine thickness (µm)	
		Min–Max	Mean ± SE	Min–Max	Mean ± SE	Min–Max	Mean ± SE	Min–Max	Mean ± SE	Min–Max	Mean ± SE
1	*Ensete glaucum*	127–140	131.80±1.30	128–144	134.20±1.48	0.95–1.03	0.98±0.008	1.02–2.12	1.62±0.10	5.22–11.25	7.46±0.69
2	*E. superbum*	120–141	128.60±1.92	111–136	126.20±2.17	0.94–1.13	1.02±0.01	1.00–2.59	1.69±0.16	5.94–10.67	7.82±0.43
3	*Musa acuminata*	96–102	98.70±0.65	95–101	97.40±0.60	0.99–1.04	1.01±0.005	0.08–2.12	1.37±0.17	3.33–5.14	4.13±0.20
4	*M. argentii*	98–116	108.10±2.26	102–116	110.90±1.50	0.88–1.04	0.97±0.01	0.76–1.86	1.09±0.10	3.92–7.06	5.04±0.36
5	*M. arunachalensis*	112–122	118.30±1.01	105–123	118.50±1.63	0.98–1.07	0.99±0.009	0.87–2.10	1.50±0.13	4.30–10.98	8.24±0.72
6	*M. aurantiaca*	100–119	113.50±1.80	112–118	114.60±0.68	89–1.04	0.99±0.01	2.50–4.30	3.18±0.18	8.12–13.50	11.34±0.61
7	*M. balbisiana*	116–121	118.80±0.53	112–121	117.50±0.94	0.97–1.05	1.01±0.01	1.85–3.40	2.79±0.16	5.77–8.17	7.00±0.26
8	*M. balbisiana var. andamanica*	101–131	118.40±3.19	103–129	117.30±2.49	0.95–1.06	1.00±0.01	0.84–1.44	1.17±0.06	2.79–5.40	4.27±0.26
9	*M. balbisiana var. bheem-kola*	109–119	115.40±1.13	106–121	116.10±1.73	0.97–1.03	0.99±0.007	0.89–2.61	1.78±0.17	3.45–7.66	5.35±0.54
10	*M. balbisiana var. elavazhai*	88–103	97.80±1.35	89–103	98.60±1.43	0.96–1.04	0.99±0.009	1.59–2.59	2.15±0.11	6.75–9.99	7.98±0.34
11	*M. balbisiana var. sepa-athiya*	97–111	103.10±1.53	97–108	103.30±1.30	0.93–1.04	0.99±0.01	1.60–3.70	2.55±0.19	2.38–3.92	3.26±0.18
12	*M. cheesmanii*	101–117	109.80±1.96	100–119	110.80±2.23	0.96–1.03	0.99±0.007	2.01–3.15	2.45±0.13	3.22–6.76	5.13±0.36
13	*M. chunii*	67–89	77.2±2.34	66–89	77.90±2.62	0.95–1.05	0.99±0.008	0.71–1.13	0.88±0.04	2.50–4.19	3.29±0.17
14	*M. cylindrica*	96–110	102.70±1.44	94–111	104.10±1.60	0.94–1.06	0.98±0.01	1.25–2.43	1.89±0.13	2.58–6.88	4.50±0.44
15	*M. flaviflora*	102–117	109.60±1.70	103–118	111.70±1.52	0.94–1.05	0.98±0.01	1.00–2.10	1.39±0.09	2.37–3.24	2.80±0.09
16	*M. itinerans*	96–106	102.30±1.08	99–108	103.00±0.93	0.94–1.06	0.99±0.01	1.40–2.56	1.92±0.12	4.43–8.93	6.89±0.51
17	*M. kattuvazhana*	84–101	94.50±1.73	88–103	95.90±1.37	0.93–1.08	0.98±0.16	1.18–2.75	2.18±0.15	3.82–5.92	4.74±0.20
18	*M. mannii*	101–114	106.60±1.36	97–111	105.20±1.60	0.98–1.06	1.01±0.009	1.69–3.88	2.62±0.22	2.70–4.55	3.40±0.19
19	*M. markkuana*	96–119	110.90±2.33	99–120	112.40±2.03	0.95–1.03	0.98±0.009	2.14–3.86	2.99±0.16	3.27–6.50	5.04±0.33
20	*M. markkui*	112–119	115.90±0.73	112–119	116.10±0.69	0.96–1.03	0.99±0.009	4.06–12.79	8.15±0.87	3.68–12.06	6.34±0.82
21	*M. nagensium*	89–105	96.60±1.53	85–106	96.30±1.95	0.93–1.14	1.00±0.02	2.27–4.59	3.35±0.25	2.46–12.76	5.03±0.92
22	*M. ochracea*	100–124	112.70±2.39	102–129	114.10±2.72	0.94–1.03	0.98±0.01	7.74–12.10	9.86±0.44	3.10–15.57	7.44±1.10
23	*M. ornata*	112–119	114.37±1.20	115–117	116.08±1.34	0.96–1.01	0.98±0.03	3.00–3.25	3.34±0.64	12.24–15.97	13.56±0.73

24	*M. pradhanii*	110–135	121.40±2.32	112–133	125.20±1.80	0.94–1.02	0.96±0.008	2.24–4.64	3.65±0.26	3.98–6.2	4.91±0.22
25	*M. puspanjaliae*	120–140	132.10±2.06	124–136	132.40±1.15	0.95–1.08	0.99±0.01	2.51–5.38	4.06±0.35	4.53–7.81	5.50±0.31
26	*M. rubra*	73–94	83.60±2.22	77–93	86.10±1.60	0.87–1.04	0.97±0.01	1.69–2.96	2.15±0.13	2.43–5.50	4.16±0.31
27	*M. sabuana*	103–115	109.70±1.05	101–115	108.20±1.66	0.94–1.14	1.01±0.01	1.09–2.72	1.93±0.15	2.77–4.31	3.73±0.13
28	*M. sikkimensis*	135–185	165.10±4.93	140–180	165.70±4.61	0.96–1.05	0.99±0.01	3.35–8.00	5.75±0.47	6.03–10.13	7.92±0.47
29	*M. sikkimensis var. simmondsii*	138–161	148.20±2.36	135–159	148.80±2.65	0.95–1.04	0.99±0.01	3.18–8.17	5.56±0.51	6.17–10.10	7.66±0.42
30	*M. thomsonii*	91–113	98.20±2.20	93–115	100.60±1.87	0.95–1.02	0.97±0.008	1.98–3.45	2.54±0.13	3.26–5.19	4.13±0.23
31	*M. velutina*	80–104	95.60±2.09	85–107	98.70±2.21	0.92–1.05	0.96±0.01	1.59–2.72	2.25±0.12	3.37–7.32	4.57±0.34
32	*M. velutina var. variegata*	81–106	96.01±2.26	83–109	97.94±1.97	0.96–1.05	0.97±0.04	1.63–2.67	2.15±0.46	3.50–6.45	4.97±0.39

Table 7. Pollen sculpturing

Sl no	Name of taxa	Surface sculpturing
1	*Ensete glaucum*	Verrucate
2	*E. superbum*	Verrucate
3	*Musa acuminata*	Rugulate
4	*M. argentii*	Rugulate
5	*M. arunachalensis*	Rugulate
6	*M. aurantiaca*	Rugulate
7	*M. balbisiana*	Verrucate
8	*M. balbisiana var. andamanica*	Verrucate
9	*M. balbisiana var. bheem-kola*	Rugulate
10	*M. balbisiana var. elavazhai*	Rugulate
11	*M. balbisiana var. sepa-athiya*	Rugulate
12	*M. cheesmanii*	Rugulate
13	*M. chunii*	Rugulate
14	*M. cylindrica*	Rugulate
15	*M. flaviflora*	Rugulate
16	*M. itinerans*	Verrucate
17	*M. kattuvazhana*	Rugulate
18	*M. mannii*	Rugulate
19	*M. markkuana*	Verrucate
20	*M. markkui*	Verrucate
21	*M. nagensium*	Verrucate
22	*M. ochracea*	Rugulate
23	*M. ornata*	Rugulate
24	*M. pradhanii*	Rugulate
25	*M. puspanjaliae*	Rugulate
26	*M. rubra*	Rugulate
27	*M. sabuana*	Verrucate
28	*M. sikkimensis*	Rugulate
29	*M. sikkimensis var. simmondsii*	Rugulate
30	*M. thomsonii*	Verrucate
31	*M. velutina*	Rugulate
32	*M. velutina var. variegata*	Rugulate

COMPARATIVE SEED MICRO-MORPHOLOGY

Seed shape and surface characters

Seed characters play significant role in the delimitation of Musaceae taxa. The seeds are non-arillate. Seeds of Indian Musaceae have four different shapes, with most common type as oblate. Both species of *Ensete* exhibit ovoid type of seeds (Fig. 80 A, B) and ellipsoid type is the characteristic feature of *M. ochracea* and *M. rubra* (Fig. 80 V, Z). Sub-globose type is common in *Musa balbisiana* (Fig. 80 G, H, I, J, K) and its all studied infraspecific taxa and *M. cheesmanii* (Fig. 80 L). In fresh conditions, the seeds of almost all the species are black in colour, which turn to either dull black, brown or remain the same without any colour change. Due to change in colour of seeds, it canot be taken as a constant character for species delimitation (Table 8).

Seed size plays a major role in Musaceae taxonomy. In the present study, both the seed length and seed width are classified into three types. Length includes, class I (1.00–2.99 mm), class II (3.00–4.99) and class III (5.00 mm and above). Species in class I are *M. argentii, M. aurantiaca, M. cylindrica, M. markkuana, M. markkui, M. velutina* var. *velutina* and *M. velutina var. variegata.* Class II includes *M. acuminata, M. arunachalensis, M. balbisiana var. balbisiana, M. balbisiana var. andamanica, M. balbisiana var. bheem-kola, M. chunii, M. flaviflora, M. itinerans, M, kattuvazhana, M. mannii, M. M. ochracea, M. ornata, M. pradhanii, M. rubra, M. sabuana, M. thomsonii,* All the other remaining taxa (*E. glaucum, E. superbum, M. balbisiana* var. *elavazhai, M. cheesmanii, M. nagensium, M. puspanjaliae, M. sikkimensis* var. *sikkimensis* and *M. sikkimensis* var. *simmondsii*) are included in class III.

Seed width includes class I (1.00–5.99 mm), class II (6.00–7.99 mm) and class III (8.00 mm and above). Majority of the taxa fall under class I, however taxa such as *E. glaucum, E. superbum, M. arunachalensis, M. flaviflora, M. itinerans, M. M. kattuvazhana* and *M. pradhanii* come under class II. Class III includes, *M. cheesmanii, M. nagensium, M. puspanjaliae, M. sikkimensis* var. *sikkimensis* and *M. sikkimensis* var. *simmondsii* (Table 10).

The seeds are tightly packed in the fruits of most species, which result in the change of shape at the base and top. However, seeds of *M. ochracea* and *M. rubra* (Fig. 80 V, Z) exhibit relatively insignificant contortion or is even absent. Some of the taxa *viz., M. argentii, M. arunachalensis, M. markkui, M. ornata, M. sabuana* and *M. thomsonii* (Fig. 80 D, E, T, W, A1, D1) show seed body that weakly tapers at the chalazal region, whereas it is absent in all the other taxa. Seeds with slight tapering towards the micropylar region is observed in about half of the Indian taxa, but it is absent in *Ensete spp., M. argentii, M. aurantiaca, M. chunii, M. cylindrica, M. flaviflora, M. mannii, M. markkuana, M. markkui, M. ochracea, M. rubra, M. sabuana, M. velutina var. velutina* and *M. velutina var. variegata* (Fig. 80 A, B, D, F, M, O, R, S, T, V, Z, A1, E1, F1). Prominent hylar rim is the key character of *Ensete spp.,* whereas, it is inconspicuous in *Musa*. Musaceae never produce prominent chalazal mucro like other Zingiberales members. However, a small acumination is seen in *M. argentii, M. arunachalensis, M. chunii, M. markkui, M. ornata, M. sikkimensis var. simmondsii* and *M. thomsonii* (Fig. 80 D, E, M, T, W, C1, D1). In some taxa, such as, *E. glaucum* and *E. superbum,* the chalazal mucro is replaced by either flat or prominent notch at the centre of the chalazal region. Size of micropylar plug and chalazal chamber is directly proportional to the seeds size (Table 8, 10).

Surface sculpturing

When the seeds are observed for surface nature under light microscope or even by naked eye, the most prominent sculpturing type is found to be verrucate. The exceptions are smooth (*E. glaucum, E. superbum, M. ochracea, M. rubra* and *M. sikkimensis* var. *sikkimensis*) and smooth to verrucate (*M. nagensium, M. puspanjaliae, M. sikkimensis* var. *simmondsii*). However, Scanning Electron Microscopic studies revealed that, the surface sculpturing patterns differ from one taxon to another (Table 9).

Outer surface sculpturing

The present study has come across eight types of outer sculpturing and three inner sculpturing patterns with diverse nature of anticlinal and periclinal cell walls. The outer sculpturing types include: alveolate (*M. aurantiaca*, *M. cheesmanii, M. cylindrica, M. itinerans* and *M. sikkimensis* var. *simmondsii*) (Fig. 81 F, L, N, P, C1); areolate (*M. flaviflora* and *M. ornata*) (Fig. 81 O, W); colliculate (*M. markkui*) (Fig. 81 T); reticulate (*M. acuminata, M. balbisiana var. bheem-kola, M. balbisiana var. elavazhai, M. balbisiana var. sepa-athiya, M. puspanjaliae, M. sabuana, M. sikkimensis* var. *sikkimensis, M. thomsonii, M. velutina* var. *velutina* and *M. velutina* var. *variegata*) (Fig. 81 C, I, J, K, Y, A1, B1, D1, E1, F1); reticulate-areolate (*M. rubra*) (Fig. 81 Z); reticulate-foveate (*M. balbisiana var. balbisiana, M. balbisiana var. andamanica, M. chunii, M. mannii, M. markkuana, M. nagensium, M. ochracea* and *M. pradhanii*) (Fig. 81 G, S, U, V, X); slightly reticulate-colliculate (*M. argentii* and *M. arunachalensis*) (Fig. 81 D, E) and tuberculate (*E. glaucum*) (Fig. 81 A).

Anticlinal walls are of three types, *viz*., shallow or raised/slightly raised to prominently raised. Shallow type is seen in *E. glaucum, E. superbum, M. arunachalensis, M. flaviflora, M. mannii, M. markkui, M.*

ochracea and *M. rubra* (Fig. 81 A, B, E O, R, T, V, Z) and the remaining taxa show raised (either slightly or prominently) type. In all studied taxa, the anticlinal cell wall is unevenly thickened; however, the texture of cell wall varies from straight, smooth to slightly folded/ folded in majority of the taxa. Exceptions are smooth to sinuous (*M. chunii, M. markkuana* and *M. thomsonii*) (Fig. 81 M, S, D1).

Periclinal wall shape plays significant role in the delimitation of taxa. *Musa acuminata, M. sikkimensis* var. *sikkimensis, M. sikkimensis* var. *simmondsii* and *M. velutina* var. *velutina* (Fig. 81 C, B1, C1, E1) possess slightly concave or concave with tubercle at centre type of periclinal wall. Wall that is convex with smooth pattern is seen in *E. glaucum, E. superbum, M. argentii,* and *M. markkui* (Fig. 81 A, B, D, T), whereas slightly convex with smooth cells are seen in *M. flaviflora* and *M. rubra* (Fig. 81 O, Z). Prominently concave with warty cells is the unique character of *M. balbisiana* and its infraspecific taxa (Fig. 81 G, H, I, J, K). Concave periclinal wall with smooth cells are seen in *M. mannii, M. markkuana, M. nagensium, M. ochracea, M. puspanjaliae, M. sabuana, M. thomsonii* and *M. velutina* var. *variegata* (Fig. 81 R, S, U, V, Y, AI, D1, F1). Whereas, slightly concave smooth type is present in most of the taxa such as *M. arunachalensis, M. aurantiaca, M. chunii, M. cylindrica, M. flaviflora, M. itinerans* and *M. pradhanii* (Fig. 81 E, F, M, N, O, P, X); slightly concave rugose is seen in *M. ornata* (Fig. 81 W). Out of all the studied taxa, *M. cheesmanii* (Fig. 81 L)exhibit unique periclinal wall cell shape as flat to slightly concave with foveolate pattern (Table 9).

Inner surface sculpturing

One of the peculiar characters of Musaceae is the presence of a secondary inner surface, formed by the separation of outer cell wall of the exotesta (Graven *et al.,* 1996), however, separation of outer cell wall is absent in the both species of *Ensete* under study. Indian Musaceae exhibits three types of inner surface sculpturing *viz.,* colliculate, reticulate and reticulate-foveate. Colliculate pattern is present in *M. flaviflora, M. markkui* and *M. pradhanii* (Fig. 82 M, R, V). The majority of the taxa show reticulate sculpturing (*M. acuminata, M. argentii, M. arunachalensis, M. aurantiaca, M. cylindrica, M. itinerans, M. markkuana, M. nagensium, M. ochracea, M. ornata, M. puspanjaliae, M. rubra, M. sabuana, M. sikkimensis* var. *sikkimensis, M. thomsonii, M. velutina* var. *variegata, M. velutina var. variegata*) (Fig. 82 A, B, C, D, L, N, Q, S, T, U, W, X, Y, Z, BI, CI, DI). Reticulate-foveate inner sculpturing is observed in *M. balbisiana* and all of its infraspecific taxa (Fig. 82 E, F, G, H, I), followed by *M. cheesmanii, M. chunii, M. mannii* and *M. sikkimensis* var. *simmondsii* (Fig. 82 J, K, P, A1).

Anticlinal walls are shallow in *M. argentii, M. chunii, M. flaviflora, M. mannii, M. markkui* and *M. sikkimensis* var. *simmondsii* (Fig. 82 B, K, M, P, R, A1), whereas the walls are raised in *M. sikkimensis* var. *sikkimensis* and *M. velutina* var. *variegata* (Fig. 82 Z, DI); *M. itinerans* shows shallow to slightly raised cell wall (Fig. 82 N). However most of the species (*M. acuminata, M. arunachalensis, M. aurantiaca, M. balbisiana* and all of its infraspecific taxa, *M. cheesmanii, M. cylindrica, M. markkuana, M. nagensium, M. ochracea, M. ornata, M. pradhanii, M. puspanjaliae, M. rubra, M. sabuana, M. thomsonii, M. velutina, M. velutina* var. *variegata*) (Fig. 82 A, C, D, E, F, G, H, I, J, L, Q, S, T, U, D1) exhibit obvious prominently raised anticlinal wall. Margins of the cell wall are straight, smooth to folded with irregular thickening in all the species, Except *M. argentii, M. nagensium* and *M. puspanjaliae* (Fig. 82 B, S, W), which possess straight, smooth to sinuous cell wall texture.

Three types of inner periclinal cell wall are seen in Indian Musaceae. *Musa markkui* possesses convex cells. Concave cells (*M. acuminata, M. argentii, M. arunachalensis, M. aurantiaca, M. chunii, M. cylindrica, M.*

flaviflora, M. mannii, M. markkuana, M. ochracea, M. pradhanii, M. puspanjaliae, M. rubra, M. sikkimensis var. *sikkimensis, M. sikkimensis var. simmondsii, M. thomsonii, M. velutina* var. *velutina* and *M. velutina* var. *variegata*) (Fig. 82 A, B, C, D, K, L, M, P, Q, T, P, W, X, Z, A1, B1, C1, D1) are the most commonly observed type. However, prominently concave cells are also seen in *M. balbisiana* and all of its infraspecific taxa, *M. cheesmanii* and *M. sabuana.* All the *Musa* taxa except *M. balbisiana* and its infraspecific taxa exhibit multi-angular crystalline body at the centre of each cell. Deeply folded structures are seen in *M. chunii, M. mannii* and *M. sikkimensis* var. *simmondsii* (Fig. 82 K, P, A1) and slightly folded structures in *M. flaviflora* (Fig. 82 M). Striate pattern is seen in *M. balbisiana* var. *balbisiana, M. balbisiana* var. *andamanica, M. balbisiana* var. *bheem-kola, M. balbisiana* var. *sepa-athiya* and *M. cheesmanii* (Fig. 82 E, F, G, I, J), whereas, *M. balbisiana var. elavazhai* (Fig. 82 H) has cell wall with smooth pattern. Most of the multi-angular silica bodies are smooth, however warty (*M. acuminata*), rugose (*M. ornata and M. thomsonii*) and smooth to rugose (*M. puspanjaliae, M. velutina var. velutina* and *M. velutina var. variegata*). Striations reported in *M. balbisiana* vary in its texture such as warty (*M. balbisiana var.* balbisiana) and rugose (*M. balbisiana var. andamanica, M. balbisiana var. bheem-kola* and *M. balbisiana var. sepa-athiya*) (Table 9).

COMPARATIVE SEED ANATOMY

Like seed micro-morphological characters, seed coat anatomy also plays an important role in species delimitation in Musaceae. Seed coat anatomy is one of the poorly studied characters among the families of Zingiberales. There are scanty references of such studies in the family in general and the genus *Musa* in particular.

In most of the taxa, the number of seed coat layers vary from 18 to 29, however, some taxa like *E. glaucum, E. superbum, M. cheesmanii, M.*

puspanjaliae, M. sikkimensis var. sikkimensis and *M. sikkimensis var. simmondsii* possess more number of layers (up to 58). The maximum number of layers is observed in *M. puspanjaliae* (50–58 layers). Seed coat thickness of the members of Indian Musaceae can be divided into three classes: *viz.* Class I (Upto 299 µm), class II (300–399 µm) and class III (400 µm and above). Class I represents majority of the species (*E. superbum, M. acuminata, M. argentii, M. arunachalensis, M. aurantiaca, M. balbisiana* (all infraspecific taxa), *M. chunii, M. cylindrica, M. flaviflora, M. kattuvazhana, M. mannii, M. markkuana, M. markkui, M. ochracea, M. ornata, M. rubra, M. sabuana, M. thomsonii, M. velutina var. velutina* and *M. velutina var. variegata*). Class II includes *E. glaucum, M. itinerans* and *M. pradhanii;* whereas *M. cheesmanii, M. nagensium, M. puspanjaliae, M. sikkimensis var. sikkimensis* and *M. sikkimensis var. simmondsii* fall under class III. Seed coat thickness is found to be the least in *M. markkui* (141–182 µm) and is maximum in *M. puspanjaliae* (735–810 µm). Seed coat thickness is directly proportional to the number of seed coat layers. In all these taxa, mesotesta is composed of pitted sclerotic cells.

In all taxa, the endotesta is 1-layered with U-shaped cells, which can also be classified based on thickness into three classes, namely, class I (Upto 10 µm), class II (10.01–14.00 µm) and class III (14.01 µm and above). Most of the taxa come under class I (*M. argentii, M. aurantiaca, M. balbisiana* var. *balbisiana, M. balbisiana* var. *andamanica, M. balbisiana* var. *bheem-kola, M. balbisiana* var. *sepa-athiya, M. cheesmanii, M. chunii, M. mannii, M. markkuana, M. markkui, M. ochracea, M. pradhanii, M. rubra, M. velutina* var. *velutina* and *M. velutina* var. *variegata*). Class II includes *E. superbum, M. arunachalensis, M. balbisiana* var. *elavazhai, M. itinerans, M. nagensium, M. ornata, M. puspanjaliae, M. sikkimensis* var. *sikkimensis* and *M. sikkimensis* var. *simmondsii.* Class III consists of *E. superbum, M. acuminata, M. cylindrica, M. flaviflora, M. sabuana* and *M. thomsonii.* In the present study, it is observed that the seed coat thickness is inversely proportional to the endotesta thickness in all taxa, except *E. superbum.* Furthermore, taxa those are included in class III, except *E. superbum,* which come under *M. acuminata* complex. The highest endotestal thickness is seen in *E. superbum* (43.36 µm) and the lowest in *M. balbisiana* var. *sepa-athiya* (5.10 µm).

Tegmen lies below the endotesta and is composed of 2-layers of elongated, spongy cells, separated by a distinct layer. Tegmen thickness can also be split into four classes, *viz*., class I (less than 5 µm), class II (5.01–11.50 µm), class III (11.51–20.00 µm) and class IV (20.01 µm and above). Class I consists of *E. superbum, M. argentii, M. aurantiaca, M. balbisiana var. sepa-athiya* and *M. cheesmanii;* class II includes *M. balbisiana var. balbisiana, M. balbisiana var. andamanica, M. balbisiana var. bheem-kola, M. chunii, M. mannii, M. markkuana, M. markkui, M. nagensium, M. pradhanii, M. puspanjaliae* and *M. velutina* var. *velutina;* class III comprises of *M. acuminata, M. balbisiana var. elavazhai, M. cylindrica, M. flaviflora, M. ochracea, M. ornata, M. rubra* and *M. velutina* var. *variegata* and class IV includes *E. glaucum, M. arunachalensis, M. itinerans, M. sabuana, M. sikkimensis* var. *sikkimensis, M. sikkimensis* var. *simmondsii* and *M. thomsonii.*

Aleurone (inner endosperm) is 1-layered in all the taxa and its thickness has great significance in taxonomy. Hence, aleurone layer thickness is grouped into three classes: Class I (thickness below 5 µm), class II (thickness 5.01–10.00 µm) and class III (thickness 10.01 µm and above). Class I consists of *M. argentii, M. aurantiaca, M. balbisiana* var. *sepa-athiya, M. mannii, M. markkuana* and *M. puspanjaliae;* class II includes *E. superbum, M. balbisiana* var. *balbisiana, M. balbisiana* var. *andamanica, M. balbisiana* var. *bheem-kola, M. cheesmanii, M. chunii, M. cylindrica, M. itinerans, M. Markkui, M. pradhanii, M. thomsonii, M. velutina* var. *velutina* and *M. velutina* var. *variegata.* Whereas class III comprises of *E. glaucum, M. acuminata, M. arunachalensis, M. balbisiana* var. *elavazhai, M. flaviflora, M. nagensium, M. ochracea, M. ornata, M. sabuana, M. sikkimensis* var. *sikkimensis* and *M. sikkimensis* var. *simmondsii* (Table 11).

Micropylar mesotestal proliferation (mmp) thickness is directly proportional to the seed coat thickness and its thickness can be classified into three classes: Class I with lowest thickness (100–499 µm), class II (500–899 µm) and highest in class III (900 µm and above). Class I is the most common type, in which most of the taxa fall, whereas, *E. superbum, M. arunachalensis, M. balbisiana var. balbisiana, M. itinerans* and *M. pradhanii* come under class II. Even though having large size as well as seed coat thickness, taxa like *Ensete glaucum, M. cheesmanii, M. nagensium, M. puspanjaliae, sepa-athiya* and *M. sikkimensis* var. *simmondsii* possess the greatest mmp thickness, and are placed in class III. The maximum micropylar mesotestal proliferation thickness is observed in *M. nagensium* (1395.88 µm) and minimum in *M. aurantiaca* (211.73 µm).

Micropylar collar is straight in majority of the species studied. Exceptions are noticed in *M. argentii, M. balbisiana* var. *elavazhai, M. mannii, M. markkuana, M. sabuana* and *M. velutina* var. *velutina* (Fig. 83 D, J, R, S, A1, E1) with weakly curved or straight to weakly curved micropylar collar. On the basis of micropylar collar length, the taxa are grouped in to three classes. Class I (Upto 699 µm), class II (700–999 µm) and class III (above 1000 µm). *M. acuminata, M. chunii, M. cylindrica, M. mannii, M. markkuana, M. markkui, M. ochracea, M. ornata, M, thomsonii, M. velutina var. velutina* and *M. velutina* var. *variegata* come under Class I; class II includes *M. arunachalensis, M. aurantiaca, M. balbisiana var. andamanica, M. balbisiana var. sepa-athiya, M. cylindrica, M. flaviflora, M. itinerans, M.*

pradhanii, M. rubra, M. sabuana and *M. sikkimensis var. sikkimensis,* while the remaining taxa comes under class III.

Chalazal chamber column is absent in *Ensete spp., M. argentii, M. aurantiaca, M. cheesmanii, M. chunii, M. cylindrica, M. mannii, M. markkuana, M. nagensium, M. pradhanii, M. thomsonii* and *M. velutina var. variegata,* whereas in some species *viz., M. acuminata, M. arunachalensis, M. flaviflora, M. ochracea, M. ornata, M. sabuana, M. sikkimensis* var. *simmondsii* and *M. velutina* var. *velutina,* the column is intermediate (1/5th of the chalazal chamber) in size. *Musa balbisiana* var. *sepa-athiya* possesses intermediate to prominent column. Chalazal chamber column is prominent in *M. balbisiana* and in all of its infraspecific taxa except *M. balbisiana* var. *sepa-athiya, M. itinerans, M. kattuvazhana, M. markkui, M. pradhanii, M. rubra,* and *M. sikkimensis* var. *sikkimensis.*

Chalazal mesotestal proliferation (cmp) thickness varies from one taxon to another. Taxa with chalazal chamber column or chalazal mucro have greater chalazal mesotestal proliferation. Similarly as the seed coat characters, cmp is also divided in to three classes. Class I (100–599 µm), class II (600–999 µm) and class III (1000 µm and above). Class I consists of most of the taxa (twenty taxa), where as class II includes *Ensete spp., M. arunachalensis, M. cheesmanii, M. cylindrica, M. itinerans, M. kattuvazhana* and *M. pradhanii.* Class III consists of *M. nagensium, M. puspanjaliae, M. sikkimensis var. sikkimensis* and *M. sikkimensis var. simmondsii,* with greatest thickness seen in *M. puspanjaliae* (1522.41 µm) (Table 11).

Chalazal pigment gap is discoid, endotestal gap is absent and embryo base is bulbous in all the taxa studied. Thus the layers of endotesta, tegmen and inner endosperm, together play an important role in the delimitation of the taxa.

Table 8. Seed characters

Sl no	Name of taxa	Shape	Colour		Seed body features			Hilar rim	Miropylar collar	Chalazal	
			Fresh	Dry	Tapering at micropyle	Tapering at chalaza	Contorte-d by tight packing in fruit			Mucro	Chamber column
1	*Ensete glaucum*	Ovoid	Black	Black	Absent	Absent	Present	Prominent	Straight	Absent	Absent
2	*E. superbum*	Ovoid	Black	Black	Absent	Absent	Present	Prominent	Straight	Absent	Absent
3	*Musa acuminata*	Oblate	Black	Brown	Present	Absent	Present	Inconspicuous	Straight	Absent	Present
4	*M. argentii*	Oblate	Brown	Brown	Absent	Present	Present	Inconspicuous	Weakly curved	Present	Absent
5	*M. arunachalensis*	Oblate	Black	Brown	Present	Present	Present	Inconspicuous	Straight	Present	Present
6	*M. aurantiaca*	Oblate	Black	Brown	Absent	Absent	Present	Inconspicuous	Straight	Absent	Absent
7	*M. balbisiana*	Sub-globose	Black	Dull black to brown	Present	Absent	Present	Inconspicuous	Straight	Absent	Present
8	*M. balbisiana var. andamanica*	Sub-globose	Black	Dull black to brown	Present	Absent	Present	Inconspicuous	Straight	Absent	Present
9	*M. balbisiana var. bheem-kola*	Sub-globose	Black	Dull black to brown	Present	Absent	Present	Inconspicuous	Straight	Absent	Present
10	*M. balbisiana var. elavazhai*	Sub-globose	Black	Dull black to brown	Present	Absent	Present	Inconspicuous	Straight to Weakly curved	Absent	Present
11	*M. balbisiana var. sepa-athiya*	Sub-globose	Black	Dull black to brown	Present	Absent	Present	Inconspicuous	Straight	Absent	Present
12	*M. cheesmanii*	Sub-globose	Black	Dull black to brown	Present	Absent	Present	Inconspicuous	Straight	Absent	Absent
13	*M. chunii*	Oblate	Black	Brown	Absent	Absent	Present	Inconspicuous	Straight	Present	Absent
14	*M. cylindrica*	Oblate	Black	Brown	Absent	Absent	Present	Inconspicuous	Straight	Absent	Absent
15	*M. flaviflora*	Oblate	Black	Brown	Absent	Absent	Present	Inconspicuous	Straight	Absent	Present
16	*M. itinerans*	Oblate	Dull-black	Brown	Present	Absent	Present	Inconspicuous	Straight	Absent	Present
17	*M. kattuvazhana*	Oblate	Black	Dull black to	Present	Absent	Present	Inconspicuous	Straight	Absent	Present

				brown							
18	*M. mannii*	Oblate	Dull-black	Brown	Absent	Absent	Present	Inconspicuous	Straight to Weakly curved	Absent	Absent
19	*M. markkuana*	Oblate	Black	Brown	Absent	Absent	Present	Inconspicuous	Straight to Weakly curved	Absent	Absent
20	*M. markkui*	Oblate	Black	Brown	Absent	Present	Present	Inconspicuous	Straight	Present	Present
21	*M. nagensium*	Oblate	Black	Dull black	Present	Absent	Present	Inconspicuous	Straight	Absent	Absent
22	*M. ochracea*	Ellipsoid	Black	Dull black	Absent	Absent	Absent	Inconspicuous	Straight	Absent	Present
23	*M. ornata*	Oblate	Black	Brown	Present	Present	Present	Inconspicuous	Straight	Present	Present
24	*M. pradhanii*	Oblate	Dull black	Brown	Present	Absent	Present	Inconspicuous	Straight	Absent	Present
25	*M. puspanjaliae*	Oblate	Black	Dull black	Present	Absent	Present	Inconspicuous	Straight	Absent	Absent
26	*M. rubra*	Ellipsoid	Black	Black	Absent	Absent	Absent	Inconspicuous	Straight	Absent	Present
27	*M. sabuana*	Oblate	Black	Dull black to brown	Absent	Present	Present	Inconspicuous	Straight to Weakly curved	Absent	Present
28	*M. sikkimensis*	Oblate	Dull black	Brown	Present	Absent	Present	Inconspicuous	Straight	Absent	Present
29	*M. sikkimensis var. simmondsii*	Oblate	Dull black	Brown	Present	Absent	Present	Inconspicuous	Straight	Present	Present
30	*M. thomsonii*	Oblate	Black	Brown	Present	Present	Present	Inconspicuous	Straight	Present	Absent
31	*M. velutina*	Oblate	Black	Brown	Absent	Absent	Present	Inconspicuous	Straight to Weakly curved	Absent	Present
32	*M. velutina var. variegata*	Oblate	Blackish-brown	Brown	Absent	Absent	Present	Inconspicuous	Straight	Absent	Absent

Table 9. Seed surface sculpturing under Light and Scanning Electron Microscopy

Sl no	Name of taxa	Light microscopy	Scanning Electron Microscopy						
			Cell shape	Surface sculpturing		Anticlinal wall		Periclinal wall	
				Outer	Inner	Outer	Inner	Outer	Inner
1	*Ensete glaucum*	Smooth	Irregularly polygonal	Tuberculate, tubercules sparsely arranged connected to each other with several fine thread like reticulate tissues	Absent	Shallow, straight to wavy, smooth to folded, unevenly thickened	Absent	Convex, smooth to finely folded	Absent
2	*E. superbum*	Smooth	Irregularly polygonal	Colliculate, sparsely arranged connected to each other with reticulate tissues	Absent	Shallow, straight to wavy, smooth to sinuous, unevenly thickened	Absent	Convex, smooth	Absent
3	*Musa acuminata*	Verrucate	Irregularly polygonal	Reticulate	Reticulate	Raised, straight, smooth to finely folded, unevenly thickened	Prominently raised, straight, smooth to folded, unevenly thickened	Slightly concave or slightly concave with centre tubercle, warty	Slightly concave with multi-angular silica body at centre, warty
4	*M. argentii*	Verrucate	Irregularly polygonal	Slightly reticulate-colliculate	Reticulate	Shallow, straight, smooth to finely folded, unevenly thickened	Shallow, straight, sinuous, unevenly thickened	Convex, smooth	Slightly concave with multi-angular silica body at centre, smooth
5	*M. arunachalensis*	Verrucate	Irregularly polygonal	Slightly reticulate-colliculate	Reticulate	Shallow, straight, smooth, unevenly thickened	Prominently raised, straight, smooth to folded, unevenly thickened	Slightly concave, smooth	Slightly concave, with multi-angular silica body at centre, smooth
6	*M. aurantiaca*	Verrucate	Irregularly polygonal	Alveolate	Reticulate	Slightly raised, straight, smooth to slightly folded, unevenly thickened	Prominently raised, straight, smooth to folded, unevenly thickened	Slightly concave, smooth	Slightly concave, with multi-angular silica body at centre, smooth

7	*M. balbisiana var. balbisiana*	Verrucate	Irregularly polygonal	Reticulate-foveate	Reticulate-foveate	Raised, straight, smooth to slightly folded, unevenly thickened	Prominently raised, straight, smooth to slightly folded, unevenly thickened	Prominently concave, warty	Prominently concave, striate, striations warty
8	*M. balbisiana var. andamanica*	Verrucate	Irregularly polygonal	Reticulate-foveate	Reticulate-foveate	Raised, straight, smooth to slightly folded, unevenly thickened	Prominently raised, straight, smooth to slightly folded, unevenly thickened	Prominently concave, warty	Prominently concave, striate, striations rugose
9	*M. balbisiana var. bheem-kola*	Verrucate	Irregularly polygonal	Reticulate	Reticulate foveate	Raised, straight, smooth, unevenly thickened	Prominently raised, straight, smooth to slightly folded, unevenly thickened	Prominently concave, warty	Prominently concave, striate, striations rugose
10	*M. balbisiana var. elavazhai*	Verrucate	Irregularly polygonal	Reticulate	Reticulate foveate	Raised, straight, smooth, unevenly thickened	Prominently raised, straight, smooth to slightly folded, unevenly thickened	Prominently concave, warty	Prominently concave, smooth to rugose
11	*M. balbisiana var. sepa-athiya*	Verrucate	Irregularly polygonal	Reticulate	Reticulate foveate	Raised, straight, smooth, unevenly thickened	Prominently raised, straight, smooth to slightly folded, unevenly thickened	Prominently concave, warty	Prominently concave, striate, striations rugose
12	*M. cheesmanii*	Verrucate	Irregularly polygonal	Alveolate	Reticulate-foveate	Raised, straight, smooth, unevenly thickened	Prominently raised, straight, smooth to slightly folded, unevenly thickened	Flat to slightly concave, foveolate	Prominently concave, striate to rugose
13	*M. chunii*	Verrucate	Irregularly polygonal	Reticulate-foveate	Reticulate-foveate	Raised, straight, smooth to sinuous, uniformly thickened	Shallow, straight to slightly folded, sinuous, unevenly thickened	Slightly concave, smooth	Concave, deeply folded, smooth
14	*M. cylindrica*	Verrucate	Irregularly polygonal	Alveolate	Reticulate	Slightly raised, straight, smooth to sinuous, uniformly	Prominently raised, straight, smooth to sinuous,	Slightly concave, smooth to	Concave, smooth to slightly warty

						thickened	uniformly thickened	slightly warty	
15	*M. flaviflora*	Verrucate	Irregularly polygonal	Areolate	Colliculate	Shallow, straight to wavy, smooth to folded, unevenly thickened	Shallow, straight to wavy, smooth to folded, unevenly thickened	Slightly convex, smooth	Concave, slightly folded, smooth
16	*M. itinerans*	Verrucate	Irregularly polygonal	Alveolate	Reticulate	Slightly raised, straight, smooth, unevenly thickened	Shallow to slightly raised, straight, sinuous, unevenly thickened	Slightly Concave, smooth	Slightly concave with multi-angular silica body at centre, smooth
17	*M. kattuvazhana*	Verrucate	-	-	-	-	-	-	-
18	*M. mannii*	Verrucate	Irregularly polygonal	Reticulate-foveate	Reticulate-foveate	Shallow, straight, smooth to folded, unevenly thickened	Shallow, straight, smooth to folded, unevenly thickened	Concave, smooth	Concave, deeply folded, smooth
19	*M. markkuana*	Verrucate	Irregularly polygonal	Reticulate-foveate	Reticulate	Raised, straight, smooth to sinuous, unevenly thickened	Prominently raised, straight, smooth to folded, unevenly thickened	Concave, smooth	Concave with multi-angular silica body at centre, smooth
20	*M. markkui*	Verrucate	Irregularly polygonal	Colliculate	Colliculate	Shallow, straight, smooth, unevenly thickened	Shallow, straight, smooth, unevenly thickened	Convex, smooth	Convex with multi-angular silica body at centre, smooth
21	*M. nagensium*	Smooth to Verrucate	Irregularly polygonal	Reticulate-foveate	Reticulate	Raised, straight to sinuous, smooth, unevenly thickened	Prominently raised, straight to sinuous, smooth, unevenly thickened	Concave, smooth to folded	Concave, warty
22	*M. ochracea*	Smooth	Irregularly polygonal	Reticulate-foveate	Reticulate	Shallow, straight, smooth, unevenly thickened	Prominently raised, straight, smooth to sinuous, unevenly thickened	Concave, smooth	Concave, with multi-angular silica body at centre, smooth
23	*M. ornata*	Verrucate	Irregularly polygonal	Areolate	Reticulate	Slightly raised, straight, smooth,	Prominently raised, straight,	Slightly concave,	Concave with multi-angular

						unevenly thickened	smooth to sinuous, unevenly thickened	rugose	silica body at centre, rugose
24	*M. pradhanii*	Verrucate	Irregularly polygonal	Reticulate-foveate	Colliculate	Raised, straight, smooth to sinuous, unevenly thickened	Prominently raised, straight to folded, smooth, unevenly thickened	Slightly concave, smooth	Convex with multi-angular crystalline body, smooth
25	*M. puspanjaliae*	Smooth-Verrucate	Irregularly polygonal	Reticulate	Reticulate	Raised, straight to sinuous, smooth, unevenly thickened	Prominently raised, straight to sinuous, smooth, unevenly thickened	Concave, smooth to finely folded	Concave with multi-angular silica body at centre, smooth to rugose
26	*M. rubra*	Smooth	Irregularly polygonal	Reticulate-Areolate	Reticulate	Shallow, straight, smooth, unevenly thickened	Prominently raised, straight, smooth to folded, unevenly thickened	Slightly convex, smooth	Concave with multi-angular silica body at centre, smooth
27	*M. sabuana*	Verrucate	Irregularly polygonal	Reticulate	Reticulate	Raised, straight, smooth, unevenly thickened	Prominently raised, straight, smooth to folded, unevenly thickened	Concave, smooth	Prominently concave multi-angular silica body at centre, smooth
28	*M. sikkimensis*	Smooth-Verrucate	Irregularly polygonal	Reticulate	Reticulate	Raised, straight, smooth to sinuous, unevenly thickened	Raised, straight, smooth to sinuous, unevenly thickened	Concave with tubercle at centre, smooth to slightly folded	Concave with multi-angular silica body at centre, smooth
29	*M. sikkimensis var. simmondsii*	Smooth-Verrucate	Irregularly polygonal	Alveolate	Reticulate-foveate	Slightly raised, straight to slightly wavy, smooth, unevenly thickened	Shallow, straight to slightly wavy, smooth to slightly folded, unevenly thickened	Concave or with faintly tubercle at centre, smooth	Concave, deeply folded, smooth
30	*M. thomsonii*	Verrucate	Irregularly polygonal	Reticulate	Reticulate	Raised, straight to wavy, smooth to sinuous, unevenly thickened	Prominently raised, straight to wavy, smooth to folded, unevenly	Concave, smooth	Concave with multi-angular silica body at centre, rugose

							thickened		
31	*M. velutina var. velutina*	Verrucate	Irregularly polygonal	Reticulate	Reticulate	Slightly raised, straight, smooth to sinuous, unevenly thickened	Prominently raised, straight, smooth to folded, unevenly thickened	Concave or rarely with faintly tubercle at centre, smooth	Concave with multi-angular silica body at centre, smooth to rugose
32	*M. velutina var. variegata*	Verrucate	Irregularly polygonal	Reticulate	Reticulate	Raised, straight, smooth to sinuous, unevenly thickened	Raised or shallow, straight, smooth to folded, unevenly thickened	Concave, smooth	Concave with multi-angular silica body at centre, smooth to rugose

Table 10. Seed size, Micropylar plug width and Chalazal chamber size

Sl no	Name of taxa	Seed length (mm)		Seed width (mm)		Micropylar plug width (mm)		Chalazal chamber length (mm)		Chalazal chamber width (mm)	
		Min–Max	**Mean ± SE**	**Min–Max**	**Mean ± SE**	**Min–Max**	**Mean ± SE**	**Min–Max**	**Mean ± SE**	**Min–Max**	**Mean ± SE**
1	*Ensete glaucum*	5.50–7.00	6.43 ± 0.13	6.50–8.75	7.67 ± 0.17	2.00–2.75	2.38 ± 0.05	1.10–1.60	1.38 ± 0.04	2.55–3.00	2.84 ± 0.04
2	*E. superbum*	5.33–7.31	6.03 ± 0.13	5.97–8.50	7.18 ± 0.19	2.51–3.33	2.93 ± 0.06	1.10–1.50	1.26 ± 0.04	2.70–3.60	3.19 ± 0.09
3	*Musa acuminata*	2.69–4.56	3.47 ± 0.15	4.06–6.29	5.46 ± 0.17	1.30–1.91	1.59 ± 0.05	0.70–0.90	0.83 ± 0.02	2.00–2.35	2.18 ± 0.04
4	*M. argentii*	1.69–2.50	2.06 ± 0.05	5.13–6.25	5.66 ± 0.09	1.60–2.00	1.88 ± 0.03	0.70–0.88	0.79 ± 0.01	2.25–2.58	2.40 ± 0.33
5	*M. arunachalensis*	3.39–4.30	3.90 ± 0.06	4.50–7.00	6.45 ± 0.16	2.00–2.45	2.27 ± 0.03	0.65–0.85	0.77 ± 0.02	2.88–3.33	3.10 ± 0.50
6	*M. aurantiaca*	2.46–3.25	2.88 ± 0.06	4.53–5.47	4.98 ± 0.07	0.80–1.25	1.02 ± 0.03	0.65–0.75	0.70 ± 0.01	2.10–2.40	2.29 ± 0.02
7	*M. balbisiana var. balbisiana*	4.50–5.25	4.91 ± 0.07	5.00–6.50	5.77 ± 0.09	1.75–2.00	1.89 ± 0.02	1.45–1.78	1.57 ± 0.03	2.35–3.80	3.24 ± 0.15
8	*M. balbisiana var. andamanica*	3.80–5.00	4.37 ± 0.09	4.50–5.50	5.14 ± 0.07	1.63–2.00	1.88 ± 0.02	0.81–1.35	1.13 ± 0.05	2.18–2.78	2.49 ± 0.05
9	*M. balbisiana var. bheem-kola*	4.00–5.00	4.60 ± 0.08	5.00–6.00	5.49 ± 0.08	1.75–2.25	2.03 ± 0.03	1.00–1.58	1.29 ± 0.04	2.40–2.85	2.61 ± 0.05
10	*M. balbisiana var. elavazhai*	4.50–5.50	5.04 ± 0.06	4.75–6.00	5.61 ± 0.09	1.60–2.25	1.89 ± 0.04	1.16–1.45	1.36 ± 0.03	2.00–2.30	2.20 ± 0.02
11	*M. balbisiana var. sepa-athiya*	3.50–4.35	4.03 ± 0.05	4.90–6.25	5.59 ± 0.09	1.70–2.25	1.93 ± 0.03	0.80–1.10	0.98 ± 0.03	1.75–2.10	1.93 ± 0.03
12	*M. cheesmanii*	5.50–7.00	6.28 ± 0.11	8.00–11.00	9.83 ± 0.20	3.00–5.75	4.31 ± 0.23	1.50–1.70	1.64 ± 0.01	5.50–5.85	5.67 ± 0.03
13	*M. chunii*	3.00–3.75	3.44 ± 0.05	4.00–5.75	5.22 ± 0.12	1.50–2.00	1.72 ± 0.04	0.63–0.80	0.69 ± 0.01	2.30–3.00	2.54 ± 0.07
14	*M. cylindrica*	2.60–3.00	2.88 ± 0.02	4.98–6.40	5.88 ± 0.10	1.40–2.00	1.77 ± 0.04	0.80–1.00	0.88 ± 0.01	1.15–2.15	1.89 ± 0.19
15	*M. flaviflora*	3.50–4.00	3.85 ± 0.03	6.00–6.75	6.37 ± 0.07	1.75–2.00	1.86 ± 0.02	0.75–0.95	0.88 ± 0.02	2.50–2.65	2.58 ± 0.01
16	*M. itinerans*	3.20–4.80	4.15 ± 0.12	4.76–8.35	6.51 ± 0.20	1.40–2.50	2.11 ± 0.08	0.90–1.15	1.07 ± 0.02	2.60–3.00	2.74 ± 0.06
17	*M. kattuvazhana*	3.75–5.00	4.25 ± 0.07	6.75–8.00	7.39 ± 0.12	1.75–2.50	1.95 ± 0.04	0.60–1.00	0.83 ± 0.03	2.00–3.35	2.93 ± 0.12
18	*M. mannii*	3.25–3.75	3.50 ± 0.03	5.00–6.00	5.50 ± 0.34	1.50–2.00	1.68 ± 0.03	0.65–0.75	0.70 ± 0.01	1.90–2.10	2.00 ± 0.02
19	*M. markkuana*	2.50–3.00	2.73 ± 0.04	5.00–6.00	5.69 ± 0.07	1.50–2.00	1.86 ± 0.03	0.35–0.55	0.47 ± 0.02	2.10–2.40	2.21 ± 0.03
20	*M. markkui*	2.50–3.50	2.97 ± 0.08	4.38–5.82	5.09 ± 0.09	1.30–1.80	1.51 ± 0.04	0.70–0.85	0.76 ± 0.01	2.15–2.25	2.19 ± 0.01
21	*M. nagensium*	6.42–7.50	7.01 ± 0.08	8.00–12.00	10.40±0.35	3.50–6.50	4.90 ± 0.20	0.95–1.25	1.11 ± 0.03	6.10–6.70	6.49 ± 0.05
22	*M. ochracea*	2.50–4.00	3.09 ± 0.09	3.16–4.00	3.56 ± 0.06	1.00–1.50	1.28 ± 0.03	0.65–0.75	0.69 ± 0.01	1.35–1.50	1.43 ± 0.01

23	*M. ornata*	3.40–4.00	3.69 ± 0.04	4.54–6.00	5.42 ± 0.10	0.90–1.75	1.36 ± 0.08	0.10–1.15	0.99 ± 0.10	2.10–2.35	2.23 ± 0.02
24	*M. pradhanii*	3.50–5.00	4.11 ± 0.10	5.50–7.67	6.77 ± 0.16	1.30–1.65	1.52 ± 0.11	0.65–1.00	0.87 ± 0.10	1.95–3.30	2.84 ± 0.13
25	*M. puspanjaliae*	6.50–7.90	7.14 ± 0.10	8.00–15.0	12.36±0.51	4.25–6.00	5.08 ± 0.10	1.15–1.20	1.17 ± 0.01	4.80–5.20	5.01 ± 0.04
26	*M. rubra*	4.25–5.00	4.72 ± 0.07	5.40–6.25	5.85 ± 0.05	1.34–1.85	1.57 ± 0.03	0.60–0.80	0.72 ± 0.02	2.15–2.68	2.46 ± 0.04
27	*M. sabuana*	3.25–3.85	3.62 ± 0.04	5.00–6.25	5.56 ± 0.12	1.75–2.25	1.98 ± 0.04	0.60–0.65	0.62 ± 0.00	2.52–2.95	2.74 ± 0.04
28	*M. sikkimensis*	5.00–7.00	5.86 ± 0.13	6.50–9.50	8.03 ± 0.23	2.35–3.25	2.84 ± 0.07	0.80–1.01	0.88 ± 0.02	3.50–3.65	3.58 ± 0.01
29	*M. sikkimensis var. simmondsii*	4.85–6.00	5.64 ± 0.08	6.00–10.5	8.56 ± 0.38	2.75–3.50	3.12 ± 0.06	0.90–1.05	0.99 ± 0.16	4.90–5.20	5.08 ± 0.03
30	*M. thomsonii*	3.00–4.00	3.60 ± 0.06	4.83–6.23	5.59 ± 0.10	1.25–1.75	1.58 ± 0.03	0.80–1.98	1.22 ± 0.15	2.35–2.85	2.57 ± 0.05
31	*M. velutina*	2.75–3.25	2.98 ± 0.04	4.35–6.25	5.39 ± 0.12	1.40–1.90	1.68 ± 0.03	0.45–0.65	0.54 ± 0.02	2.40–2.85	2.57 ± 0.04
32	*M. velutina var. variegata*	2. 05–3.00	2.50 ± 0.24	4.20–5.63	5.02 ± 0.02	1.30–1.75	1.56 ± 0.04	0.40–0.50	0.46 ± 0.01	2.40–2.55	2.48 ± 0.01

Table 11. Seed coat anatomical characters (I)

Sl no	Name of taxa	Number of layers	Seed–coat thickness (µm)		Endotesta thickness (µm)		Tegmen thickness (µm)		Inner endosperm layer thickness (µm)	
			Min–Max	Mean ± SE	Min–Max	Mean ± SE	Min–Max	Mean ± SE	Min–Max	Mean ± SE
1	*Ensete glaucum*	42–48	326.48–383.93	356.98 ± 3.66	39.82–46.03	43.36 ± 0.43	35.11–37.49	36.51 ± 0.20	10.70–11.58	11.13 ± 0.07
2	*E. superbum*	30–38	245.29–315.98	280.19 ± 5.25	12.62–13.78	13.29 ± 0.09	2.41–4.83	3.81 ± 0.22	7.51–8.23	7.89 ± 0.05
3	*Musa acuminata*	20–25	206.58–277.36	233.30 ± 5.25	15.20–16.77	16.09 ± 0.12	16.67–18.80	18.14 ± 0.15	12.54–13.64	13.13 ± 0.09
4	*M. argentii*	18–21	163.31–240.45	209.76 ± 5.44	5.78–6.22	6.03 ± 0.03	2.42–2.88	2.67 ± 0.03	2.10–2.32	2.25 ± 0.01
5	*M. arunachalensis*	28–32	247.62–290.48	273.56 ± 3.55	12.83–13.75	13.32 ± 0.07	20.76–22.29	21.63 ± 0.12	11.61–12.07	11.83 ± 0.03
6	*M. aurantiaca*	22–25	129.29–184.63	156.29 ± 3.47	5.64–6.19	5.96 ± 0.04	2.04–2.25	2.16 ± 0.18	1.26–1.54	1.43 ± 0.04
7	*M. balbisiana var. balbisiana*	24–29	238.95–294.75	271.09 ± 4.63	8.84–9.94	9.31 ± 0.07	5.30–8.79	8.22 ± 0.22	7.68–8.58	8.21 ± 0.07
8	*M. balbisiana var. andamanica*	27–30	219.23–282.11	248.86 ± 4.31	5.68–6.23	5.98 ± 0.04	8.64–9.05	8.83 ± 0.03	7.04–7.54	7.28 ± 0.04
9	*M. balbisiana var. bheem–kola*	23–27	247.36–286.83	267.41 ± 2.96	6.25–6.84	6.60 ± 0.04	8.22–8.77	8.53 ± 0.04	7.96–9.29	8.71 ± 0.10
10	*M. balbisiana var. elavazhai*	28–31	249.67–298.75	275.17 ± 4.46	10.54–12.07	11.43 ± 0.13	12.80–14.35	13.59 ± 0.13	12.42–13.74	13.02 ± 0.11
11	*M. balbisiana var. sepa–athiya*	24–29	198.92–255.13	228.04 ± 4.92	4.70–5.54	5.10 ± 0.05	4.54–4.97	4.79 ± 0.03	4.50–4.98	4.75 ± 0.03
12	*M. cheesmanii*	38–45	520.46–630.91	561.88 ± 8.67	7.14–7.59	7.38 ± 0.03	4.29–4.81	4.56 ± 0.04	6.08–6.47	6.30 ± 0.03
13	*M. chunii*	26–30	178.16–227.89	201.60 ± 3.68	4.86–7.35	6.35 ± 0.22	8.50–11.00	9.85 ± 0.19	6.25–7.35	6.91 ± 0.09
14	*M. cylindrica*	18–25	200.88–258.28	224.47 ± 4.42	14.50–15.75	15.22 ± 0.10	15.85–18.11	17.29 ± 0.20	8.77–10.16	9.54 ± 0.10
15	*M. flaviflora*	21–25	186.24–233.39	208.39 ± 3.84	13.03–14.62	14.02 ± 0.12	17.00–19.93	18.73 ± 0.25	10.24–10.77	10.51 ± 0.04
16	*M. itinerans*	28–31	325.00–372.17	348.22 ± 3.71	10.27–11.94	11.09 ± 0.15	18.89–22.85	21.23 ± 0.31	7.62–9.28	8.47 ± 0.15
17	*M. kattuvazhana*	-	191.82–244.18	221.42 ± 4.78	-	-	-	-	-	-
18	*M. mannii*	23–26	201.31–247.57	222.08 ± 3.94	6.52–7.58	7.01 ± 0.10	7.89–9.25	8.56 ± 0.12	3.00–4.66	3.90 ± 0.15
19	*M. markkuana*	24–27	194.39–259.81	229.34 ± 5.38	7.63–8.10	7.89 ± 0.03	9.47–10.08	9.93 ± 0.03	3.83–4.6	4.16 ± 0.03
20	*M. markkui*	26–30	141.44–182.14	160.17 ± 3.16	6.40–7.83	7.13 ± 0.11	7.73–9.01	8.45 ± 0.10	8.30–8.75	8.50 ± 0.04
21	*M. nagensium*	28–35	550.91–596.32	578.14 ± 3.87	10.39–12.44	11.36 ± 0.17	10.12–12.59	11.48 ± 0.21	21.67–23.09	22.29 ± 0.12
22	*M. ochracea*	26–32	166.71–198.19	184.47 ± 2.43	8.88–9.21	9.08 ± 0.02	16.07–17.69	17.14 ± 0.12	10.67–12.17	11.53 ± 0.12

23	*M. ornata*	19–24	184.74–216.09	203.36 ± 2.63	9.30–10.86	10.23 ± 0.13	16.89–19.09	18.13 ± 0.17	10.86–12.50	11.68 ± 0.13
24	*M. pradhanii*	22–27	287.59–354.63	325.07 ± 5.85	9.36–10.24	9.79 ± 0.06	6.50–7.01	6.79 ± 0.04	7.38–8.19	7.71 ± 0.06
25	*M. puspanjaliae*	50–58	735.04–810.82	780.49 ± 6.44	11.41–12.52	12.07 ± 0.10	9.36–9.94	9.67 ± 0.04	2.39–3.23	2.86 ± 0.06
26	*M. rubra*	19–24	158.57–221.33	193.86 ± 4.29	7.24–8.36	7.83 ± 0.08	16.03–18.15	17.15 ± 0.17	6.55–8.27	7.39 ± 0.12
27	*M. sabuana*	22–26	183.92–228.50	210.86 ± 3.50	15.00–17.56	16.46 ± 0.20	22.70–23.96	23.37 ± 0.0	12.31–14.04	13.27 ± 0.13
28	*M. sikkimensis*	29–37	445.69–511.11	476.95 ± 5.97	12.67–13.63	13.20 ± 0.08	29.43–32.12	30.93 ± 0.22	13.45–14.73	14.06 ± 0.11
29	*M. sikkimensis var. simmondsii*	33–39	418.22–459.95	439.41 ± 3.72	9.82–15.31	12.61 ± 0.46	28.16–31.02	29.76 ± 0.24	10.90–13.70	12.48 ± 0.22
30	*M. thomsonii*	24–28	191.77–266.09	216.42 ± 4.63	14.32–15.55	14.97 ± 0.09	23.53–25.45	24.61 ± 0.16	7.50–8.53	8.10 ± 0.08
31	*M. velutina*	25–30	171.65–196.19	182.95 ± 1.90	5.47–7.19	6.41 ± 0.15	8.52–9.82	9.21 ± 0.10	6.69–7.95	7.31 ± 0.09
32	*M. velutina var. variegata*	25–28	162.60–195.43	180.74 ± 2.50	4.94–6.69	5.80 ± 0.14	9.70–13.13	11.82 ± 0.28	7.08–7.64	7.35 ± 0.04

Table 12. Seed coat anatomical characters (II)

Sl no	Name of taxa	Micropylar mesotestal proliferation (µm)		Chalazal mesotestal proliferation (µm)		Micropylar collar length (µm)	
		Min–Max	Mean ± SE	Min–Max	Mean ± SE	Min–Max	Mean ± SE
1	*Ensete glaucum*	1051.57–1166.28	1112.74 ± 8.06	703.40–794.46	749.73 ± 8.08	1284.35–1357.98	1321.04 ± 6.15
2	*E. superbum*	758.04–930.34	860.12 ± 13.77	689.31–751.03	721.88 ± 5.80	1347.23–1450.33	1390.26 ± 8.10
3	*Musa acuminata*	342.78–444.29	388.19 ± 8.62	527.70–589.90	561.40 ± 5.27	639.17–730.17	678.38 ± 9.31
4	*M. argentii*	399.88–509.37	437.04 ± 7.40	423.25–477.52	453.95 ± 4.49	1003.91–1067.79	1036.55 ± 6.17
5	*M. arunachalensis*	463.86–558.48	501.18 ± 6.73	810.24–932.81	880.27 ± 8.00	908.57–990.95	951.11 ± 5.89
6	*M. aurantiaca*	186.03–244.07	211.73 ± 5.29	317.08–348.85	333.38 ± 2.45	583.98–667.14	627.41 ± 6.58
7	*M. balbisiana*	531.81–633.24	593.0 ± 8.42	429.67–533.71	474.50 ± 8.13	962.14–1039.14	1011.56 ± 5.27
8	*M. balbisiana* var. *andamanica*	433.46–503.75	476.96 ± 5.56	453.55–548.46	496.47 ± 6.88	835.36–924.57	887.01 ± 8.20
9	*M. balbisiana* var. *bheem–kola*	447.90–533.65	482.35 ± 7.71	562.29–629.26	591.89 ± 5.33	1023.03–1093.25	1056.27 ± 5.01
10	*M. balbisiana* var. *elavazhai*	455.51–543.63	492.18 ± 6.37	541.44–624.55	585.95 ± 6.10	1002.02–1102.13	1036.15 ± 7.34
11	*M. balbisiana* var. *sepa–athiya*	347.44–473.97	411.67 ± 8.91	413.87–486.98	449.11 ± 5.46	801.43–896.08	844.70 ± 6.82
12	*M. cheesmanii*	932.46–1085.26	998.85 ± 9.50	551.59–657.42	610.78 ± 8.30	1128.09–1214.85	1168.10 ± 8.28
13	*M. chunii*	318.44–420.92	372.21 ± 8.54	458.81–548.71	512.50 ± 6.89	505.22–597.52	549.12 ± 8.12
14	*M. cylindrica*	281.30–375.53	337.01 ± 6.44	449.11–541.90	798.81 ± 7.90	607.01–699.89	656.88 ± 7.49
15	*M. flaviflora*	318.64–411.19	360.47 ± 8.49	531.21–583.67	558.98 ± 4.10	734.79–796.49	763.24 ± 5.16
16	*M. itinerans*	461.29–556.39	529.12 ± 7.53	834.25–880.41	857.56 ± 4.45	767.30–851.47	808.68 ± 7.18
17	*M. kattuvazhana*	409.73–492.73	452.19 ± 7.47	548.54–677.18	623.95 ± 7.95	769.27–837.36	807.15 ± 5.90
18	*M. mannii*	317.85–408.78	345.24 ± 6.60	253.64–373.83	307.74 ± 7.67	603.91–677.36	634.61 ± 6.35
19	*M. markkuana*	286.73–393.27	352.07 ± 6.87	309.72–398.41	351.45 ± 6.69	607.47–693.26	652.90 ± 7.87
20	*M. markkui*	324.28–448.93	367.02 ± 9.05	558.24–603.54	578.68 ± 4.10	520.14–607.49	565.50 ± 7.96
21	*M. nagensium*	1350.67–1460.53	1395.88 ± 9.70	1330.90–1424.75	1391.94 ± 6.88	1705.48–1780.20	1737.43 ± 6.53
22	*M. ochracea*	313.71–424.76	359.07 ± 7.67	330.43–401.48	368.00 ± 5.14	518.14–589.23	560.11 ± 6.37
23	*M. ornata*	311.79–424.60	373.13 ± 7.13	371.72–442.80	404.74 ± 5.14	638.95–735.99	692.47 ± 7.98

24	*M. pradhanii*	530.64–640.14	583.22 ± 7.70	824.35–907.96	860.75 ± 7.05	900.45–988.23	944.53 ± 6.81
25	*M. puspanjaliae*	1284.22–1378.07	1330.08 ± 7.45	1474.68–1559.63	1522.41 ± 6.38	1306.23–1397.79	1351.87 ± 7.25
26	*M. rubra*	272.53–372.39	343.26 ± 7.14	377.92–452.34	412.80 ± 6.49	721.55–793.49	754.83 ± 6.94
27	*M. sabuana*	350.74–420.93	388.55 ± 5.53	513.91–584.47	553.06 ± 5.13	657.37–768.85	711.40 ± 8.67
28	*M. sikkimensis*	948.58–1060.40	1009.00 ± 9.03	1369.88–1435.20	1407.05 ± 5.99	901.85–964.19	928.12 ± 5.58
29	*M. sikkimensis var. simmondsii*	970.00–1016.52	988.24 ± 3.90	1293.06–1358.74	1324.92 ± 6.00	1114.80–1198.13	1152.49 ± 7.58
30	*M. thomsonii*	297.18–406.59	358.28 ± 8.29	501.72–590.90	556.83 ± 5.93	593.86–640.90	621.26 ± 4.05
31	*M. velutina*	268.53–393.56	332.77 ± 7.45	239.29–308.31	276.34 ± 5.81	566.80–622.63	596.27 ± 4.89
32	*M. velutina var. variegata*	277.99–330.04	301.40 ± 3.95	228.31–283.70	253.06 ± 4.40	526.99–584.79	553.39 ± 5.26

Chapter 7

PHENETICS

PHENETICS

Operational Taxonomic Unit of of 32 taxa of the family Musaceae were examined for 55 characters (Table. 13). This includes 23 vegetative and 32 reproductive (4 pollen and 28 seed) characters (OUT's) that falls under 36 qualitative and 19 quantitative. From the phenogram obtained, family Musaceae separated in to four groups. In which, *Ensete* in to group I, and *Musa* is separated in to three groups: group II, group III and group IV, mainly on the basis of differences in their seed size, shape and seed surface sculpturing. All the taxa are separated at a distance of 100 bootstraps (Fig. 86).

Group I

The genus *Ensete* differs from *Musa* having seeds with prominent hylar rim and the absence of inner surface sculpturing of seed. All other vegetative and reproductive characters are overlapping with *Musa* spp.

Group II

Group II includes four taxa *viz., M. sikkimensis* var. *simmondsii, M. sikkimensis* var. *sikkimensis, M. puspanjaliae* and *M. nagensium*. In this group, seeds are oblate, with smooth-rugose surface under light microscope and are large in size (5 × 8 mm and above). Number of seed coat layers of all the taxa exceeds 30, thickness above 400 µm with endotesta above14.01 µm. Here, *M. sikkimensis* var. *simmondsii* is more allied to *M. sikkimensis* var. *sikkimensis* and *M. puspanjaliae* is more allied to *M. nagensium.* This group shows close resemblances with the group I, in having large sized seeds with thick seed coat. However, group II differs from the out-group in having ovoid shaped seeds with smooth surface characters.

Group III

Group III includes seven taxa *viz., M. cheesmanii, M. balbisiana var. elavazhai, M. kattuvazhana, M. balbisiana var. bheem-kola, M. balbisiana var. andamanica* and *M. balbisiana var. balbisiana.* The infrageneric classification of *M. balbisiana* cultivars has been subject to controversy. The taxa aligned in this group share several characters such as sub-globose seed shape with verrucate surface under light microscope, however, *M. kattuvazhana* exhibits oblate seed shape with reticulate-foveate inner surface sculpturing with prominently concave and striate periclinal wall. In this group, *M. cheesmanii* is the out-group to all the other taxa. It shows close similarities with the members of group I, in its seed size, number of layers, seed coat and endotesta thickness. However, thickness of tegmen is 4 µm in *M. cheesmanii* against above 9 µm in group II. Other characters shared by all the taxa in this group, except *M cheesmanii,* include: the presence of prominent chalazal chamber column (*vs*. absent), adaxial guard cell length larger than abaxial (*vs*. abaxial larger than adaxial). Though some of the seed characters of *M. kattuvazhana* are unavailable, all the taxa except *M. cheesmanii* and *M. kattuvazhana* exhibit identical characters. Both of these taxa come under class I (100–599 µm) of chalazal mesotestal proliferation, whereas the rest of the species come under class III with cmp between 600–999 µm. Another interesting result is the position of *M. balbisiana* var. *elavazhai* remains distinct from all other infraspecific taxa of *M. balbisiana,* because of the presence of 1-layered hypodermis above the larger vascular bundle.

Group IV

Group IV includes all the rest of the *Musa* taxa with moderately small sized oblate or ellipsoid seeds. It is again divided in to 6 sub groups.

Subgroup I

It consists of *M. ochracea, M. markkui* and *M. chunii,* that share some specific characters *viz.,* seed body tapering absent at micropylar, presence of chalazal mucro, micropylar collar length (below 699 µm) and endotestal thickness within class I (below 10 µm). In addition, *M. chunii* shows more resemblance with *M. markkui* and *M. ochracea* is out grouped to the other two species. Both *M. chunii & M. markkui* share similar characters such as, 3-layered adaxial hypodermal cells (*vs.* 2-layerd in *M. ochracea*), oblate seed shape (*vs.* ellipsoid) and verrucate surface under light microscope (*vs.* smooth).

Subgroup II

This subgroup consists of three species *viz. M. pradhanii, M. itinerans* and *M. arunachalensis.* All species share similar characters *viz.,* anticlinal wall of abaxial inter-costal cells wavy to sinuous, obovate larger vascular bundles, verrucate seed surface, slightly concave, smooth outer periclinal wall, presence of chalazal chamber column. In this subgroup, *M. pradhanii* shows close similarities with *M. itinerans* than those with *M. arunachalensis* and the later is out grouped to *M. pradhanii* and *M. itinerans.* The specific characters similar in *M. pradhanii* and *M. itinerans* are sub-equal length of guard cells in both the epidermis (*vs.* adaxial larger than abaxial) and inner endosperm layer thickness that falls under class II with 5–10 µm (Class III with 10.01 µm and above).

Subgroup III

This subgroup consists of *M. sabuana,* with unique character such as 4-layered adaxial hypodermal cells. Though it forms a separate group, it shows similarities with both subgroup II (*M. arunachalensis*) and subgroup III (*M. flaviflora*) in some characters. The similar characters include length of adaxial guard cell larger than abaxial, presence of chalazal chamber column and thickness of inner endosperm layer that falls in class III (10.01 µm and above). In addition, *M. sabuana* has some characters *viz*., endotesta thickness (class III) and obovate larger vascular bundle, similar to *M. flaviflora* the neighboring taxa within the subgroup IV.

Subgroup IV

Consists of *M. flaviflora* and *M. argentii,* and share similar characters such as wavy to sinuous abaxial anticlinal costal cell, 1-layered adaxial hypodermis above the larger vascular bundles, attachment of larger vascular bundles on adaxial hypodermis, lamina thickness above smaller vascular bundle (300–399 µm), shallow outer and inner anticlinal wall and seed coat thickness that falls in class I (upto 299 µm).

Subgroup V

Musa rubra, M. mannii, M. velutina var. *velutina, M. markkuana, M. velutina* var. *variegata* and *M. aurantiaca* are grouped in this subgroup. In this subgroup, species show several shared characters *viz*., 1-layered adaxial hypodermis, 1-layered hypodermis above the larger vascular bundles, length of adaxial guard cell larger than abaxial, lamina thickness that falls in class I (upto 299 µm), seed body tapering at both micropylar and chalazal region, seed coat thickness that falls in class I (upto 299 µm), thickness of micropylar mesotestal proliferation included in class I (100–499 µm) and endotestal thickness that falls in class I (up to 10 µm). In addition, seed length of *M. rubra, M. mannii* and *M. velutina* var. *velutina* falls under class II (3.00–4.99 mm), and that of *M. markkuana, M. velutina* var. *variegata* and *M. aurantiaca* falls under class III (5 mm and above).

Subgroup VI

Subgroup VI includes four taxa *viz., M. thomsonii, M. ornata, M. cylindrica* and *M. acuminata*. Reticulate inner surface sculpturing of seed, raised inner anticlinal wall and endotesta thickness falls under class IV (14.01 µm and above), except for *M. ornata* (vs. class II - 5.01–10 µm). In addition, *M. ornata* shows difference in its lamina anatomy due to the absence of air canal and parenchymatous septa as well as smaller vascular bundles suspended in the mesophyll. This result also supports the findings of Tomlinson (1969).

Table 13. Character and character states of 32 taxa of Indian Musaceae for Phenetic analysis

Sl.no	Character	Character states	Remarks
Epidermal characters			
1	Adaxial costal cell-shape	(0) Polygonal (1) Rectangular	
2	Abaxial costal cell-shape	(0) Polygonal (1) Rectangular	
3	Adaxial inter-costal cell-shape	(0) Irregularly-polygonal (1) Rectangular	
4	Abaxial costal cell-shape	(0) Irregularly-polygonal (1) Rectangular (2) Irregular	
5	Guard cell length	(0) Sub-equal (1) Abaxial larger than adaxial (2) Adaxial larger than abaxial	
Lamina characters			
6	Lamina thickness above smaller vascular bundle	(0) Up to 299 µm (1) 300–399 µm and above (2) 400 µm and above	
7	Lamina thickness above larger vascular bundle	(0) Up to 299 µm (1) 300–399 µm and above (2) 400–449 µm and above (3) 450 µm and above	

Hypodermal characters			
8	Adaxial layers	(0) 1-layered (1) 2-layered (2) 3-layered (3) 4-layered	Taken from both sides of larger vascular bundles
9	Adaxial shape	(0) Rectangular (1) Hexagonal	
10	Abaxial layers	(0) 1-layered (1) 2-layered	
11	Abaxial shape	(0) Rectangular (1) Hexagonal	
Adaxial hypodermal cell above larger vascular bundle			
12	Number of layers	(0) 1-layered (1) 2-layered	
13	Alignment of layers	(0) Isodiametric (1) Anisodiametric (2) Not applicable	
14	Proportion of cells in anisodiametric layers	(0) Above larger and below smaller (1) Above smaller and below larger (2) Not applicable	
15	Outer cell shape	(0) Polygonal (1) Hexagonal (2) Irregular	
16	Outer cell character	(0) Isodiametric (1) Higher than broad (2) Broader than high (3) Irregular	
17	Inner cell shape	(0) Polygonal (1) Hexagonal (2) Not applicable	
18	Inner cell character	(0) Isodiametric (1) Higher than broad (2) Broader than high (3) Not applicable	
Larger vascular bundle characters			
19	Shape	(0) Elliptic (1) Obovate (2) Ovate (3) Ventricose	

20	Attachment	(0) Adaxial and abaxial (1) Adaxial only	
21	Adaxial bundle sheath cell type	(0) Thin-wall followed by thick-wall (1) Thick-wall	
Petiole			
22	Abaxial shape	(0) U-shaped (1) Wide U-shaped	
23	Arc I shape	(0) Y-shaped (1) V-shaped (2) U-shaped	
Pollen morphology			
24	Shape	(0) Spheroidal (1) Oblate-spheroidal or Prolate-spheroidal	
25	Surface sculpturing	(0) Rugulate (1) Verrucate	
26	Exine thickness	(0) 0–1.99 µm (1) 2–4.99 µm (2) 5 µm and above	
27	Intine thickness	(0) 0–1.99 µm (1) 2.00–4.99 µm (2) 5.00 µm and above	
Seed Morphology			
28	Seed shape	(0) Ellipsoid (1) Ovoid (2) Oblate (3) Sub-globose	
29	Seed length	(0) 0–2.99 mm (1) 3–4.99 mm (2) 5 mm and above	
30	Seed width	(0) 0–5.99 mm (1) 6.00–7.99 mm (2) 8.00 mm and above	
31	Chalazal chamber width	(0) 1.00–2.99 mm (1) 3.00–4.99 mm (2) 5.00 mm and above	
32	Seed body tapering at micropyle	(0) Present (1) Absent	
33	Tapering at chalaza	(2) Present (0) Absent	

34	Seed shape contorted by tight packing	(0) Present (1) Absent	
35	Hilar rim	(0) Prominent (1) Inconspicuous	
36	Micropylar collar	(0) Straight (1) Weakly curved	
37	Chalazal mucro	(0) Present (1) Absent	
38	Chalazal chamber column	(0) Present (1) Absent	
39	Seed surface under LM sculpturing	(0) Smooth (1) Verrucate (2) Smooth-verrucate	
SEM Analysis			
40	Outer surface sculpturing	(0) Tuberculate (1) Colliculate (2) Alveolate (3) Reticulate (4) Slightly-reticulate-colliculate (5) Reticulate-foveate (6) Reticulate-areolate (7) Areolate	
41	Inner surface sculpturing	(0) Colliculate (1) Reticulate (2) Reticulate-foveate	
42	Outer anticlinal wall nature	(0) Shallow (1) Prominently raised (2) Raised (3) Slightly raised	
43	Inner anticlinal wall nature	(0) Shallow (1) Raised (2) Prominently raised	
44	Outer periclinal wall nature	(0) Convex (1) Concave (2) Prominently concave (3) Concave with tubercle at centre	

45	Outer periclinal wall texture	(0) Smooth (1) Warty (2) Foveolate (3) Rugose	
46	Inner periclinal wall nature	(0) Convex (1) Prominently concave (2) Concave	
47	Inner periclinal wall texture	(0) Smooth (1) Striate (2) Folded (3) Warty (4) Angular crystalized	
Seed anatomy			
48	Seed coat thickness	(0) Upto 299 µm (1) 300–399µm (2) 400 µm and above	
49	Number of seed coat layers	(0) Upto 29 layers (1) 30 layers and above	
50	Endotesta thickness	(0) Upto 10 µm (1) 10.01–14 µm (2) 14.01 µm and above	
51	Tegmen thickness	(0) 0–5 µm (1) 5.01–11.50 µm (2) 11.51–20.00 µm (3) 20.01 µm and above	
52	Inner endosperm layer thickness	(0) 0–5 µm (1) 5.01–10.00 µm (2) 10.01 µm and above	
53	Micropylar mesotestal proliferation thickness	(0) 100–499 µm (1) 500–899 µm (2) 900 µm and above	
54	Micropylar collar length	(0) Upto 699 µm (1) 700–999 µm (2) 1000 µm and above	
55	Chalazal mesotestal proliferation	(0) 100–599 µm (1) 600–999 µm (2) 1000 µm and above	

Chapter 8

SUMMARY

SUMMARY

Musaceae, the most ancient family within Zingiberales, is highly related to Strelitziaceae, Lowiaceae and Heliconiaceae (Tomlinson, 1962; Kress 1990, 1995; Kress *et al*., 2001). It includes seeded wild species to seedless cultivars with various ploidy levels (Singh *et al.,* 2001; Prasad *et al*., 2013). The banana family comprises of three genera, *Ensete, Musella* and *Musa*. In India, the family is represented by 34 wild taxa under two genera (*Ensete* and *Musa*) within which, a total of 20 taxa are endemic, out of which 15 are endemic to northeast India. Musaceae are regarded as one of the taxonomically complicated family within the order Zingiberales and the present study on anatomy, palynology and seed micro-morphology is an attempt to solve the complexities within the taxa.

Scanty literature is available on the anatomical studies of the vegetative parts of Musaceae. The studies, that began with Skutch (1927) was later on followed by the anatomical approach of Tomlinson (1959), towards the classification of Musaceae. Subsequently, he altered his concept regarding "the species of *Musa* are identical in structure" (1969). Study by Triplett and Kirchoff (1991) in four taxa of Musaceae, concluded that the species are all different in their cell structure, that in turn supported Tomlinson (1969).

The present study is the first attempt to elucidate the anatomical features of all wild taxa of Indian Musaceae. This novel approach has provided us significant data on the anatomy of laminar architecture, petiole and midrib. The results obtained strongly support the findings of Skutch (1927), Tomlinson (1969) and Triplett and Kirchoff (1991). However, the present study, barely support the concept of Tomlinson (1959), who considered sub-equal distribution of stomata on both the surface of lamina of *Ensete* as its delimiting character.

The major vegetative anatomical features considered for delimitation of the taxa include lamina thickness, epidermal cell shape (costal and inter-costal cells), ratio of adaxial and abaxial guard cell length, number of layers on adaxial and abaxial hypodermis. In addition to these characters, the present study has used some more characters that were not considered in earlier studies. They include cell shape and number of layers of adaxial hypodermis above the larger vascular bundle, shape of arc I bundle of petiole and the shape of larger vascular bundle of lamina.

Thickness of lamina varies from one taxon to another and it provides sufficient data for species delimitation (Skutch, 1927; Tomlinson, 1969; Triplett & Kirchoff, 1991). It varies from 201 to 634. µm. Shape of the adaxial and abaxial epidermal cells vary from rectangular or polygonal with straight, folded, wavy or sinuous anticlinal wall. Hypodermis exhibits the most important characters with great taxonomic importance. Hypodermal cells are either hexagonal or rectangular in addition, the number of hypodermal layers on adaxial (1, 2, 3, or 4) and abaxial (1 or 2) surfaces are constant to some taxa. In addition, the shape and number of layers on the hypodermal cells above the larger vascular bundles also possess significant role even in the infraspecific taxa. One of the unique features of Musaceae is the presence of large air canals or with paraenchymatous septa in the mesophyll, which differs this family from other families of the order Zingiberales. Exceptions are seen in the case of *M. ornata* without having air canal and parenchymatous septa and it considered as the intermediate form, shows similarities with Heliconiaceae (Tomlinsosn, 1959).

Vascular bundles are four types (Elliptic, obovate, ovate and ventricose) with most of the taxa possess attachment in adaxial hypodermis. However, some of the species show attachment on both hypodermises. The unique feature observed in the adaxial bundle sheath is the presence of thin-walled sclerenchyma with larger lumen, followed by thick-walled with smaller lumen. Whereas, all other taxa possess thick-walled sclerenchyma with smaller lumen, followed by thin walled with larger lumen.

In genus *Musa,* petiole of both adaxial and abaxial surfaces are U-shaped, whereas in *Ensete,* petiole exhibits wide U-shape in the abaxial portion. Midrib of all taxa of *Musa* studied possess U-shaped adaxial and abaxial surface. The petiolar wing of *Musa* in most taxa are open, however, certain taxa have closer to completely overlapped wings. Both petiole and midrib consist of Bundle arcs I, II and III; arc I of larger vascular bundles is situated adaxial to and pectinating with air canal, arranged in different shapes (U, V or Y-shaped); Arc II and arc III consists of small vascular bundles and numerous fibrous bundles. Cellular constituents show similarities in their structure in both petiole and midrib in all taxa studied, except for proportions of the size of vascular bundles. More sclerenchymatous cells are seen in adaxial epidermis than in the abaxial surface, whereas, more chlorenchymatous tissues are seen in abaxial and a few in adaxial surface. Air chambers in petiole and midrib show differences in the number when the plants are collected form dry as well as from wet areas. Hence, number of the air chambers has no significance in taxonomy. Calcium oxalate crystals are common throughout the petiole and midrib.

Palynology

Most of the taxa within Musaceae are palynologically unknown. The available authentic data on pollen morphology of Musaceae is by Simmonds (1960), and reported that the genus *Musa* possess smaller pollen grains when compared to *Ensete.* The present study supports this view except for few Indian endemic species. Scanning Electron Microscopic analysis of pollen grains of *Ensete* spp. from Thailand by Inta *et al.,* 2015 reported both verrucate (*E. glaucum*) and perforated (*E.* superbum) sculpturing. Present study confirmed that only verrucate sculpturing is present in both *Ensete* spp.

Though previous studies have reported exineless pollen grains in Zingiberales (Kress *et al.,* 1978; Dahlgren & Clifford, 1982; Zavada, 1983; Dahlgren *et al.,* 1985), the present study confirmed the presence of prominent thick exine to skinny exine.

Morphology and anatomy of Seed

The present study is the first comprehensive investigation on the seed micro-morphological and anatomical aspects of Indian Musaceae. Various seed characters like shape, size, surface sculpturing (light microscopy and SEM), seed coat thickness, layer characters and chalazal chamber column were considered. Seed characters play a significant role in the delimitation of taxa as they are more stable than the vegetative (anatomical) and pollen features. The same provides the most important character states for phenetic analysis.

Seed characters play an important role in Musaceae taxonomy. The major characters used for the separation of genus *Ensete* from *Musa* is the presence of prominent hylar rim and absence of secondary (inner surface) surface. Colour of the seeds shows variation, *ie*., Black turning to dull black, hence it cannot be taken as a constant character for species delimitation.

Aril is absent in all taxa. Majority of the seeds are oblate in shape with verrucate surface, however, some of them are smooth-verrucate. Ovoid seeds with smooth surface (under light microscopy) are the characteristic feature of the genus *Ensete,* where as sub-globose with verrucate type are diagnostic character of *M. balbisiana* (all the infraspecific taxa) and *M. cheesmanii.* In addition, ellipsoid seeds with smooth surface (LM) are present in *M. ochracea* and *M. rubra.* Seed size also plays an important role in the identification of the taxa to some extent. The interesting thing observed is that, all taxa with erect or sub-horizontal inflorescence possess small seeds, whereas the taxa with larger pseudostem (pendulous inflorescence) possess both smaller and larger seeds. Size of the seeds is directly proportional to seed coat thickness and number of layers. However, the thickness of endotesta, tegmen and inner endosperm layer shows differences in smaller sized as well as larger sized seeds.

One of the peculiar characters of Musaceae is the presence of a secondary inner surface, formed by the separation of outer cell wall of the exotesta (Graven *et al.,* 1996), however, separation of outer cell wall is absent in both species of *Ensete*. The present study observed eight types of outer sculpturing (alveolate, areolate, reticulate, reticulate-areolate, reticulate-foveate, slightly reticulate-colliculate and tuberculate) and three inner sculpturing (colliculate, reticulate and reticulate-foveat) with diverse nature of anticlinal and periclinal cell walls

Phenetics

Phenetic analyses of 32 taxa of Indian Musaceae resulted in four groups that well support the morphological as well as molecular studies. Group I clustered with the genus *Ensete* (*E. glaucum* and *E. superbum*), which differs from *Musa* in having arc I of petiole arranged in U-shape, ovoid seeds with prominent hylar rim, smooth surface sculpturing except *M. rubra* and *M. ochracea,* sparsely arranged tuberculate or colliculate outer surface sculpturing and outer cell wall not separating from the exotesta and not form the secondary inner surface.

Group II includes *M. sikkimensis* var. *simmondsii, M. sikkimensis* var. *sikkimensis, M. puspanjaliae* and *M. nagensium*, whereas, group III includes six taxa *viz. M. cheesmanii, M. balbisiana var. elavazhai, M. kattuvazhana,* *M. balbisiana var. bheem-kola, M. balbisiana var. andamanica* and *M. balbisiana var. balbisiana.* All taxa grouped in both II and III are tall herbs with pendulous inflorescence with non-revolute bracts with flowers arranged in two rows, and larger seeds. However, comparatively large sized, oblate seeds with smooth-verrucate surface are distinct features of the first group, whereas the second group has sub-globose, verrucate seeds.. Within the second group, an exception is *M. kattuvazhana,* with oblate seeds and revolute bract.

Group IV consists of pendulous, horizontal and erect inflorescence with arrangement of flowers in either single or double row. Subgroup I comprises of *M. ochracea, M. markkui* and *M. chunii,* having sub-horizontal inflorescence with revolute bracts. However, *M. markkui* and *M. chunii* show more similarities with each other than *M. ochracea*. *Musa ochracea* possesses top-shaped male bud and flowers are arranged in two rows, whereas, the former two species have lanceolate male bud and single row of floral arrangements. *Musa pradhanii, M. itinerans* and *M. arunachalensis* are grouped into a single sub-group (II). All species possess arched to sub-horizontal inflorescence with flowers arranged in two rows. In this subgroup, *M. pradhanii* shows similarities with *M. itinerans* in having sub-horizontal inflorescence with the bract colour pink purple or deep maroon with yellow patches against arched inflorescence with bright coloured bracts in *M. arunachalensis.* Subgroup III consists of *M. sabuana,* with unique characters such as spiral arrangement of leaves at top, sub-horizontal to pendulous inflorescence with colour of bracts ranging from green to purple with intermediate shading and purple with green stripes.

Subgroup IV is represented by *M. flaviflora* and *M. argentii.* Though, both the species are similar in their anatomy and seed micro-morphology, these two species show great differences in their morphology. The subgroup

V includes *M. rubra, M. mannii, M. velutina* var. *velutina, M. markkuana, M. velutina* var. *variegata* and *M. aurantiaca.* These taxa exhibit similar morphology (earlier, these members were treated in the *Section Rhodochlamys,* based on morphology and chromosome number) *viz.,* all are small herbs with pseudostem below 3 meter in height, erect inflorescence with bright coloured bracts, and flowers arranged in single row. Exceptions are seen in *M. rubra* and *M. mannii,* exhibiting variations in their inflorescence nature. Typically, these two species show erect inflorescence, but in some cases, the inflorescence may bend down.

The last subgroup consists of *M. thomsonii, M. ornata, M. cylindrica* and *M. acuminata.* All species in this subgroup exhibit more than 3 meter long pseudostem with pendulous inflorescence, deep-purple to brown purple coloured, revolute bracts and flowers arranged in two rows. *M. ornata,* is an exception in this subgroup. Though it has some anatomical and seed micro-morphological characters similar to other taxa in the subgroup, this species has erect inflorescence, bright coloured, non-revolute bracts and floral arrangements in one row. In addition, mesophyll without air canal, parenchymatous transverse septa and arrangement of smaller vascular bundle are different from the former. Tomlinson (1959) noted similar characters in both *Heliconia* and *M. ornata* and considered the latter an intermediate between Musaceae and Heliconiaceae.

The data obtained from the phenogram greatly supports the recent sectional classification proposed by Hakkinen (2013). Earlier classification of Cheesman (1947b) treated erect inflorescence as a separate section - *Sect. Rhodochlamys.* Based on the molecular studies, Hakkinen merged the erect inflorescence taxa into the *Sect. Musa.* The data obtained from the phenogram strongly correlates with the recent sectional classification. Here both *M. acuminata and M. balbisiana* show great bootstrapping and the remaining taxa with erect and sub-horizontal inflorescence lie between them. In addition, the positioning of *M. acuminata,* as sister to *M. ornata,* with minimum distance substantiates the findings of earlier molecular investigations (Christelova *et al.,* 2011; Novak *et al.,* 2014; Janssens *et al.,* 2016; Lamare *et al.,* 2017).

The present studies based on the anatomical and palynological aspects of Indian Musaceae revealed that, all Indian taxa shows differences in these characters. Foliar anatomical characters like lamina thickness, shape of epidermis, number and shape of hypodermal cells, shape of arc I in petiole *etc*. were used for species delimitation. Pollen characters *viz.,* surface sculpture, thickness of exine and intine is also suited for species delimitation. Seed characters such as shape, size, ornamentation, number of seed coat layers and thickness, thickness of endotesta, tegmen and inner endosperm layers are more stable and play a significant role in the identification of taxa. The phenetic analysis, based on 55 characters (OTU's) of 32 taxa expressed to a phenogram which strongly support the morphology as well as the recent molecular classification.

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APPENDIX

APPENDIX 1

PUBLICATIONS

List of articles published

1. **Hareesh**, **V.S.,** Joe, A., Sreejith, P.E. & M. Sabu. (2017) *Musa markkuana stat. nov.* (Musaceae)-A reassessment of *Musa velutina* subsp. *markkuana*. *Phytotaxa* 303(3): 279–284. **(IF- 1. 24).**

2. **Hareesh**, **V.S.,** Joe, A., Alappat, J.P. & M. Sabu. (2017) Musaceae of Andaman and Nicobar Islands with two new synonyms and one distributional record. *Rheedea* 27(2): 71–78.

Paper presented in International & National seminar/Symposia

1. **Hareesh**, **V.S.** & M. Sabu. Seed micromorphology and anatomy of Indian Musaceae. *8th International Zingiberales Symposium,* Singapore Botanic Garden, Singapore, July 23–27, 2018. 83 pp.

2. **Hareesh**, **V.S.** & Sabu, M. Foliar anatomy of Indian Musaceae in relation to taxonomy. *International Symposium on Plant Systematics*, Department of Botany, Delhi University, Kolhapur. November 7–9, 2017. 48 pp.

3. **Hareesh**, **V.S.,** Alfred Joe, Sreejith, P.E. & Sabu, M, Morphological, anatomical and micromorphological characteristics of *Musa velutina* and *Musa velutina* subsp. *markkuana* (Musaceae) in India. *International seminar on Advancements in angiosperm systematics and conservation*, Department of Botany, Calicut University, Kerala. November 19–21, 2015. pp 226

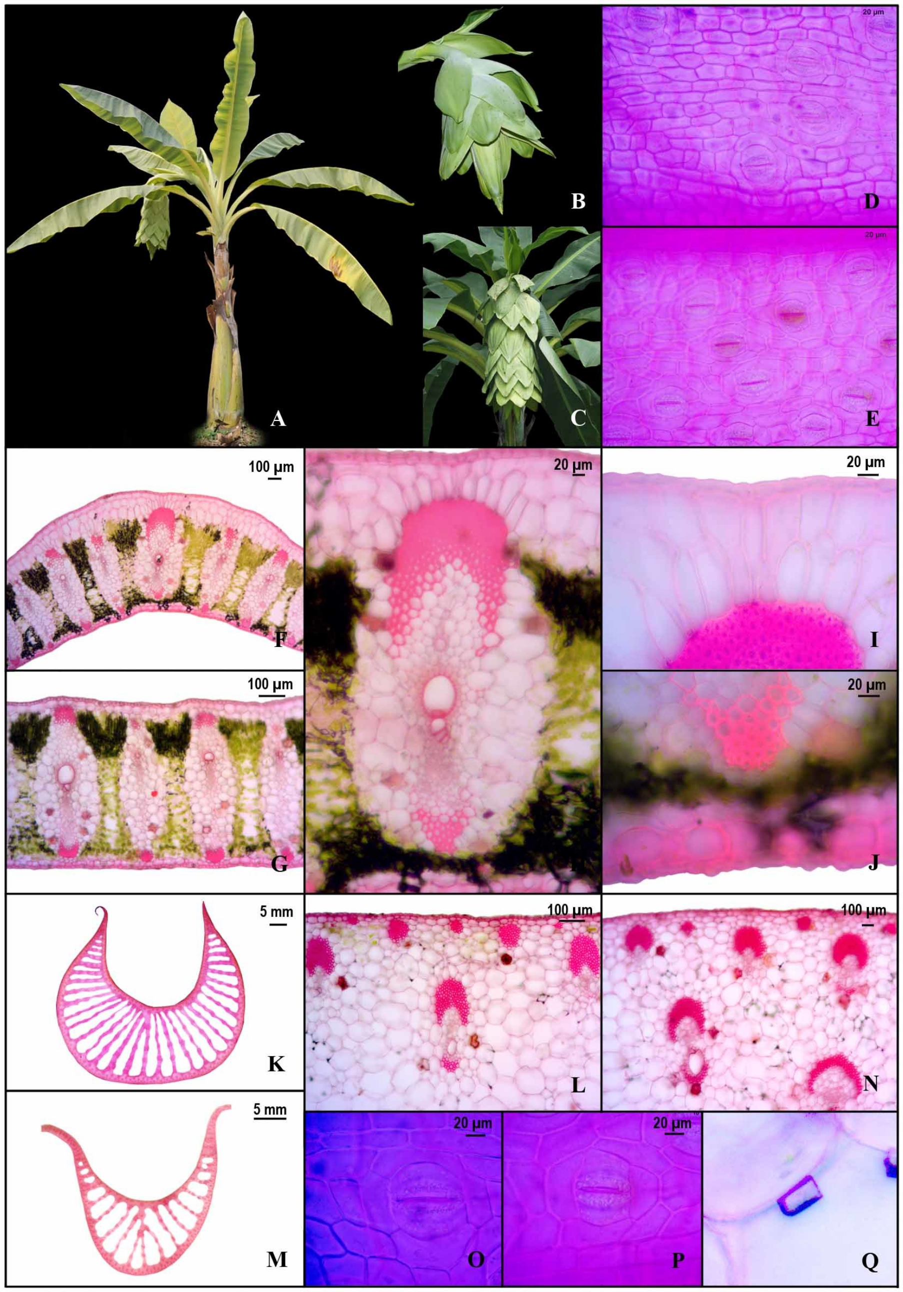


Fig. 6. ***Ensete glaucum.*** **A.** habit; **B & C.** inflorescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

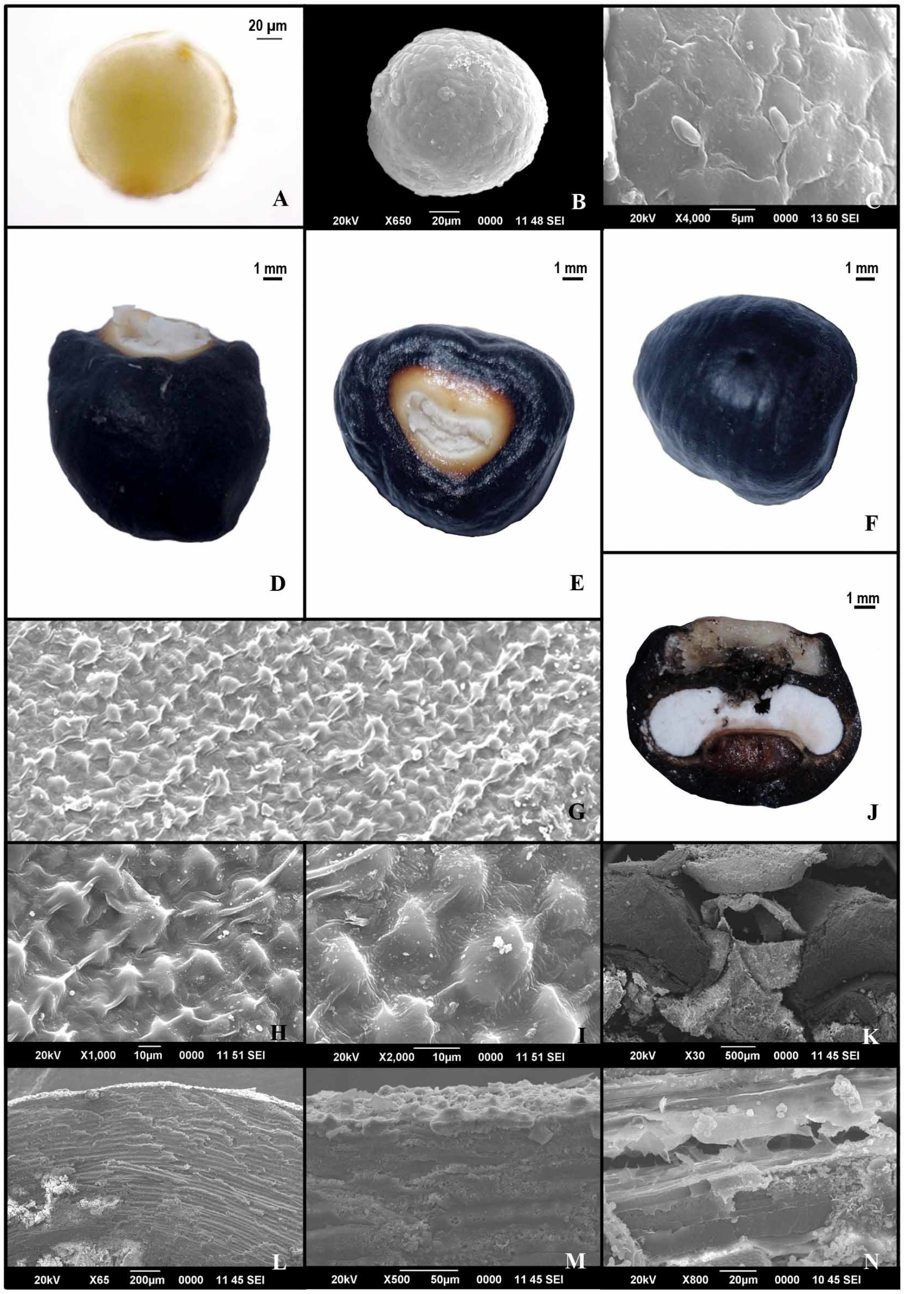


Fig. 7. ***Ensete glaucum.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-O.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-I.** Seed micromorphology; **G, H & I.** outer surface; **J-N.** Seed anatomy. **J.** L.S. of seed; **K.** micropylar region; **L.** seed coat entire; **M.** outer layers of seed coat; **N.** inner layers of seed coat showing endotesta, tegmen & aleurone layer.

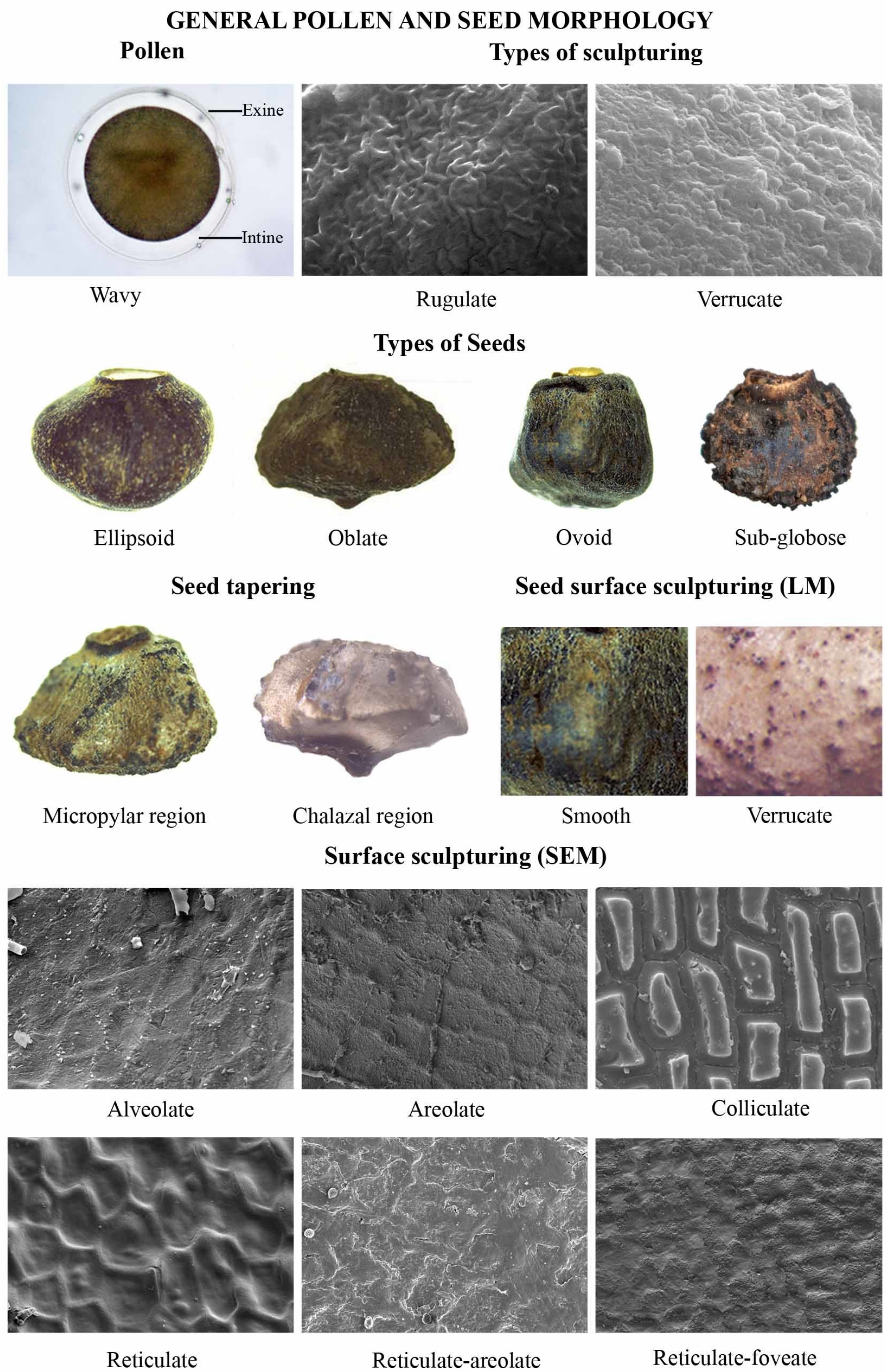


Figure 4: Pollen and seed morphology.

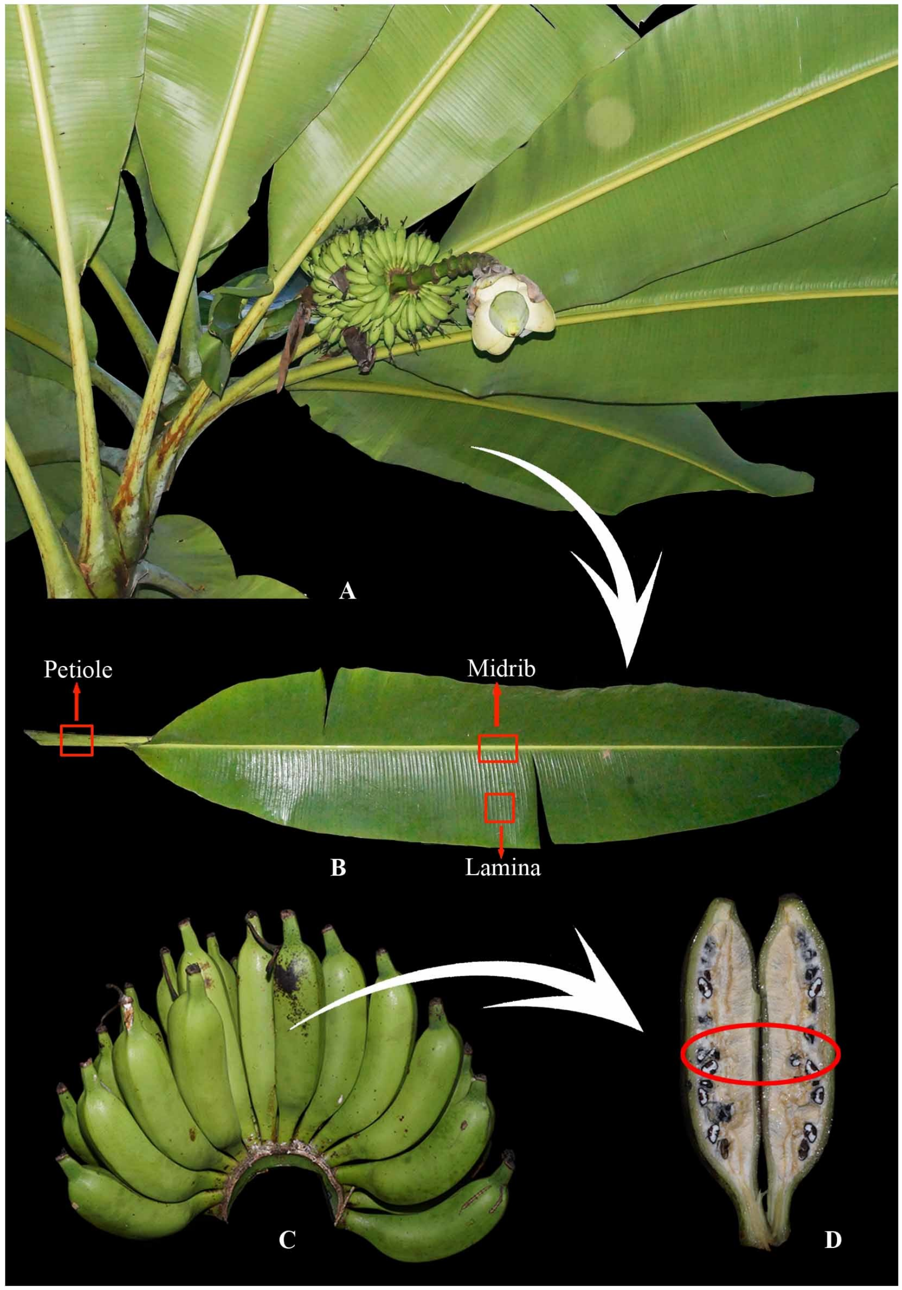
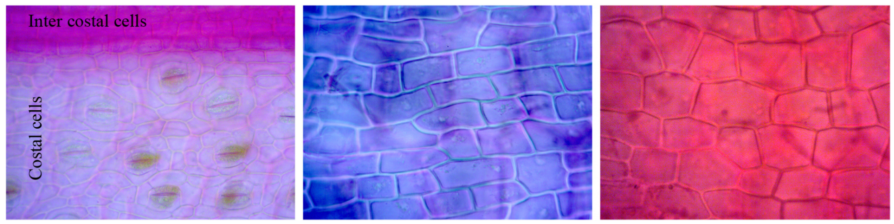


Fig. 1. Selection of plant material. A. Habit (arrow indicating third leaf from the top; **B.** single leaf; **C.** Mature fruit bunch; **D.** Fruit split open showing area of selection of seeds.

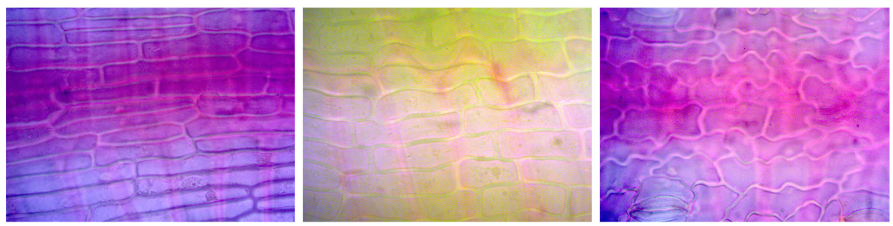
GENERAL VEGETATIVE ANATOMY

Different types of epidermal cells



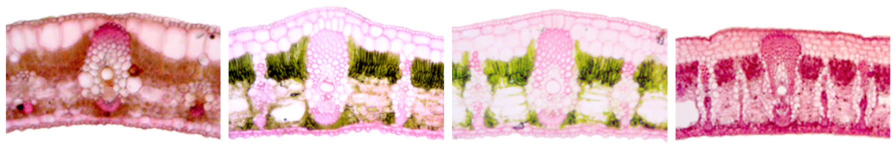
Abaxial epidermis | Rectangular | Polygonal

Anticlinal cell wall types



Straight | Wavy | Sinuous

Adaxial hypodermal cell layers



1-layered | 2-layered | 3-layered | 4-layered

Adaxial hypodermal cells above larger vascular bundles

1-layered

2-layered

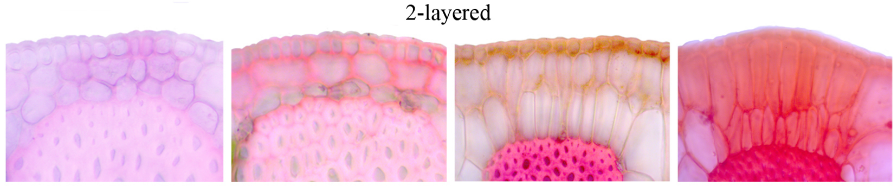


Fig. 2. Vegetative anatomy part I

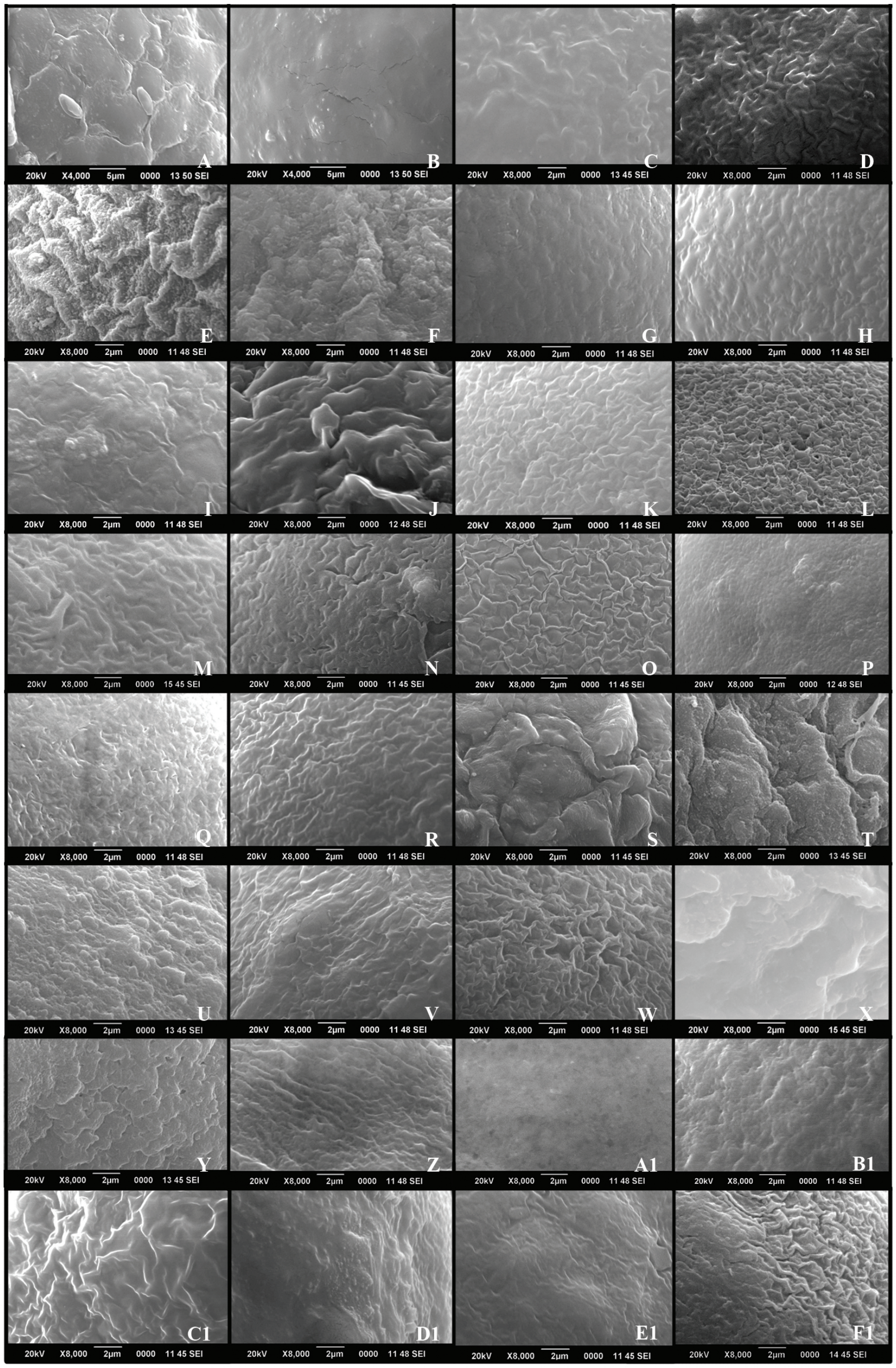


Fig. 79. **Comparative seed coat anatomy. A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis* var. *sikkimenis*; **C1**. *M. sikkimensis* var. *simmondsii*; **D1.** *M. thomsonii;* **E1**. *M. velutina* var. *velutina*; **F1.** *M. velutina* var. *variegata.*

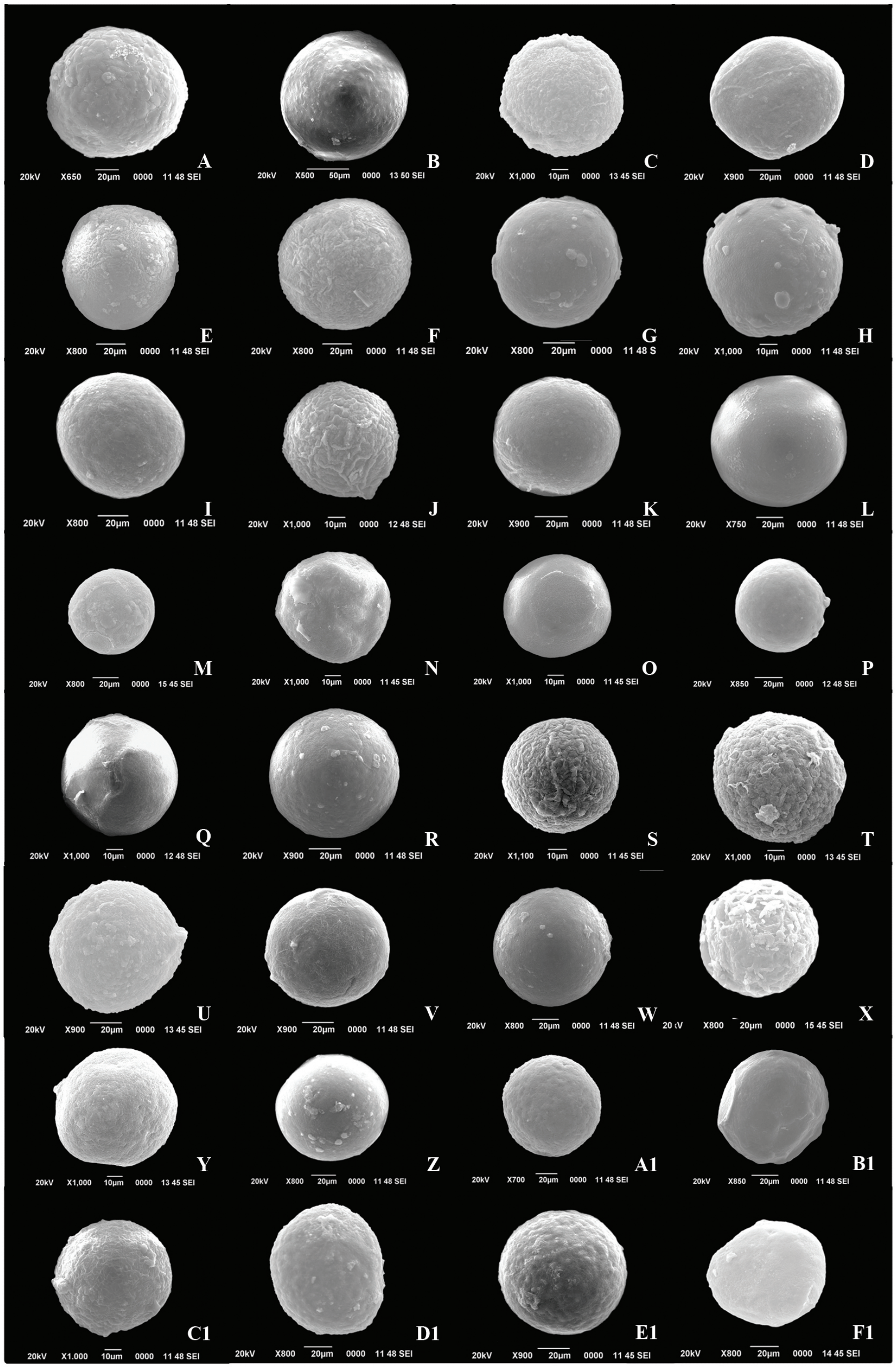


Fig. 78. **Comparative pollen morphology (SEM). A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis* var. *sikkimenis*; **C1**. *M. sikkimensis* var. *simmondsii*; **D1.** *M. thomsonii;* **E1**. *M. velutina* var. *velutina*; **F1.** *M. velutina* var. *variegata.*

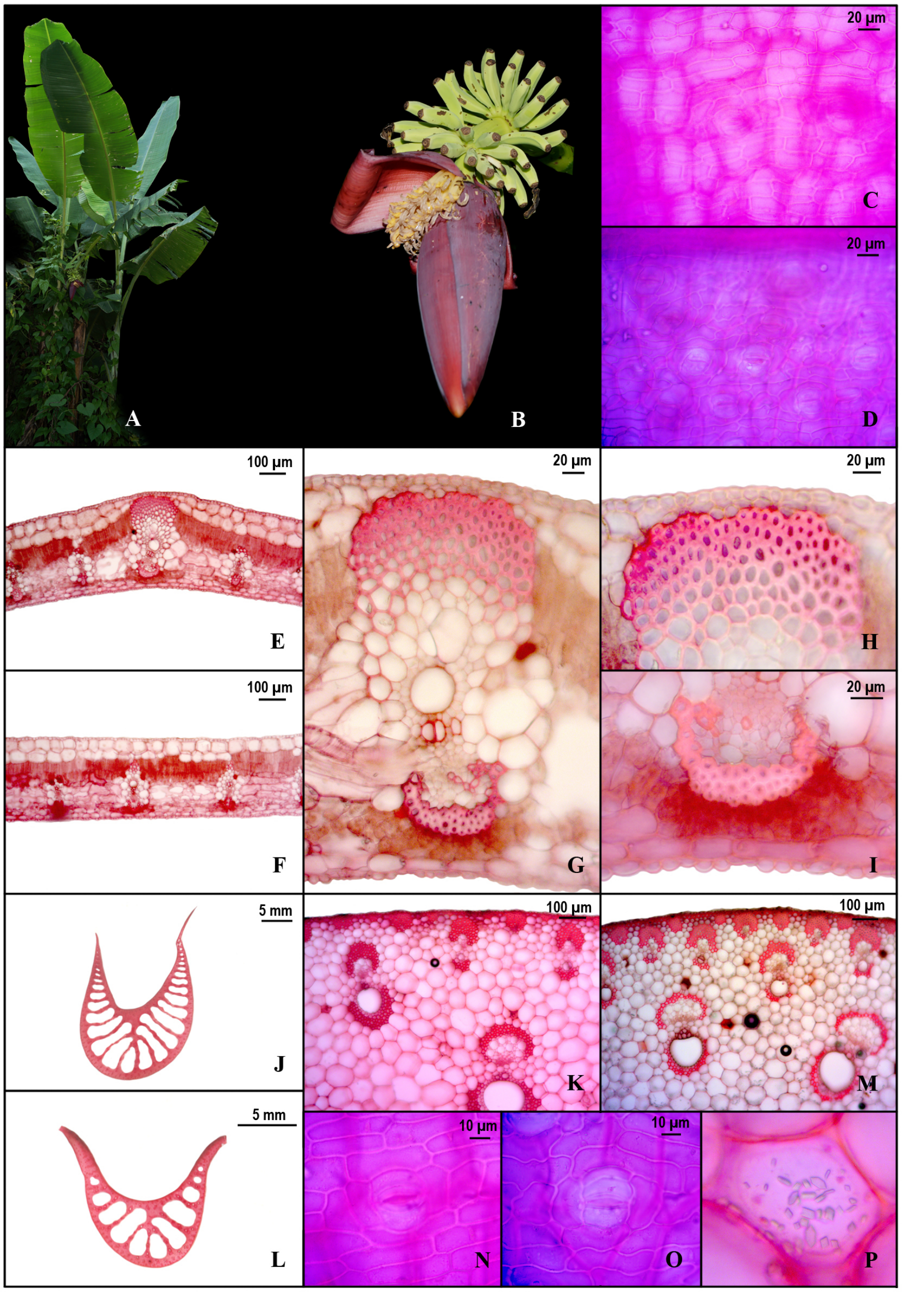


Fig. 64. ***Musa thomsonii.*** **A.** habit; **B.** inflorescence; **C.** adaxial epidermis; **D.** abaxial epidermis; **E-I.** cross section of lamina**. E.** lamina showing larger and smaller vascular bundles; **F.** lamina showing smaller vascular bundles; **G.** larger vascular bundle enlarged; **H.** adaxial hypodermis above larger bundle; **I.** abaxial hypodermis below the larger bundle; **J.** c.s. of petiole diagramatic; **K.** abaxial portion of petiole enlarged; **L.** c.s. of midrib; **M.** abaxial portion of petiole enlarged; **N.** adaxial stoma; **O.** abaxial stoma; **P.** crystals in petiole.

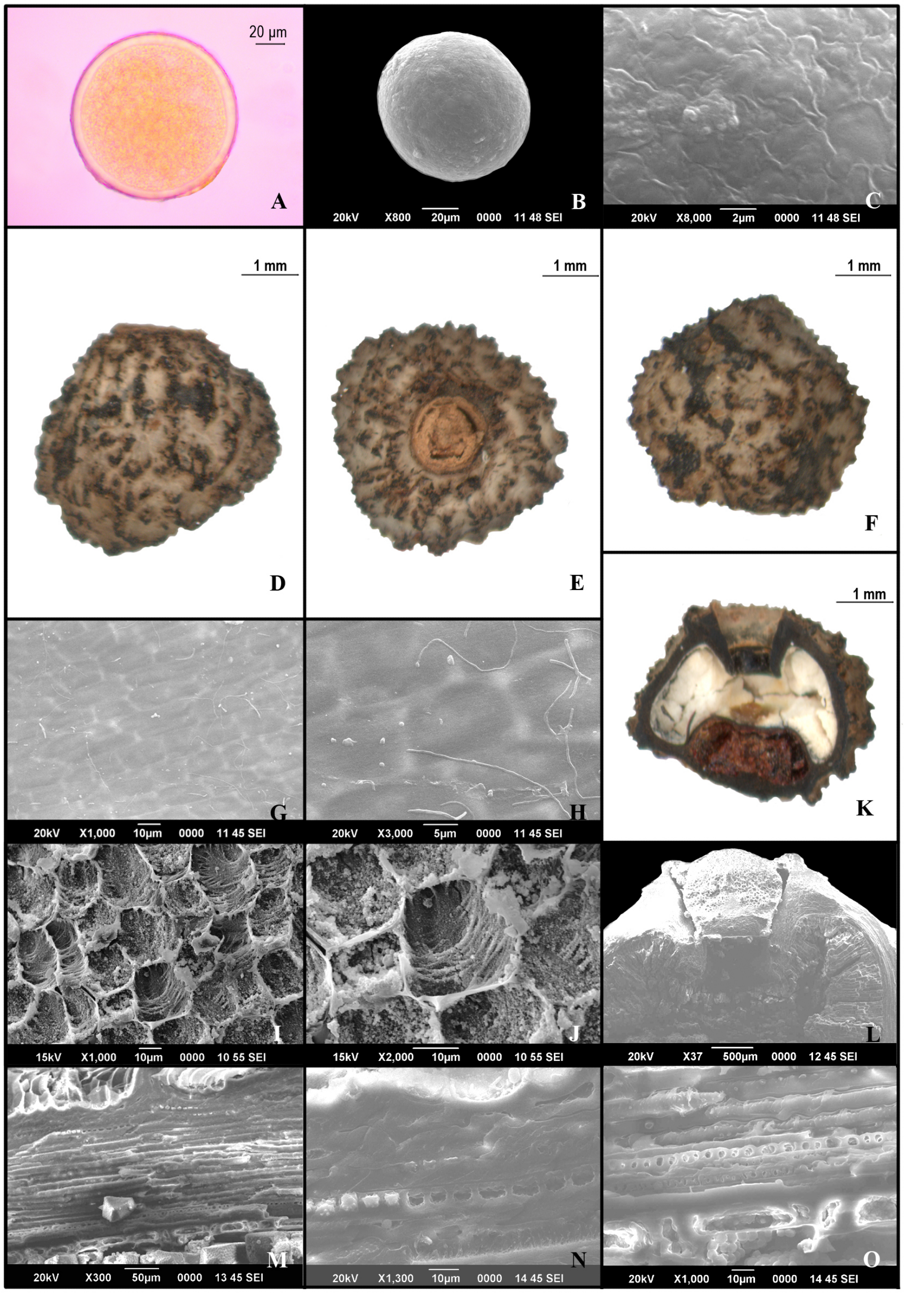


Fig. 23. ***Musa balbisiana* var. *bheem-kola.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

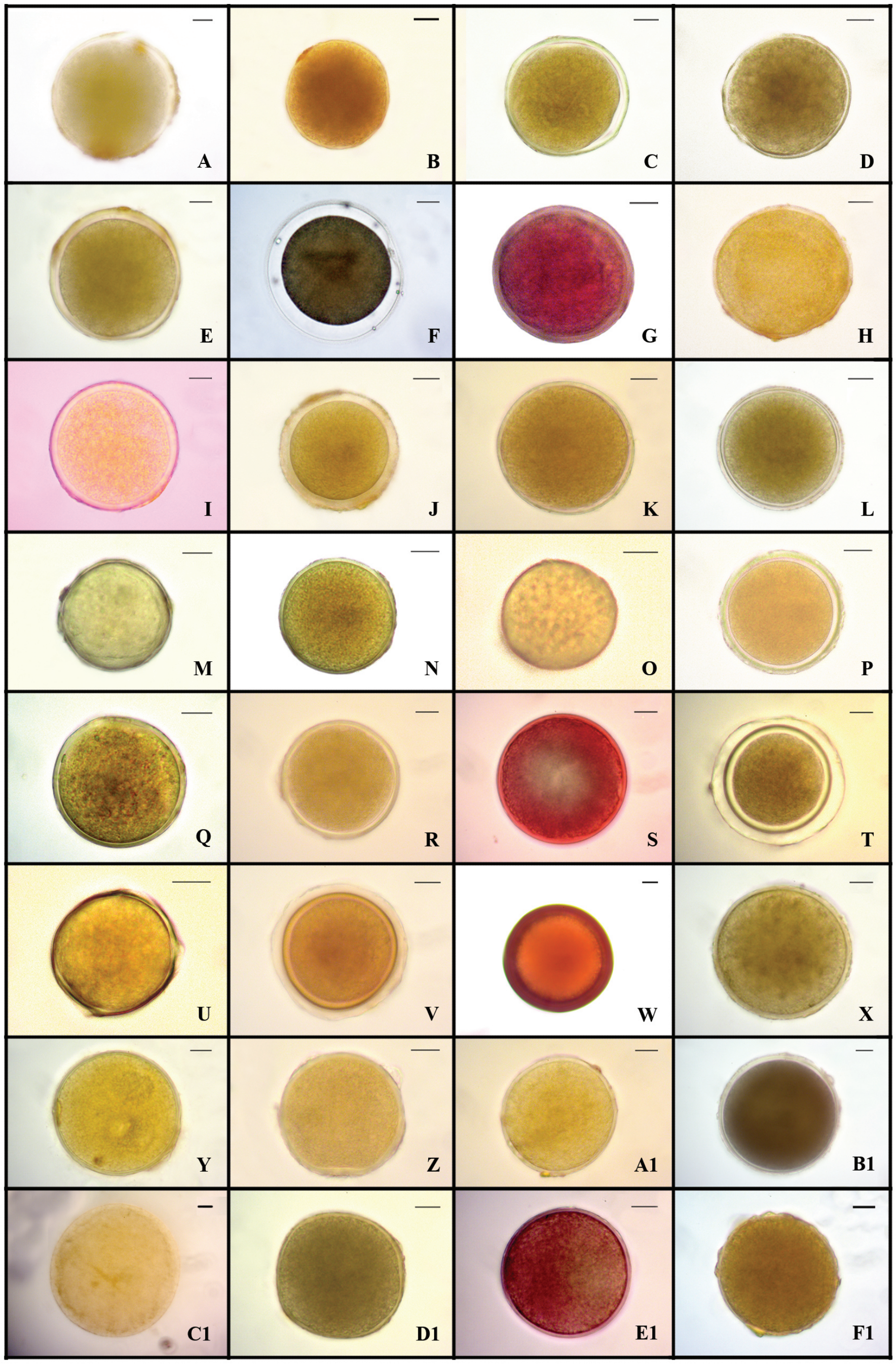


Fig. 77. **Comparative pollen morphology (LM). A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii***;** **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis* var. *sikkimensis*; **C1**. *M. sikkimensis* var. *simmondsii*; **D1.** *M. thomsonii;* **E1**. *M. velutina* var. *velutina*; **F1.** *M. velutina* var. *variegata*. (Scale bar = 20 μm).

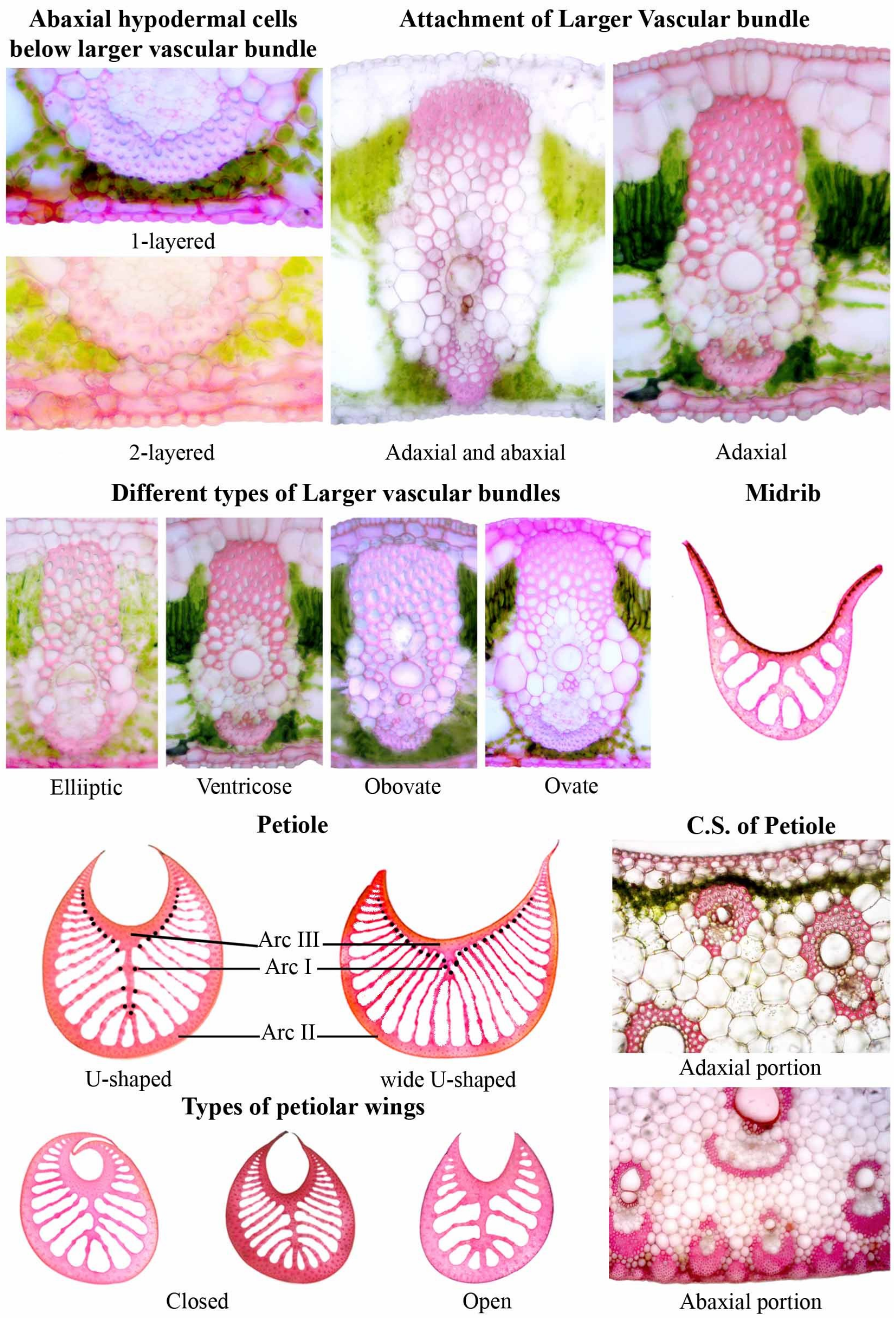


Fig. 3. Vegetative anatomy part II.

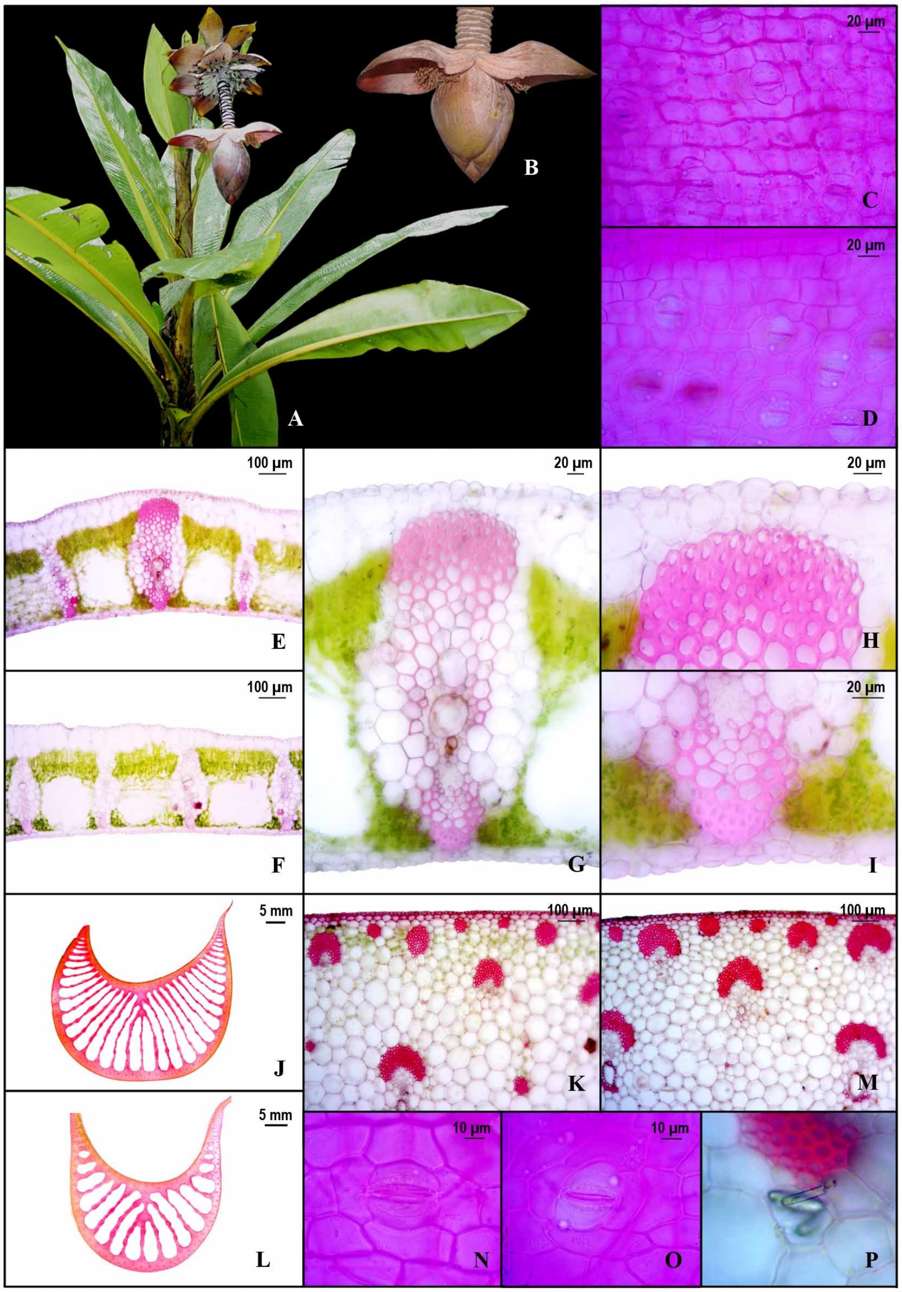


Fig. 8. ***Ensete superbum.*** **A.** habit; **B.** male bud; **C.** adaxial epidermis; **D.** abaxial epidermis; **E-I.** cross section of lamina**. E.** lamina showing larger and smaller vascular bundles; **F.** lamina showing smaller vascular bundles; **G.** larger vascular bundle enlarged; **H.** adaxial hypodermis above larger bundle; **I.** abaxial hypodermis below the larger bundle; **J.** c.s. of petiole; **K.** abaxial portion of petiole enlarged; **L.** c.s. of midrib; **M.** abaxial portion of petiole enlarged; **N.** adaxial stoma; **O.** abaxial stoma; **P.** crystals in petiole.

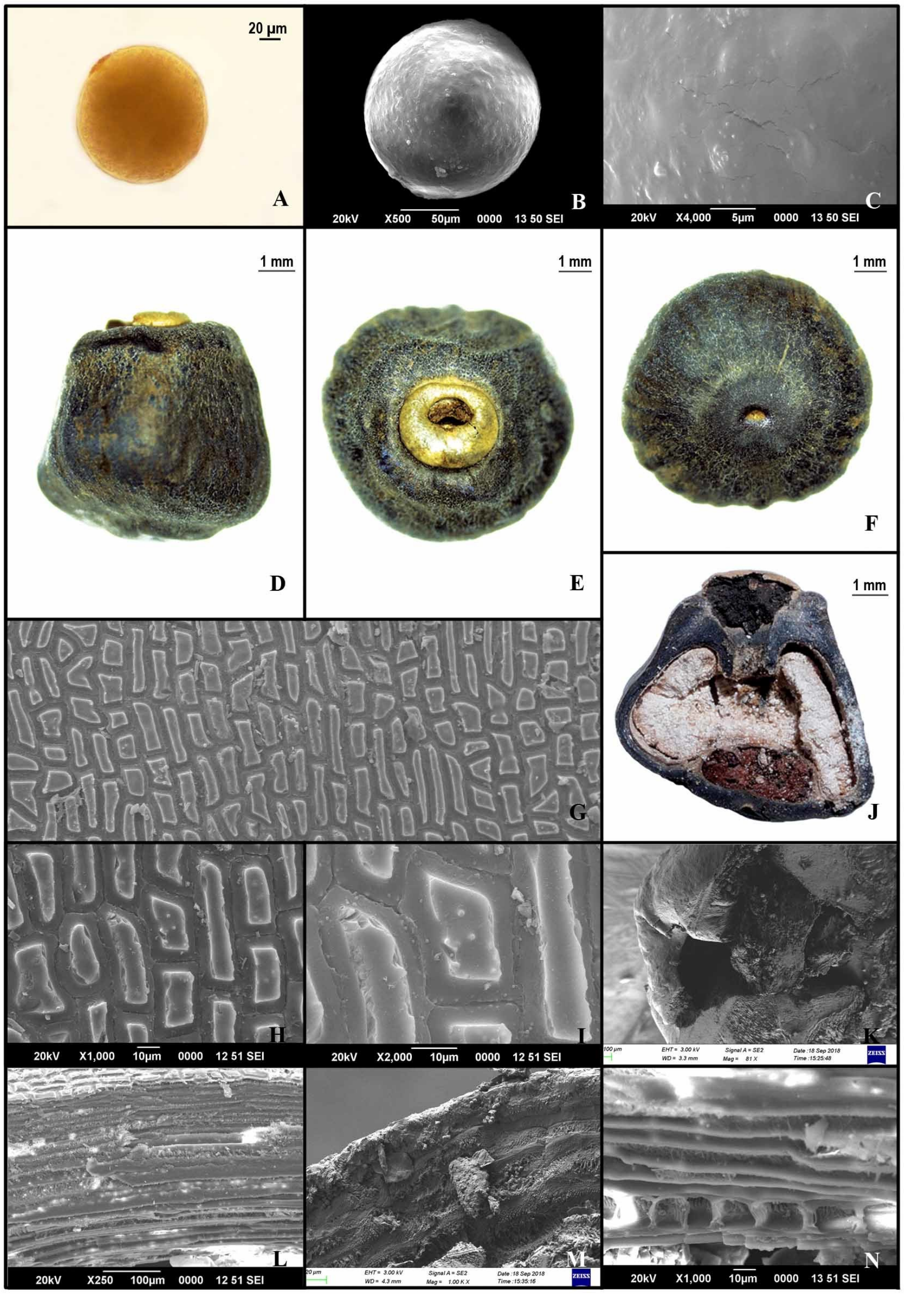


Fig. 9. ***Ensete superbum.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-O.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-I.** Seed micromorphology; **G, H & I.** outer surface; **J-N.** Seed anatomy. **J.** L.S. of seed; **K.** micropylar region; **L.** seed coat entire; **M.** outer layers of seed coat; **N.** inner layers of seed coat showing endotesta, tegmen & aleurone layer.

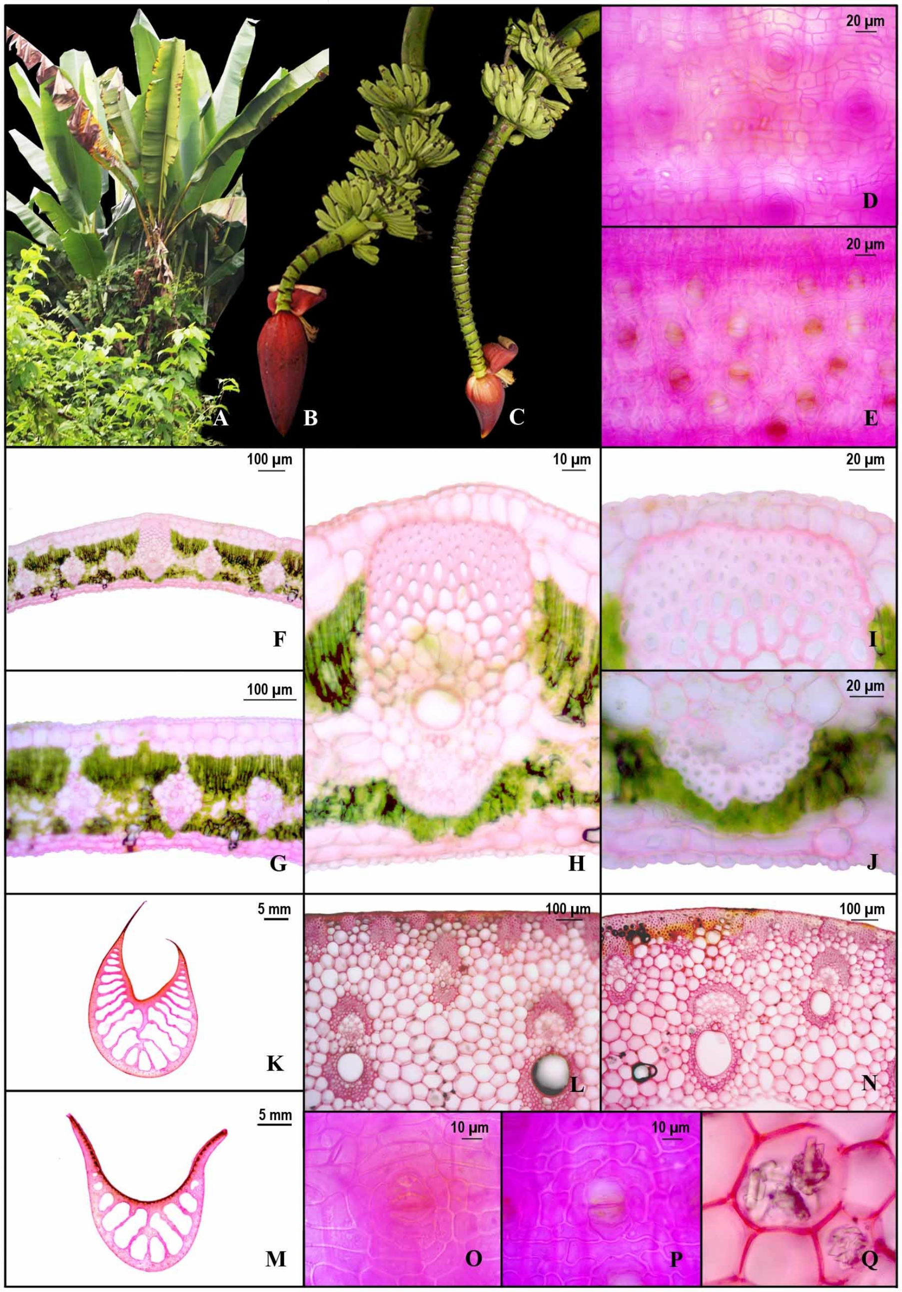


Fig. 10. ***Musa acuminata.*** **A.** habit; **B & C.** infructescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

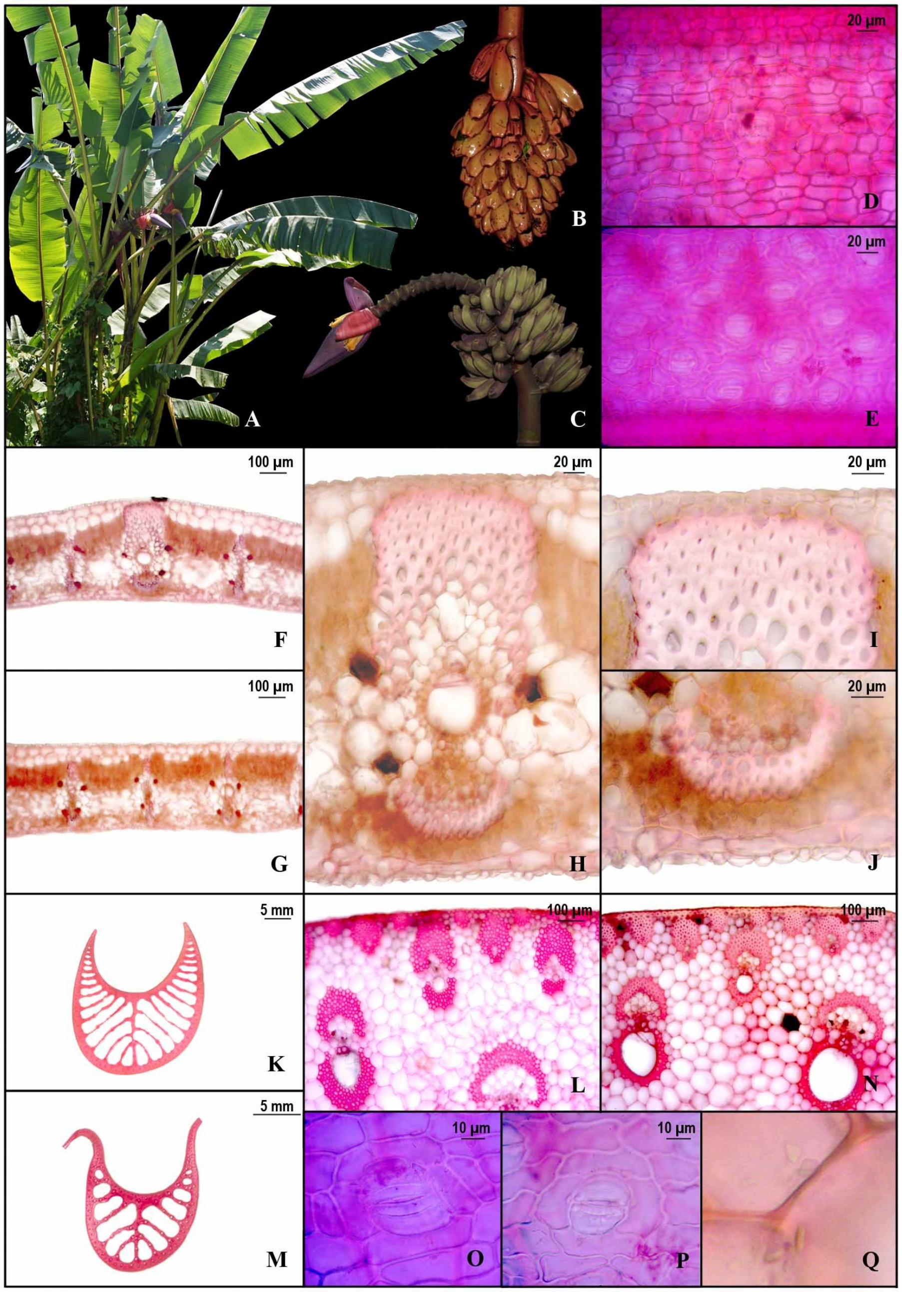


Fig. 12. ***Musa argentii.*** **A.** habit; **B & C.** infructescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

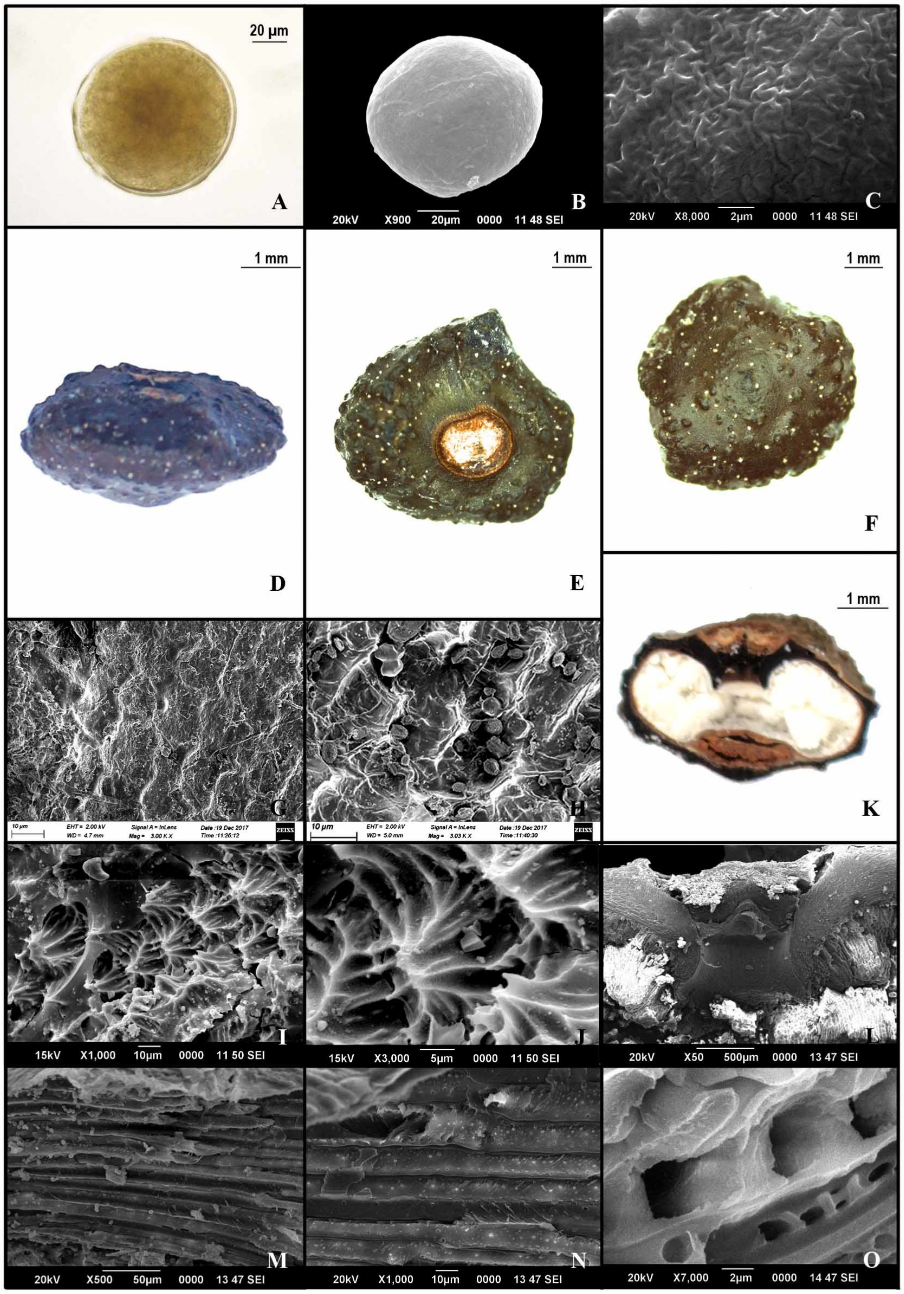


Fig. 13. ***Musa argentii.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

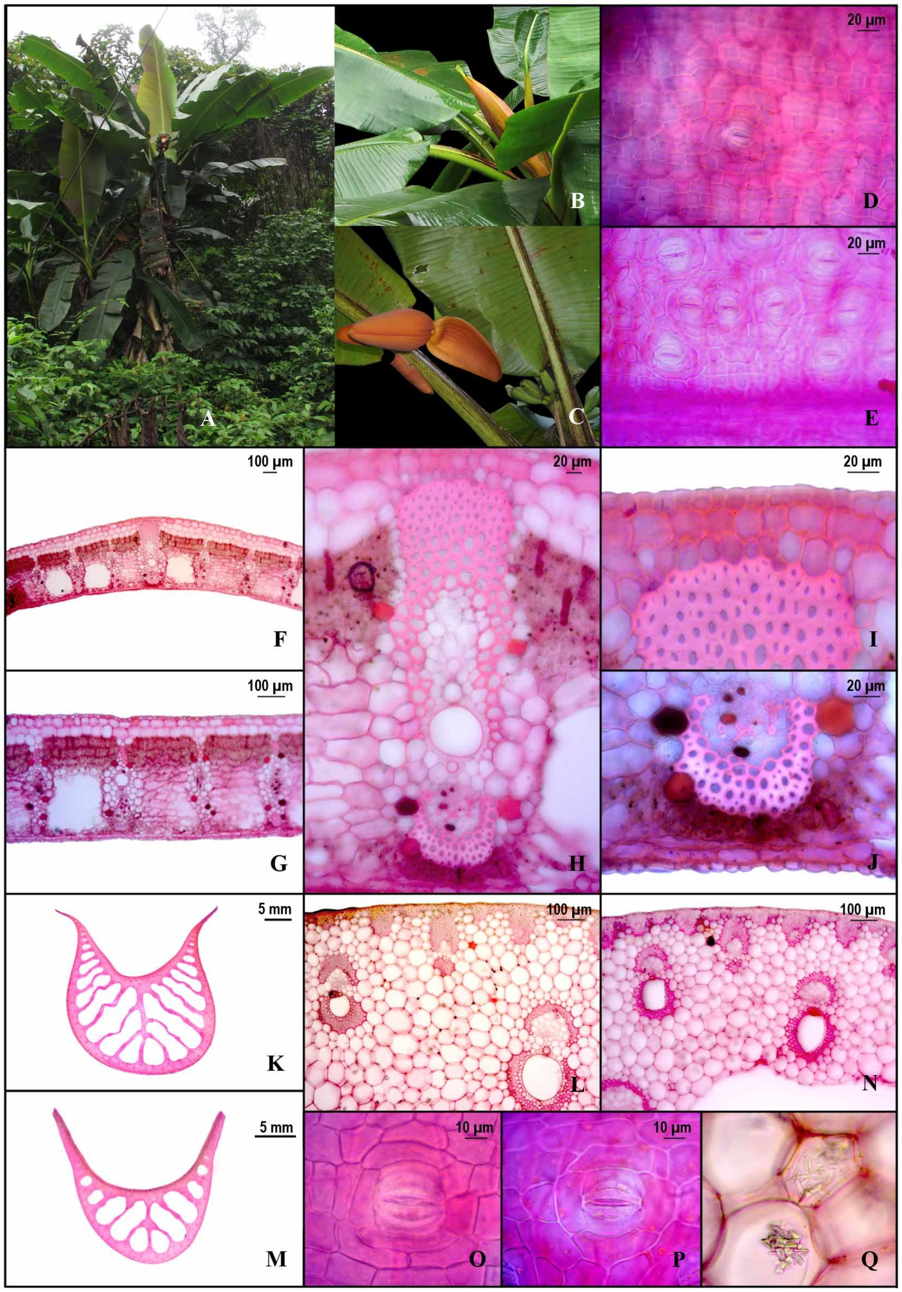


Fig. 14. ***Musa arunachalensis.*** **A.** habit; **B & C.** inflorescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

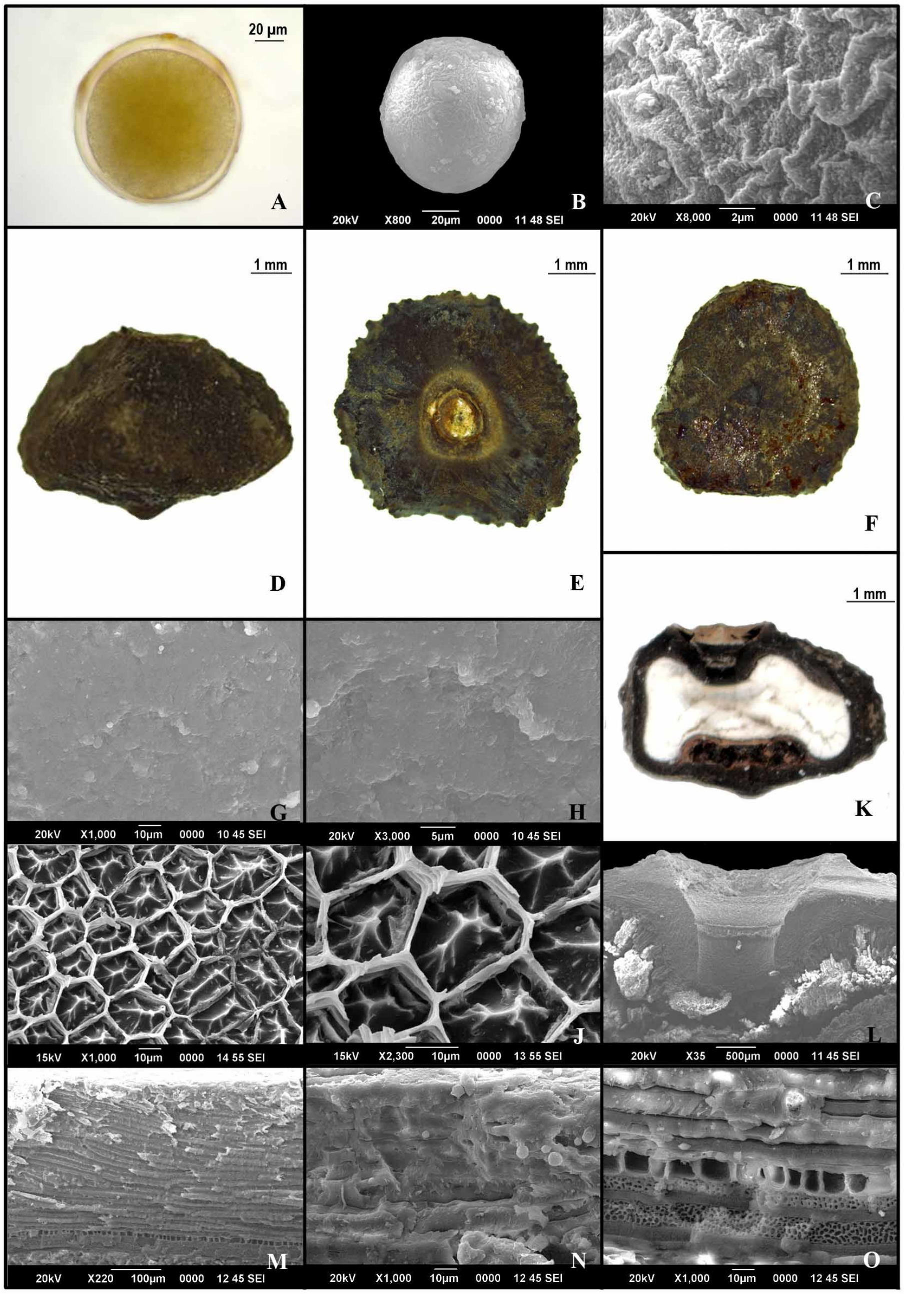


Fig. 15. ***Musa arunachalensis.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

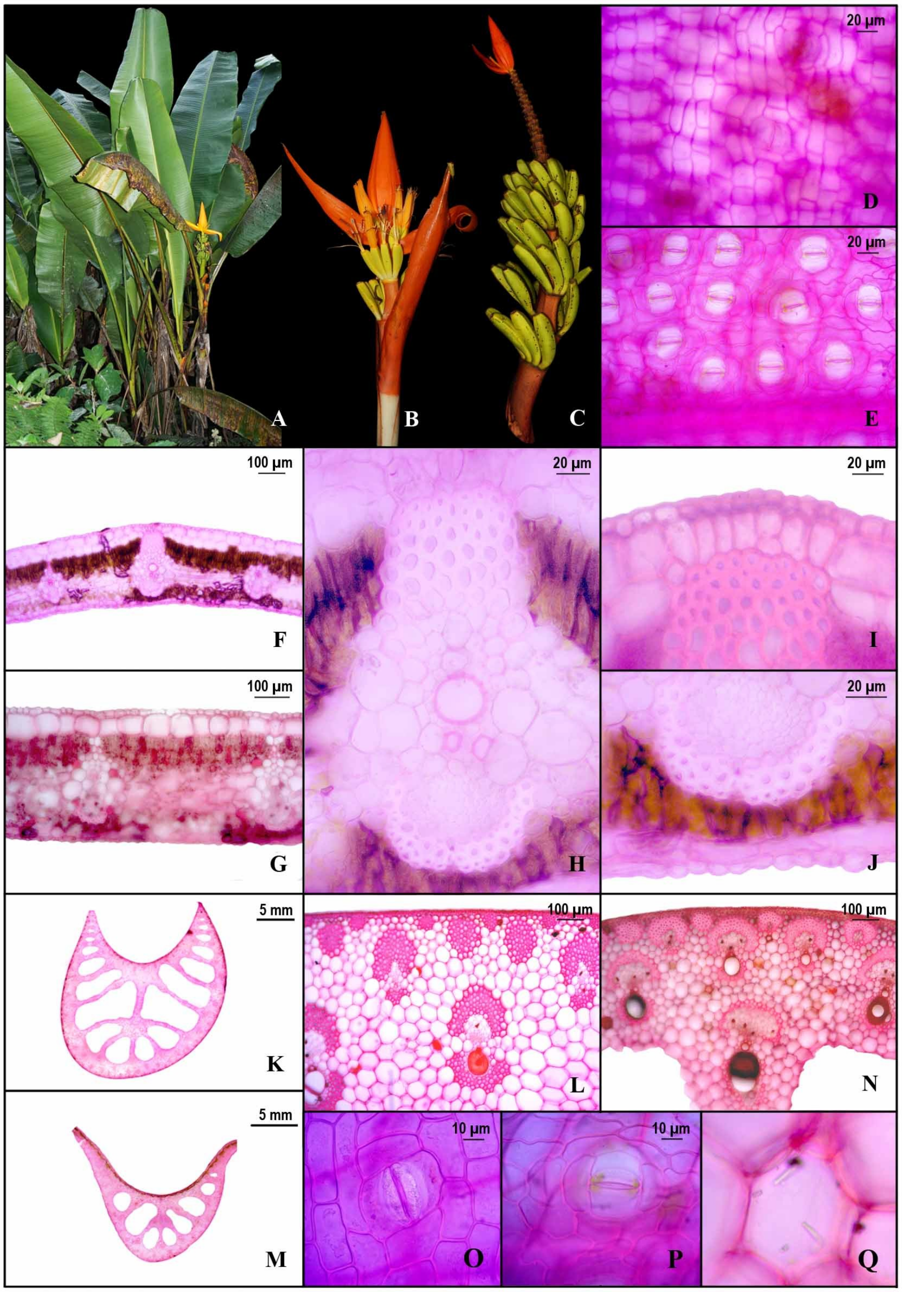


Fig. 16. ***Musa aurantiaca.*** **A.** habit; **B & C.** inflorescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

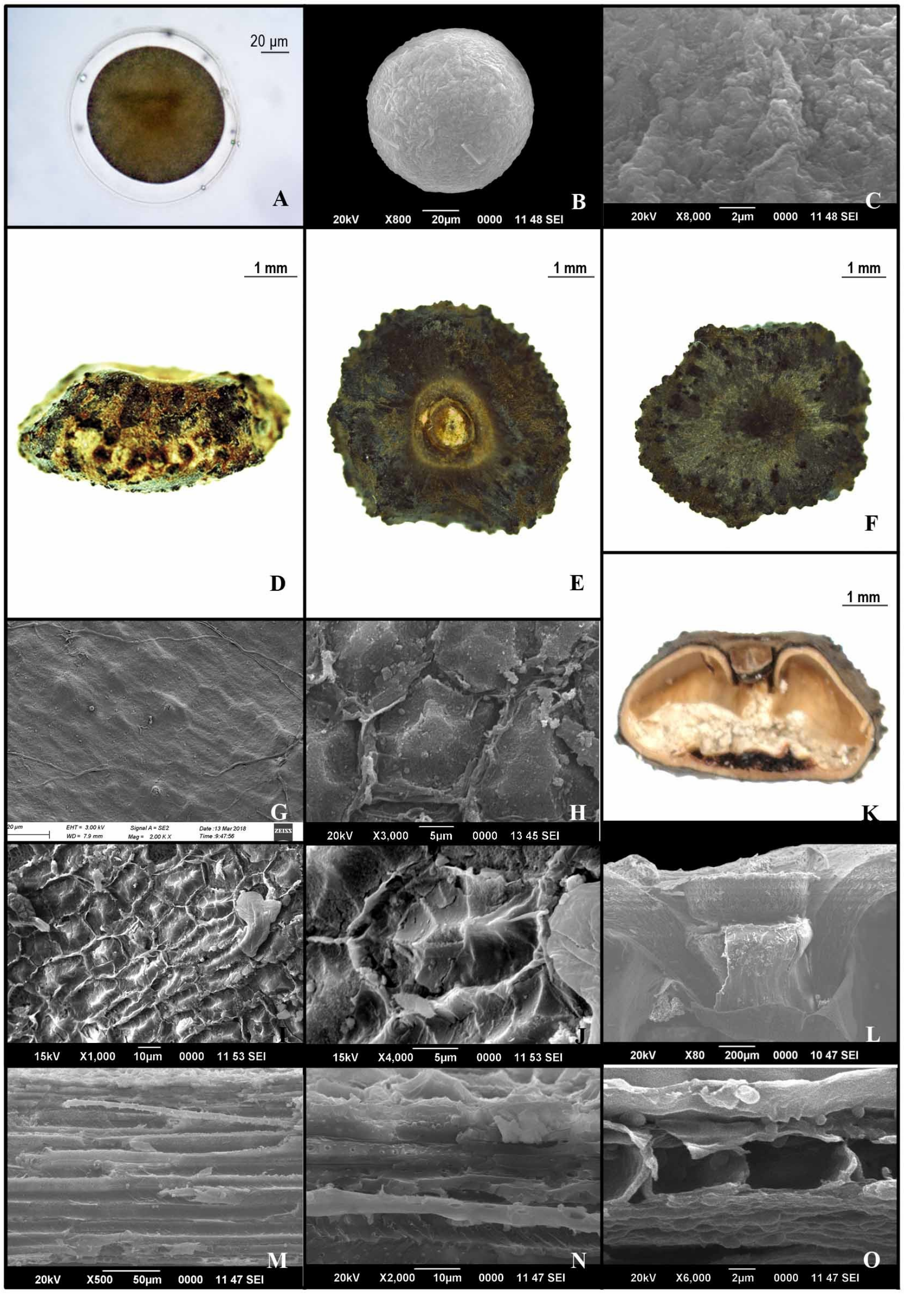


Fig. 17. ***Musa aurantiaca.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

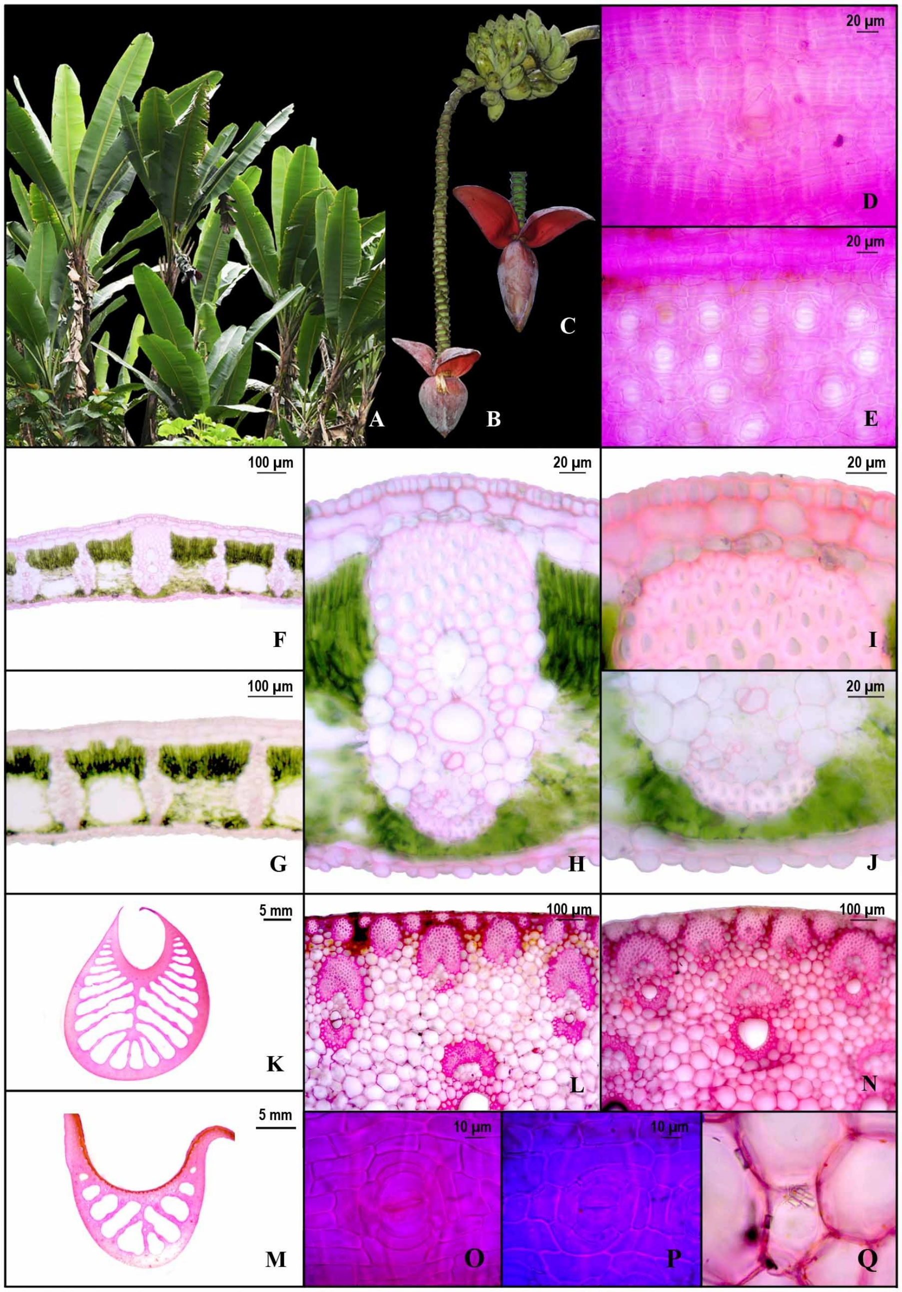


Fig. 18. ***Musa balbisiana*** var**. *balbisiana*. A.** habit; **B.** infructescence; **B.** male bud; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**: F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

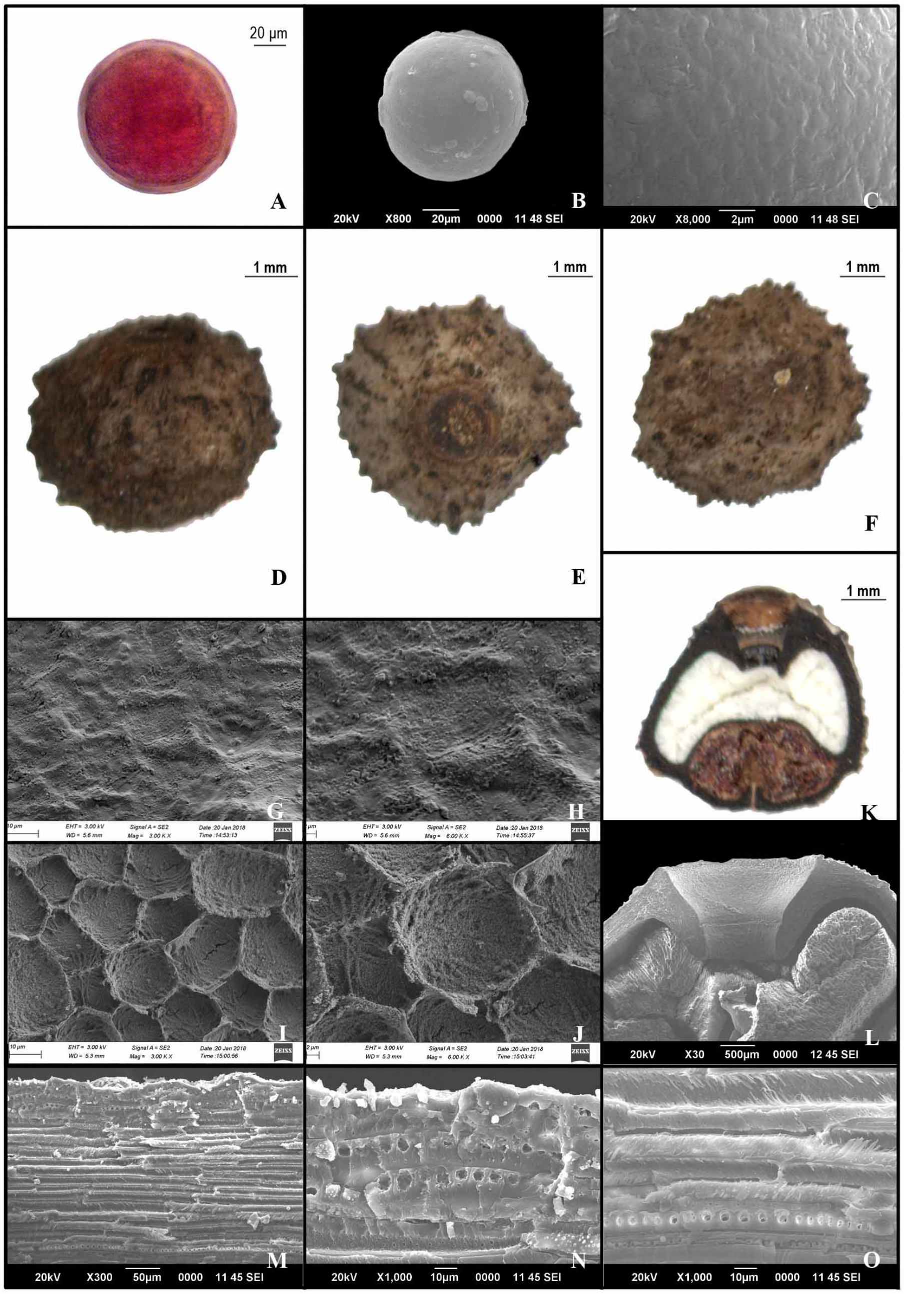


Fig. 19. ***Musa balbisiana var. balbisiana.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

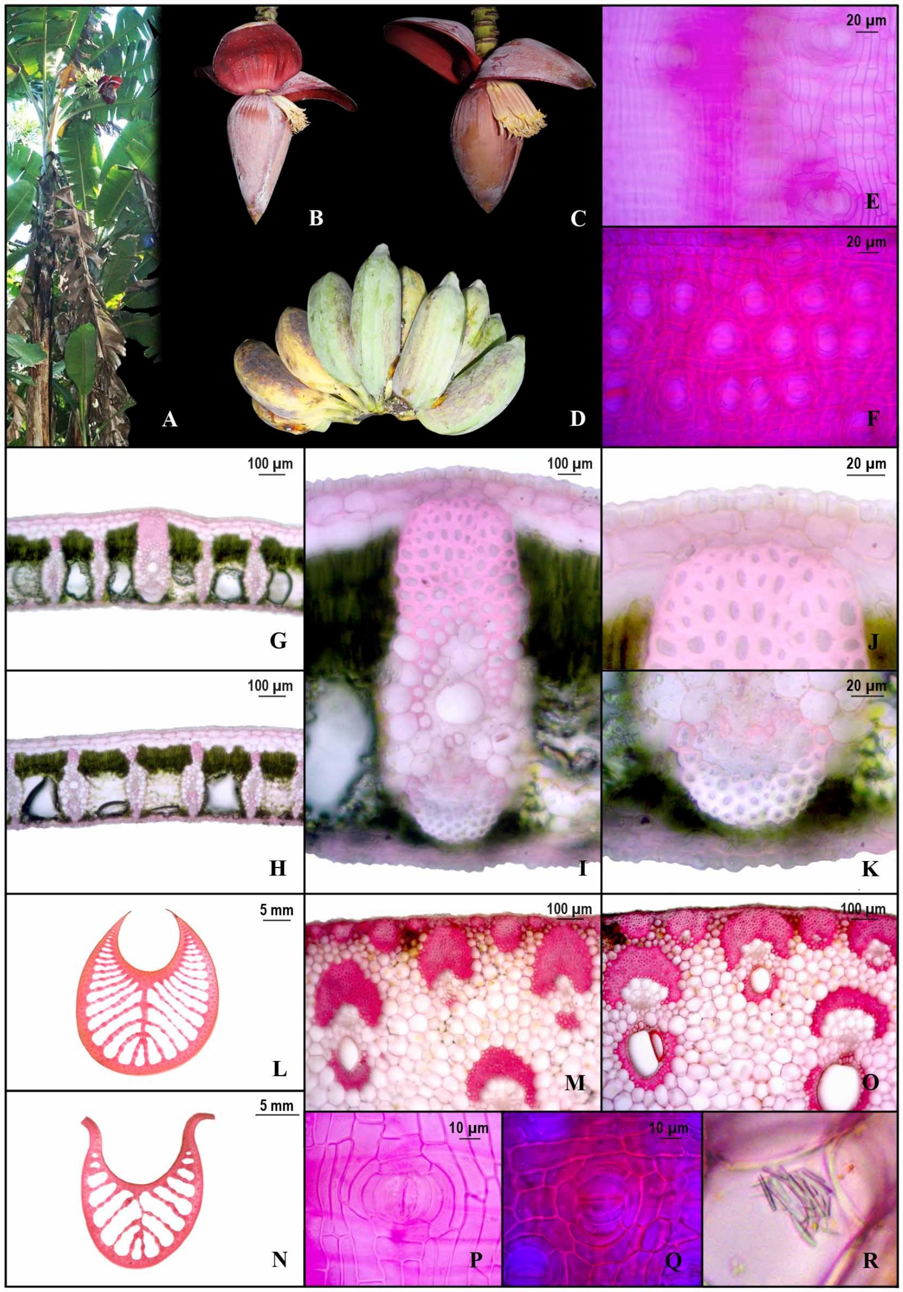


Fig. 20. ***Musa balbisiana*** **var.** ***andamanica*** **A.** habit; **B & C.** male bud; **D.** fruit bunch; **E.** adaxial epidermis; **F.** abaxial epidermis; **G-K.** cross section of lamina**:** **G.** lamina showing larger and smaller vascular bundles; **H.** lamina showing smaller vascular bundles; **I.** larger vascular bundle enlarged; **J.** adaxial hypodermis above larger bundle; **K.** abaxial hypodermis below the larger bundle; **L.** c.s. of petiole; **M.** abaxial portion of petiole enlarged; **N.** c.s. of midrib; **O.** abaxial portion of midrib enlarged; **P.** adaxial stoma; **Q.** abaxial stoma; **R.** crystals in petiole.

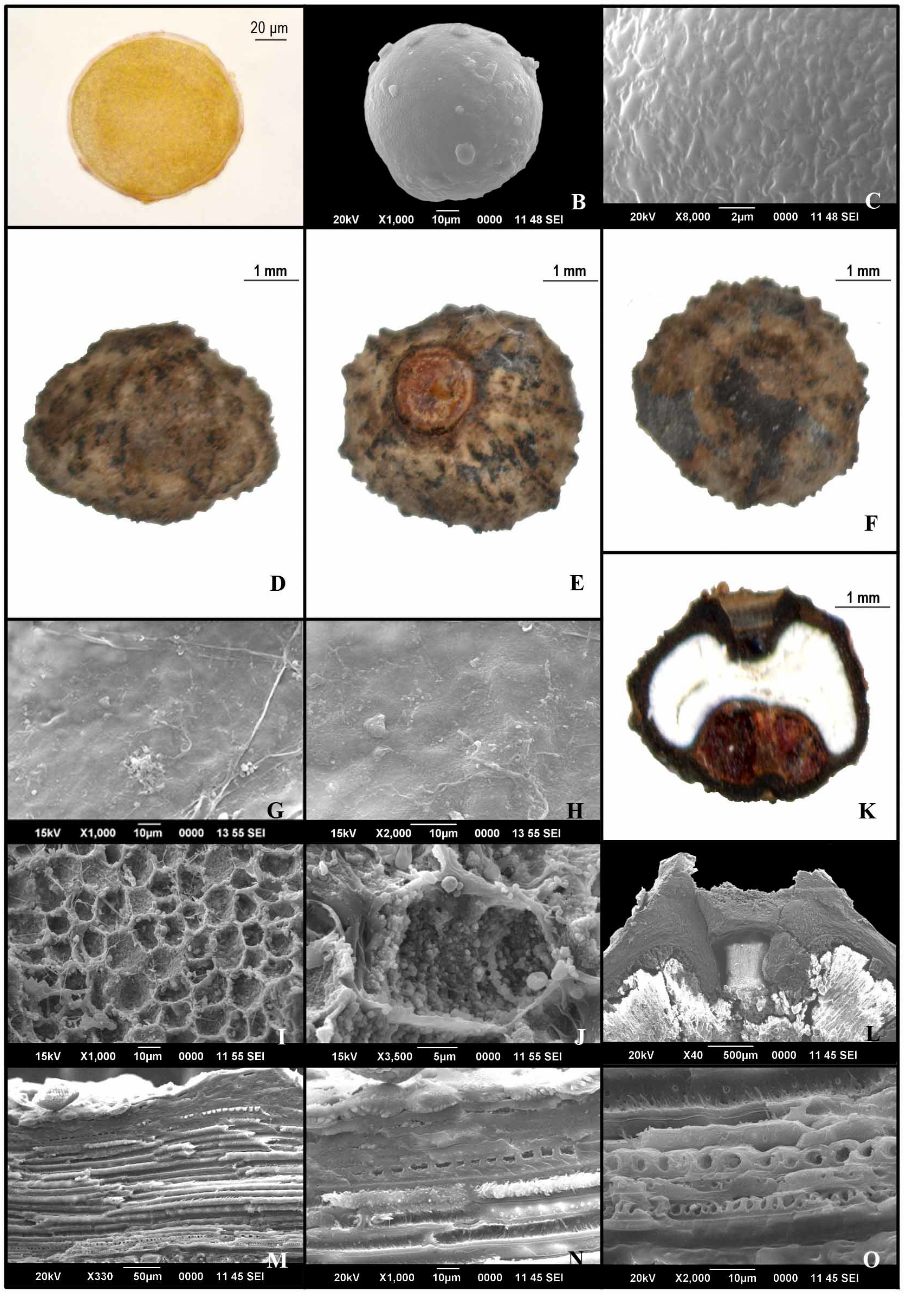


Fig. 21. ***Musa balbisiana* var. *andamanica*. A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

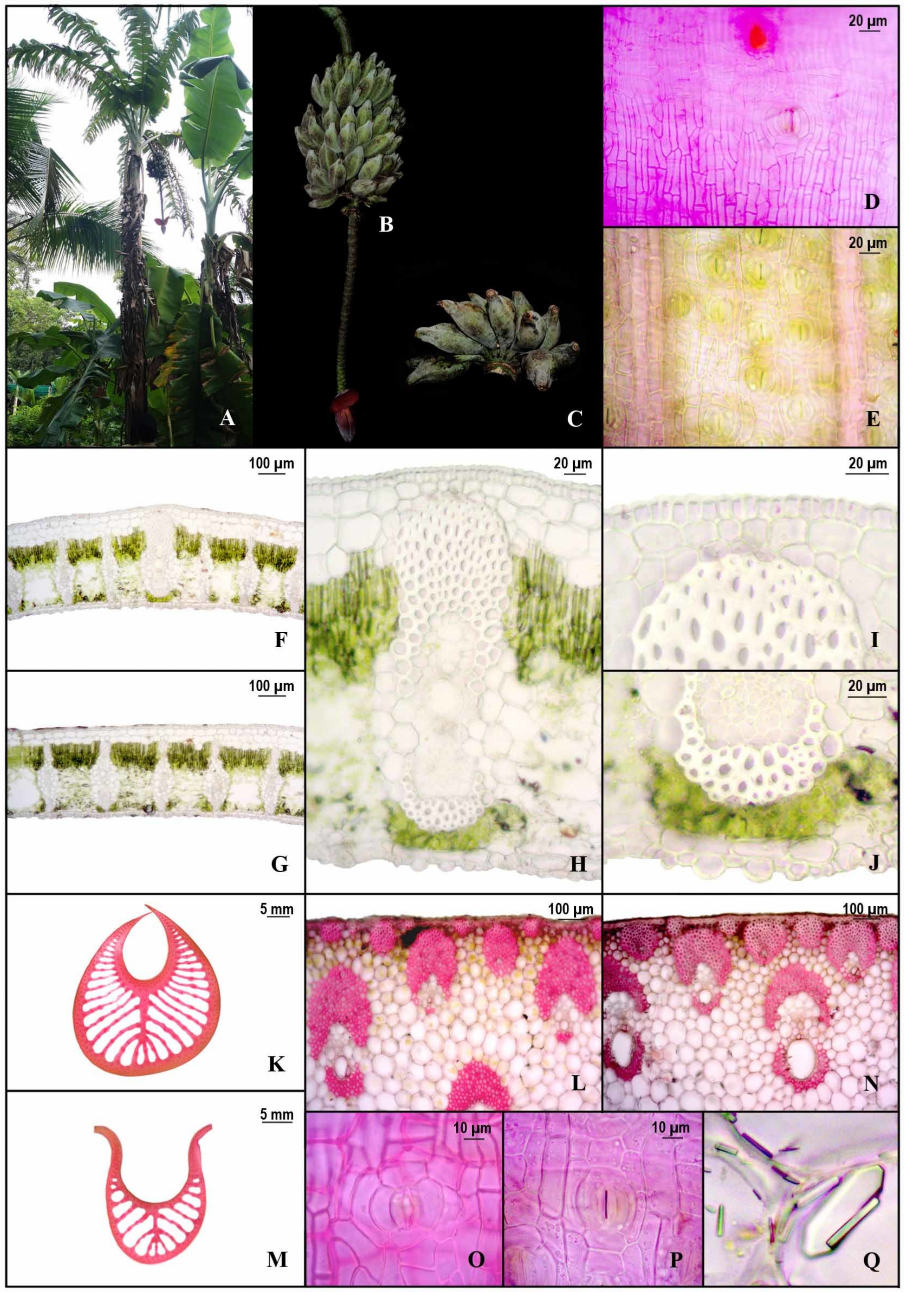


Fig. 22. ***Musa balbisiana* var. *bheem-kola*.** **A.** habit; **B.** infructescence; **C.** fruit bunch; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

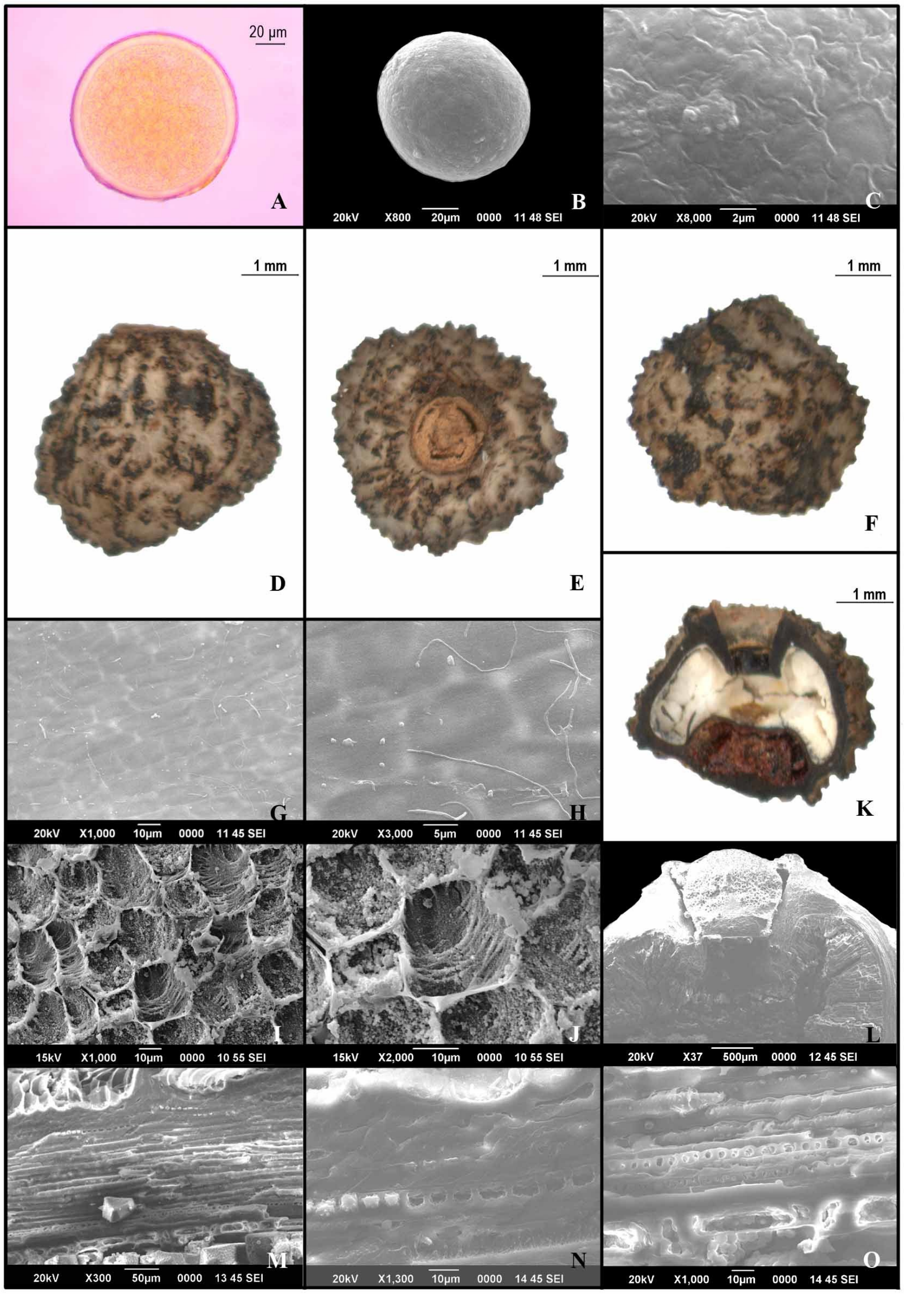


Fig. 23. ***Musa balbisiana* var. *bheem-kola.* A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

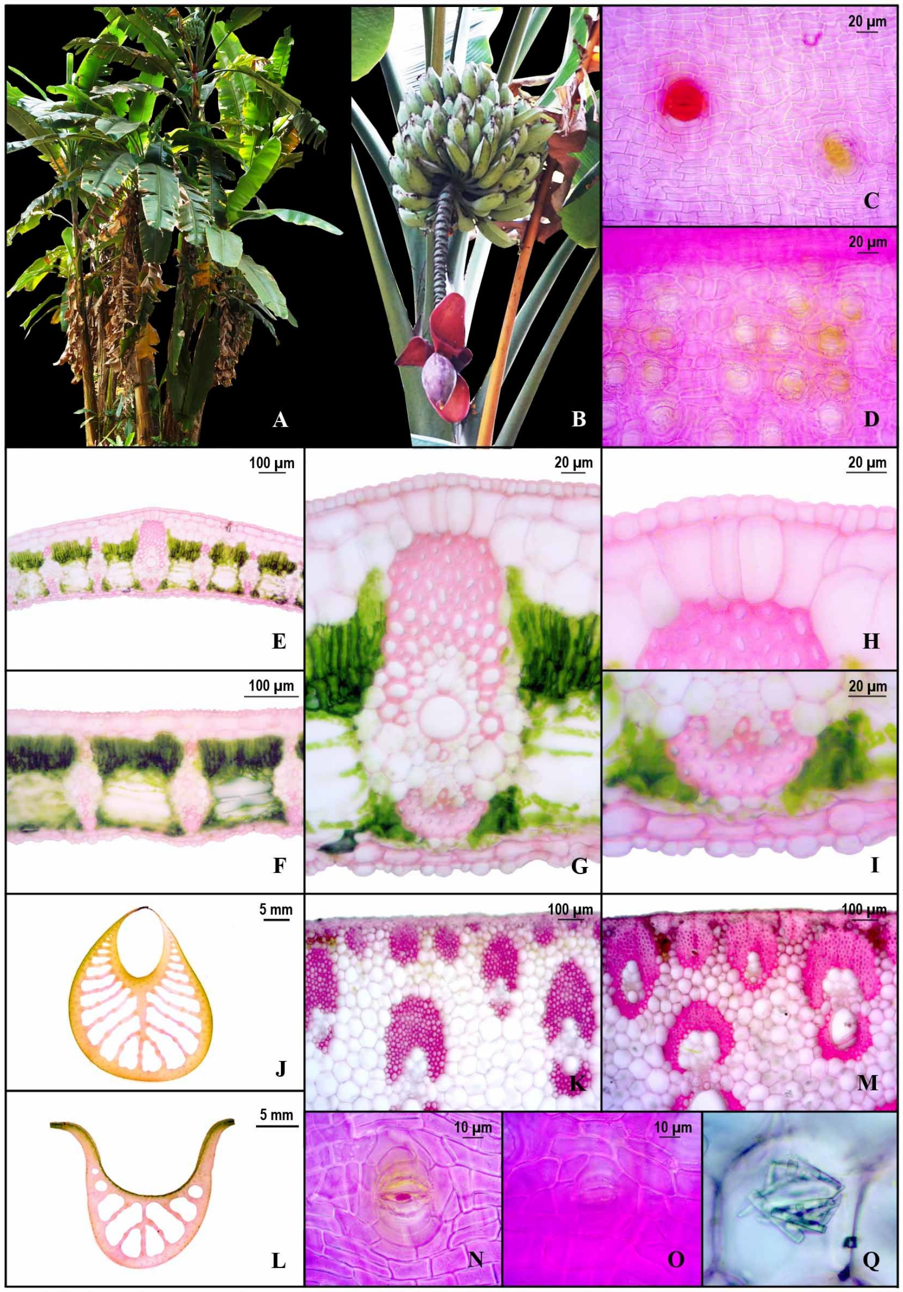


Fig. 24. ***Musa balbisiana* var. *elavazhai.*** **A.** habit; **B.** infructescence; **C.** adaxial epidermis; **D.** abaxial epidermis; **E-I.** cross section of lamina**. E.** lamina showing larger and smaller vascular bundles; **F.** lamina showing smaller vascular bundles; **G.** larger vascular bundle enlarged; **H.** adaxial hypodermis above larger bundle; **I.** abaxial hypodermis below the larger bundle; **J.** c.s. of petiole; **K.** abaxial portion por petiole enlarged; **L.** c.s. of midrib; **M.** abaxial portion of petiole enlarged; **N.** adaxial stoma; **O.** abaxial stoma; **P.** crystals in petiole.

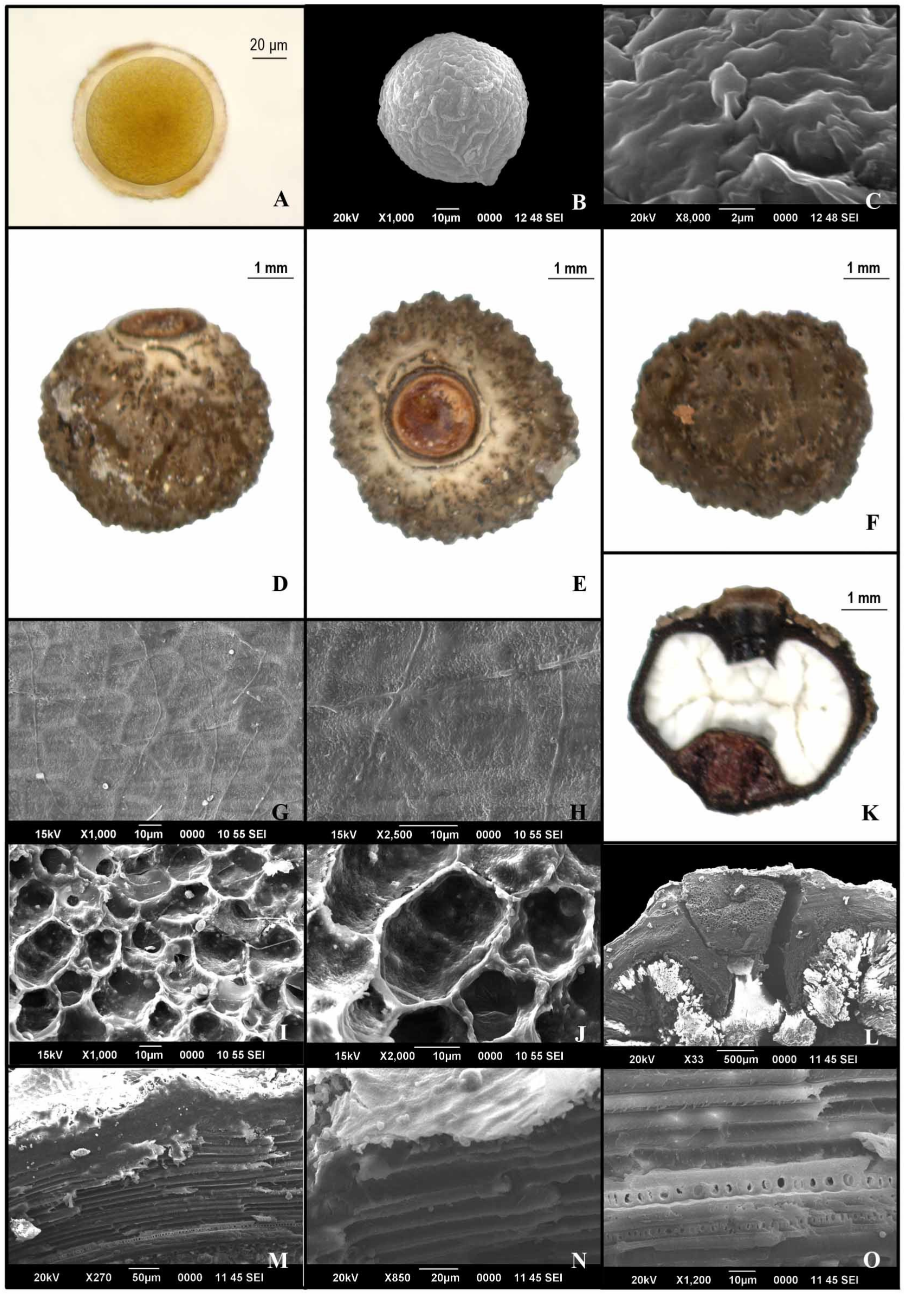


Fig. 25. ***Musa balbisiana* var. *elavazhai*. A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

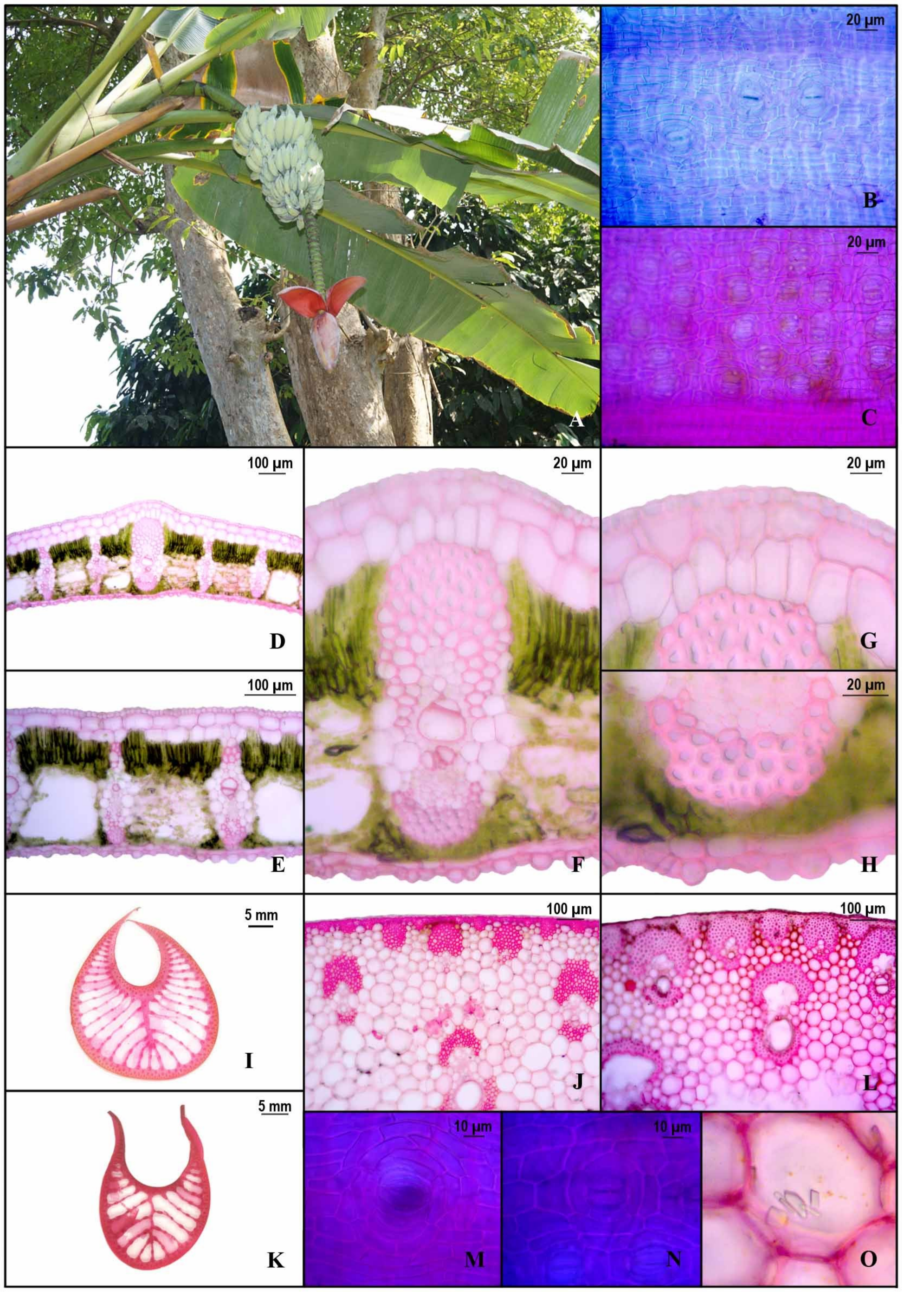


Fig. 26. ***Musa balbisiana* var. *sepa-athiya*.** **A.** habit; **B.** adaxial epidermis; **C.** abaxial epidermis; **D-H.** cross section of lamina**. D.** lamina showing larger and smaller vascular bundles; **E.** lamina showing smaller vascular bundles; **F.** larger vascular bundle enlarged; **G.** adaxial hypodermis above larger bundle; **H.** abaxial hypodermis below the larger bundle; **I.** c.s. of petiole; **J.** abaxial portion of petiole enlarged; **K.** c.s. of midrib; **L.** abaxial portion of petiole enlarged; **M.** adaxial stoma; **N.** abaxial stoma; **O.** crystals in petiole.

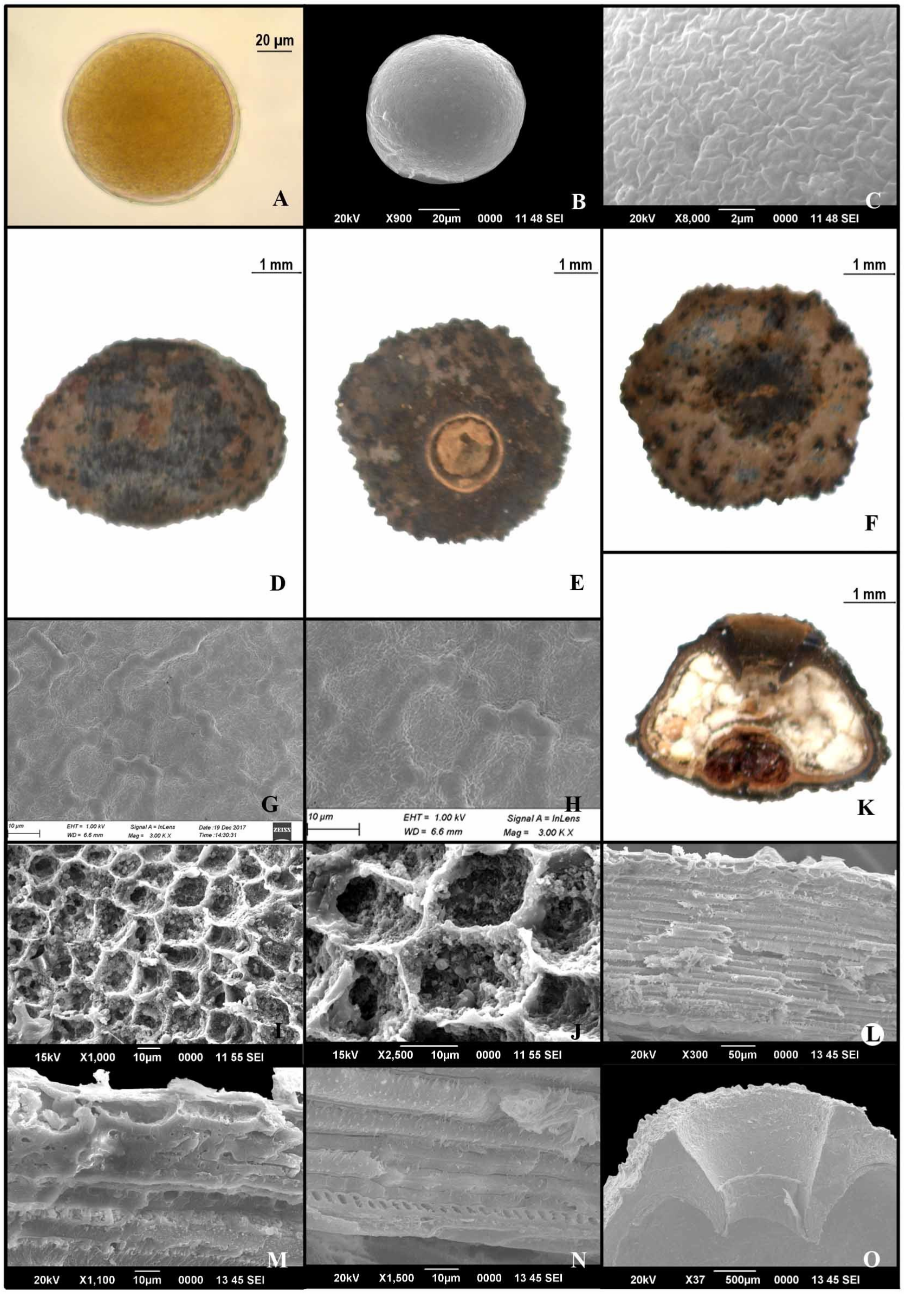


Fig. 27. ***Musa balbisiana* var. *sepa-athiya*.** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

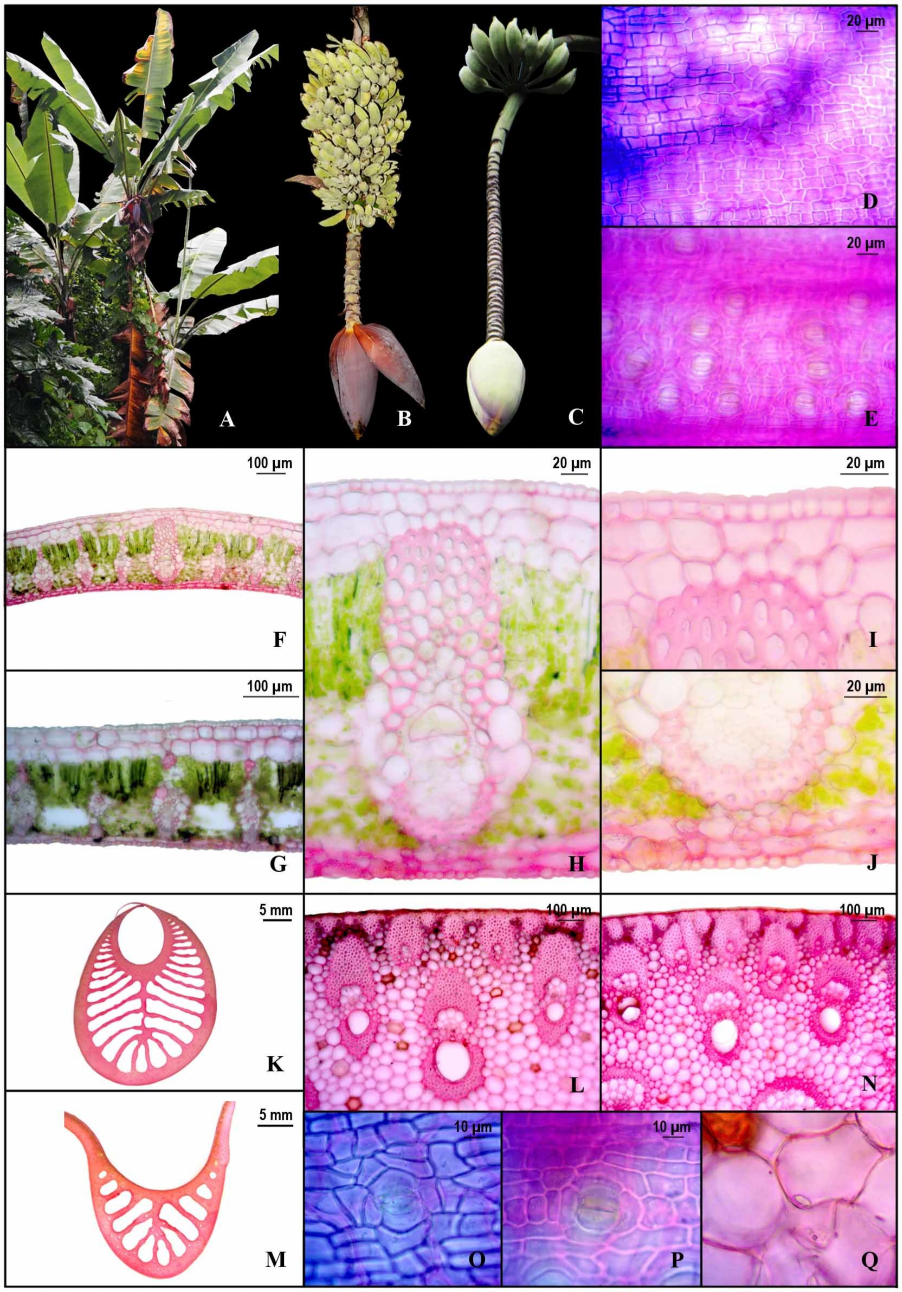


Fig. 28. ***Musa cheesmanii.*** **A.** habit; **B & C.** infructescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

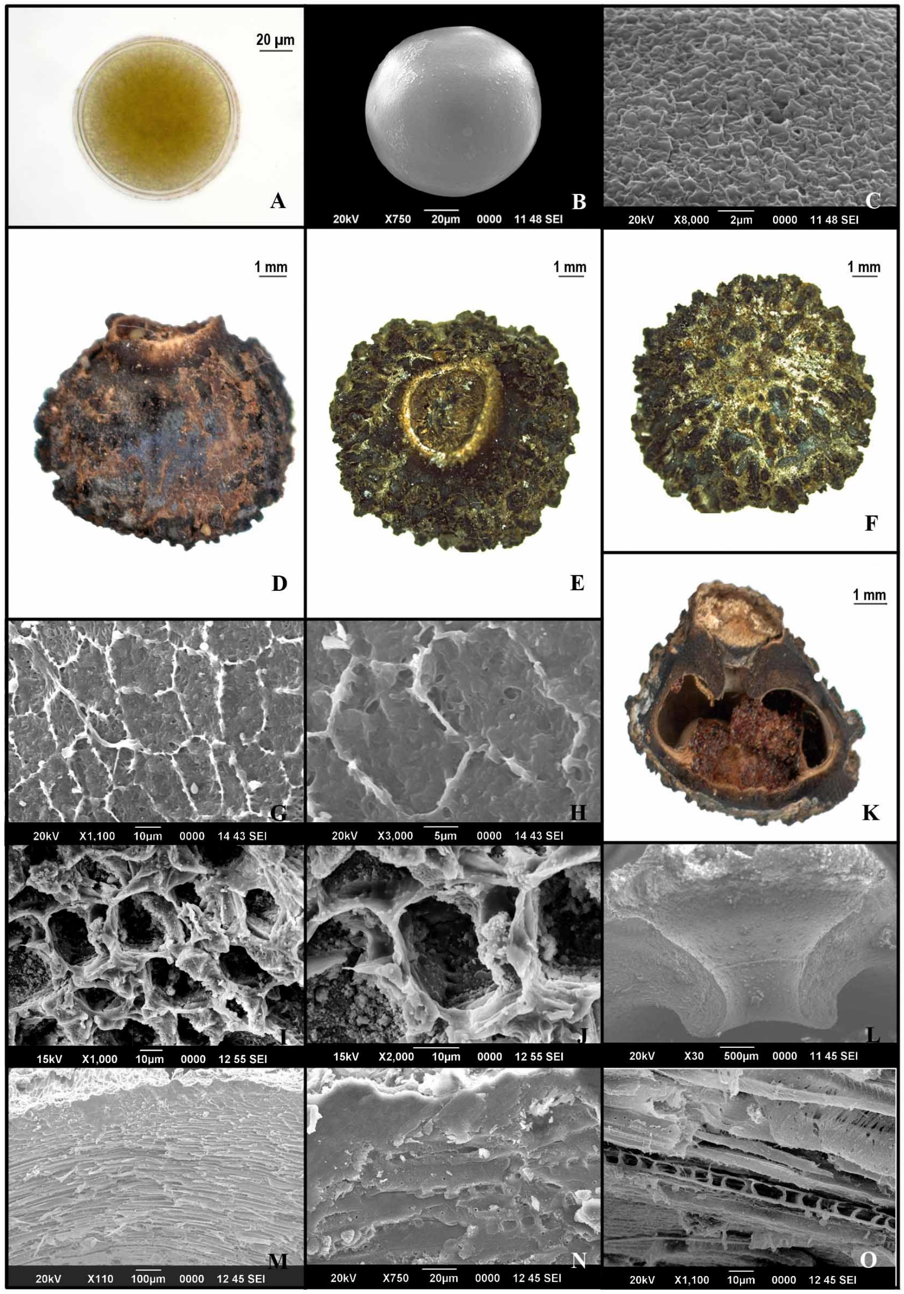


Fig. 29. ***Musa cheesmanii.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

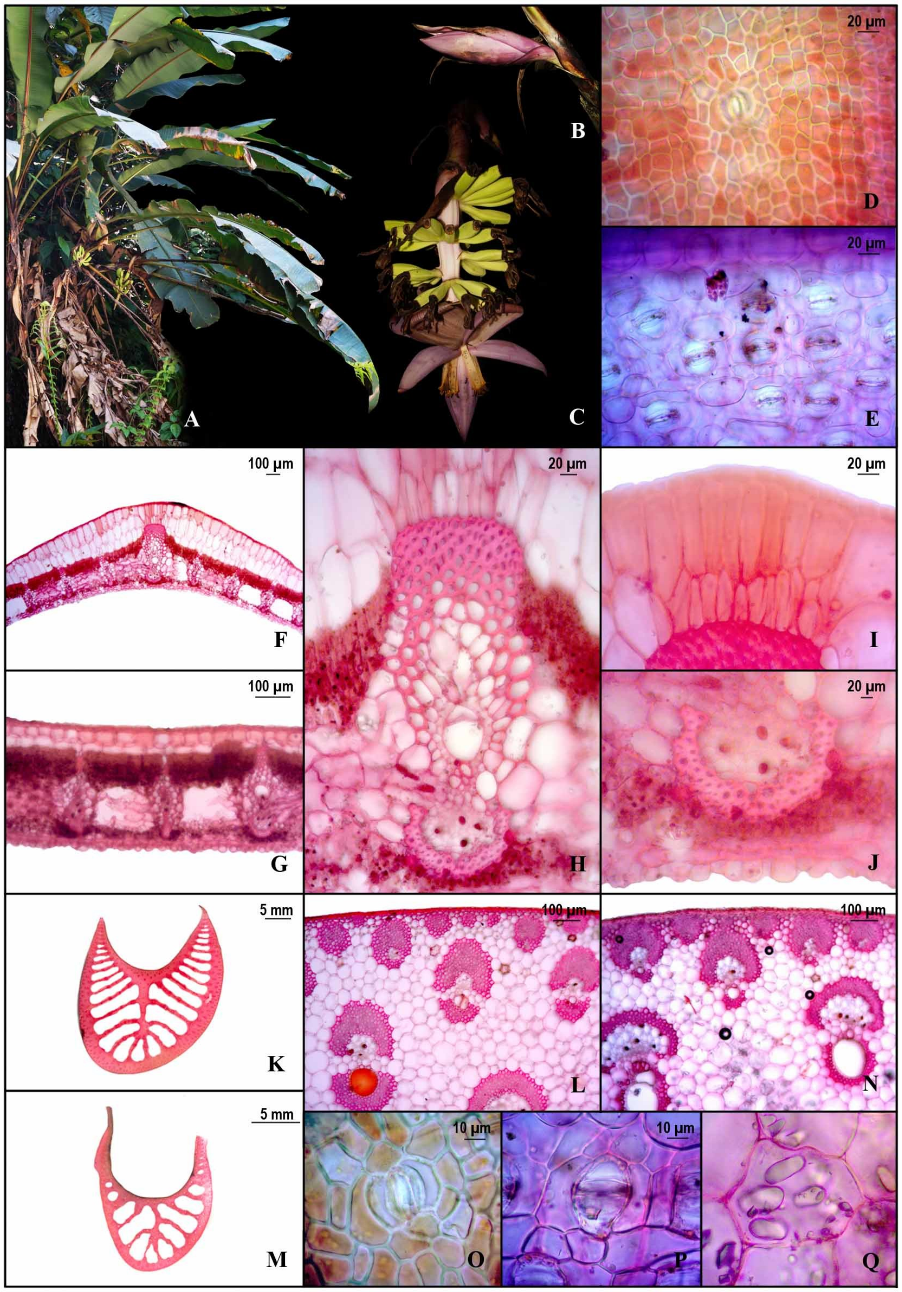


Fig. 30. ***Musa chunii.*** **A.** habit; **B & C.** inflorescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

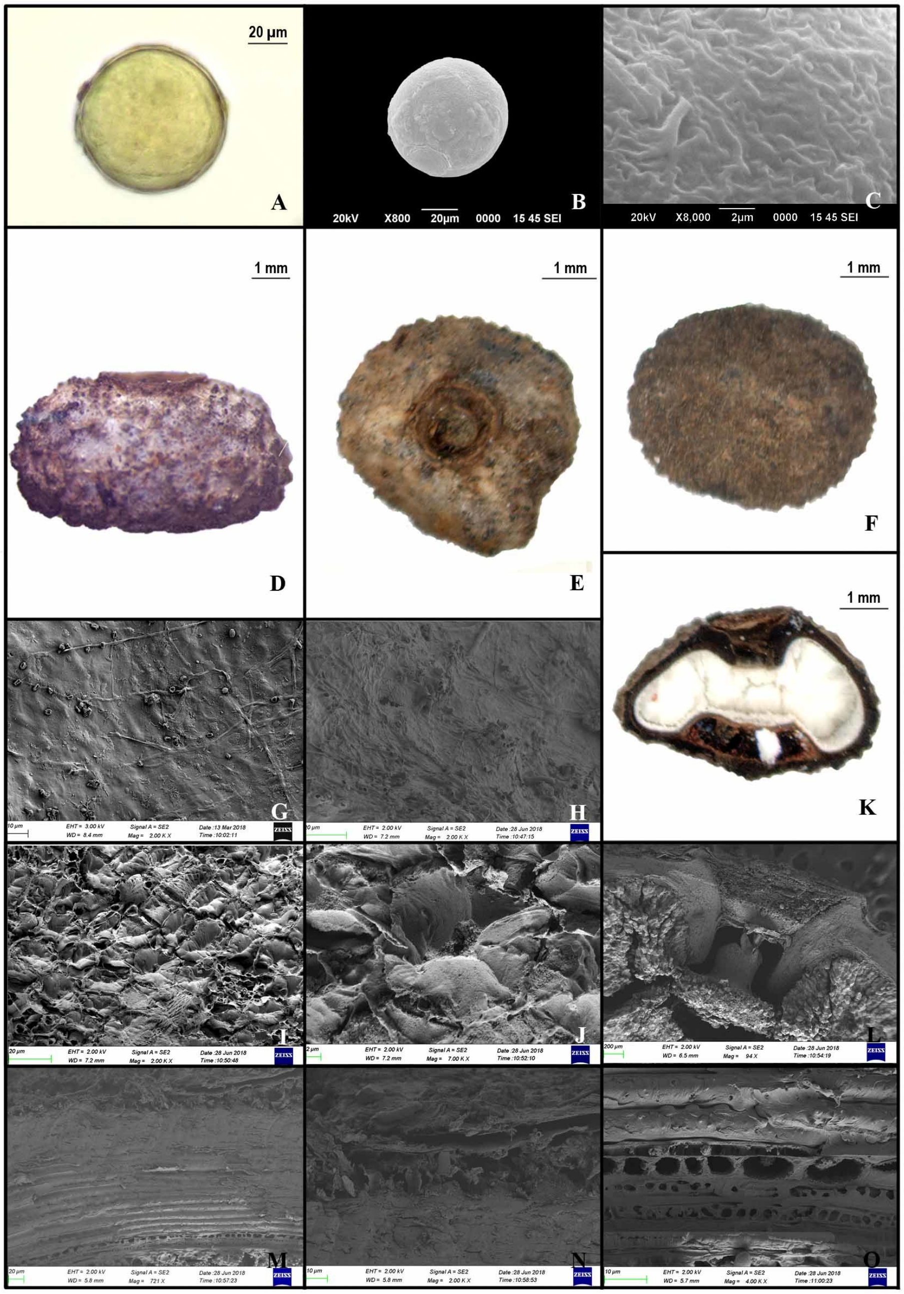


Fig. 31. ***Musa chunii.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

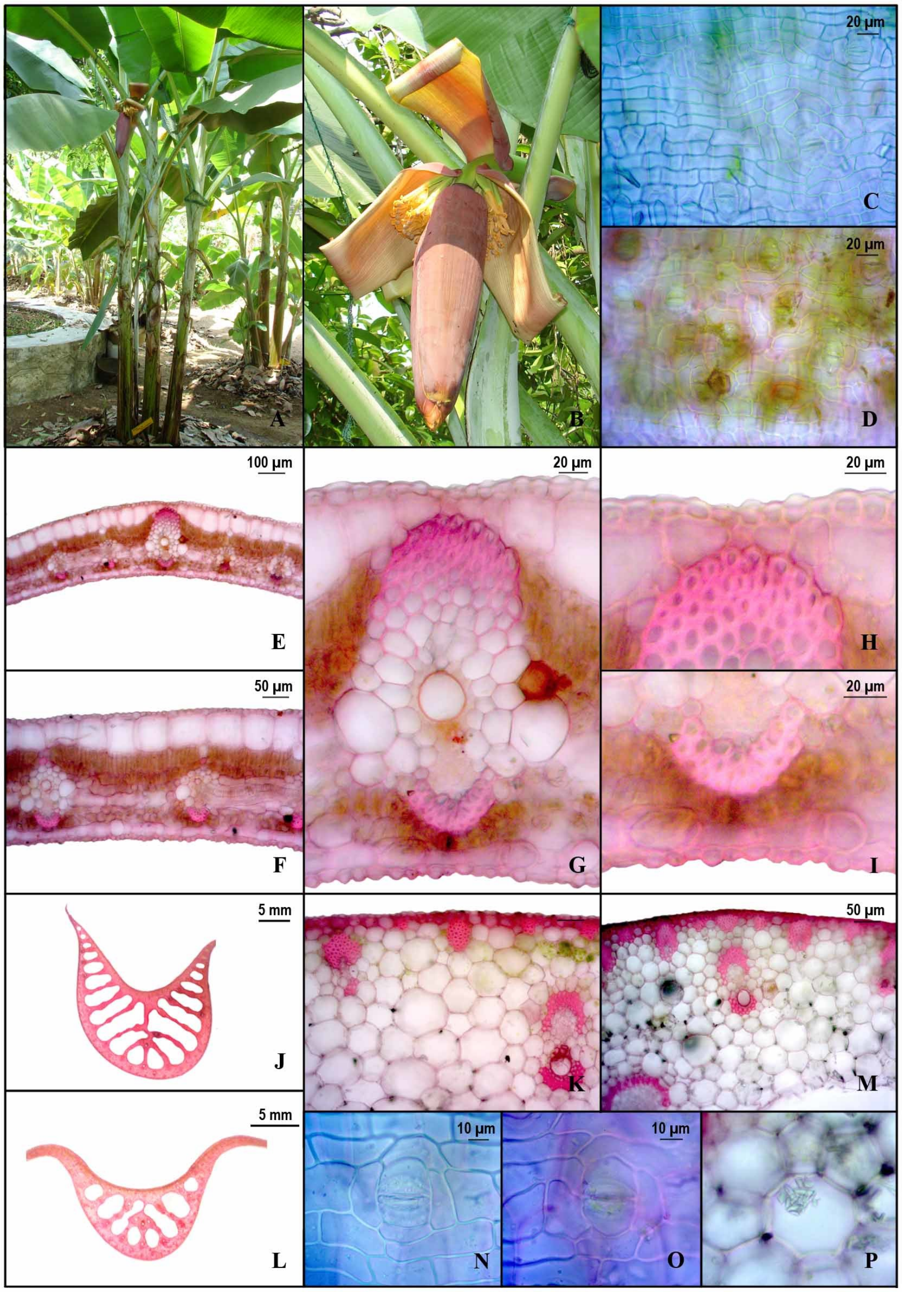


Fig. 32. ***Musa cylindrica.*** **A.** habit; **B.** female bud; **C.** adaxial epidermis; **D.** abaxial epidermis; **E-I.** cross section of lamina**. E.** lamina showing larger and smaller vascular bundles; **F.** lamina showing smaller vascular bundles; **G.** larger vascular bundle enlarged; **H.** adaxial hypodermis above larger bundle; **I.** abaxial hypodermis below the larger bundle; **J.** c.s. of petiole; **K.** abaxial portion of petiole enlarged; **L.** c.s. of midrib; **M.** abaxial portion of petiole enlarged; **N.** adaxial stoma; **O.** abaxial stoma; **P.** crystals in petiole.

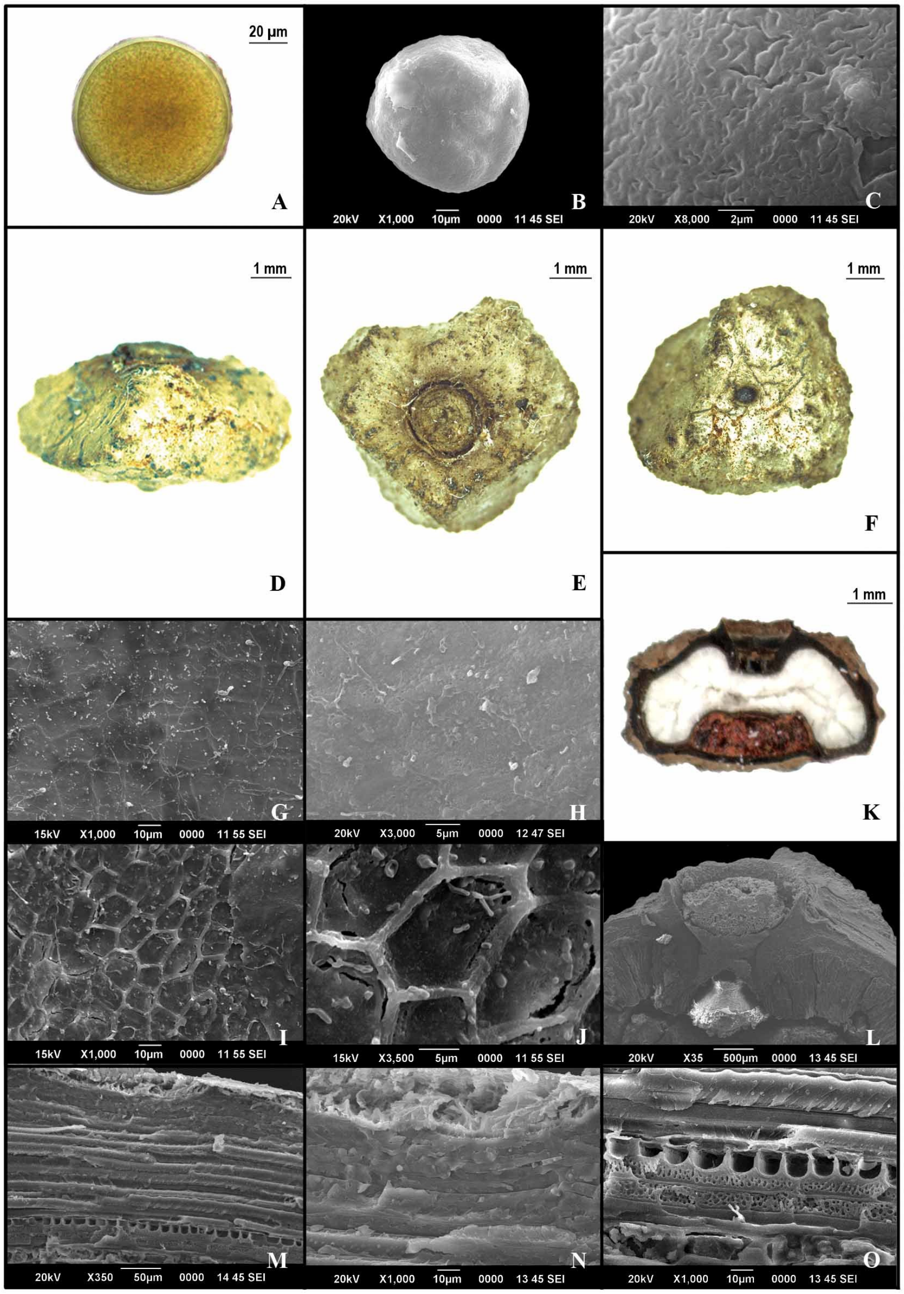


Fig. 33. ***Musa cylindrica.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

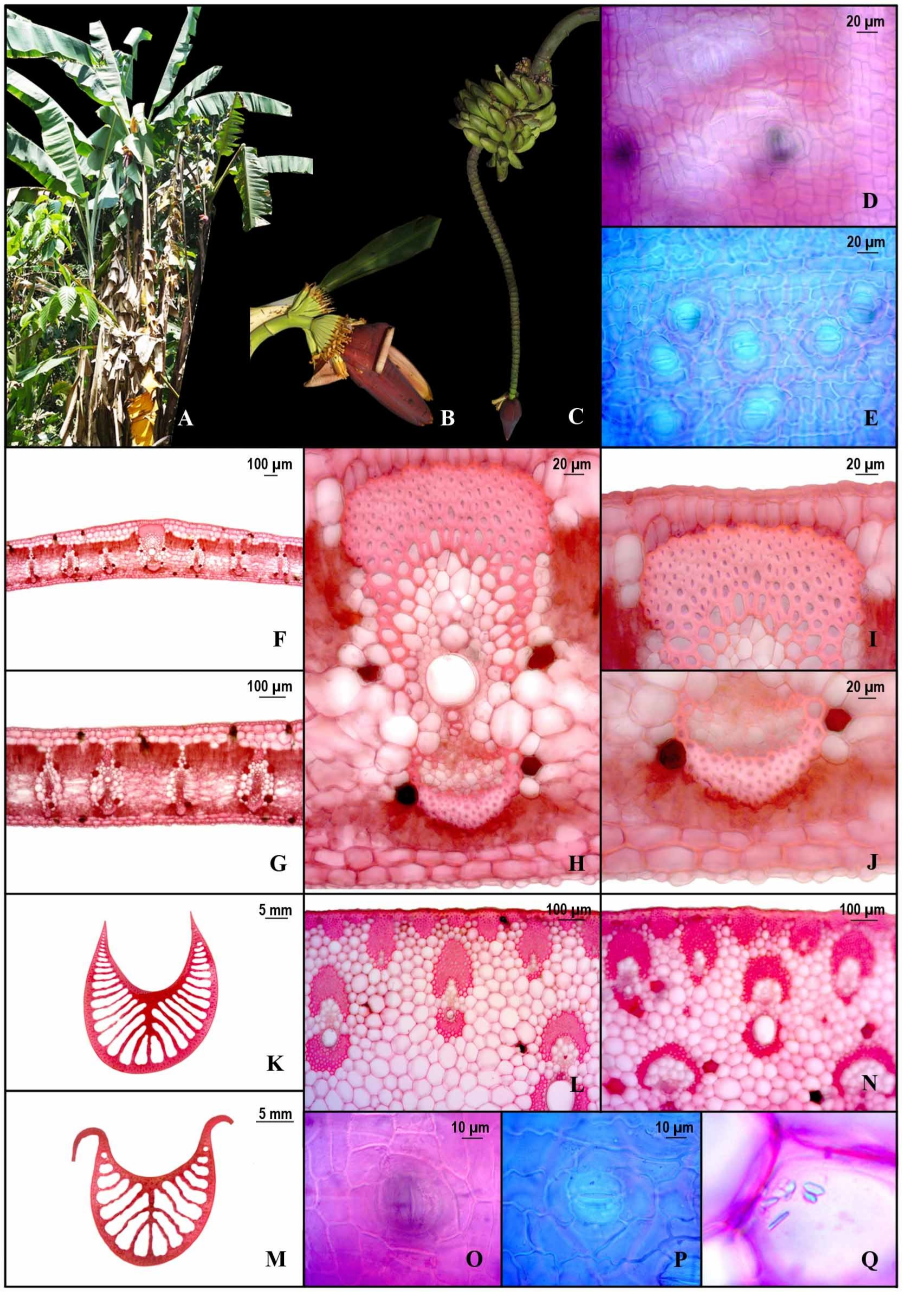


Fig. 34. ***Musa flaviflora.*** **A.** habit; **B.** female bud; **C.** infructescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

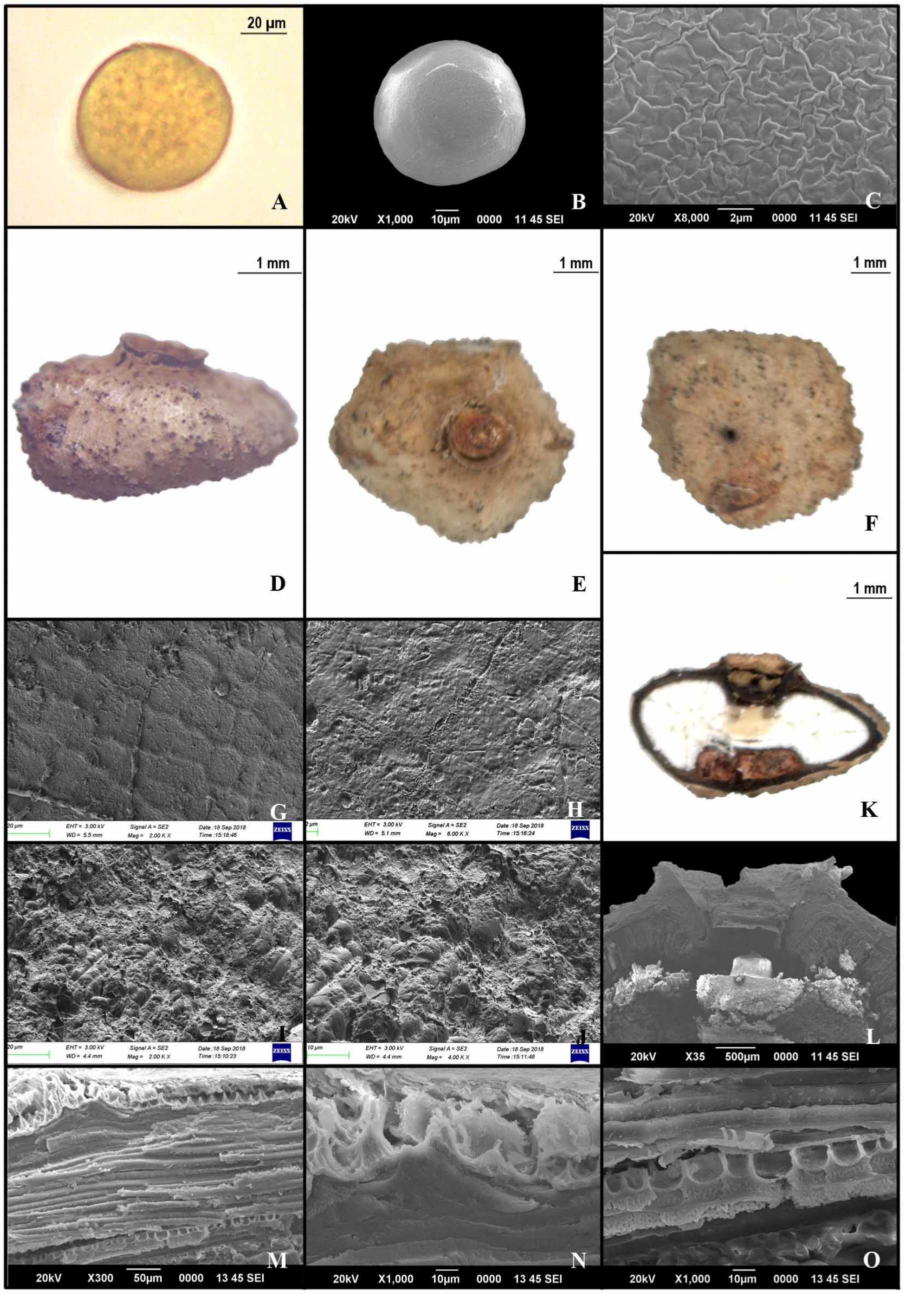


Fig. 35. ***Musa flaviflora.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

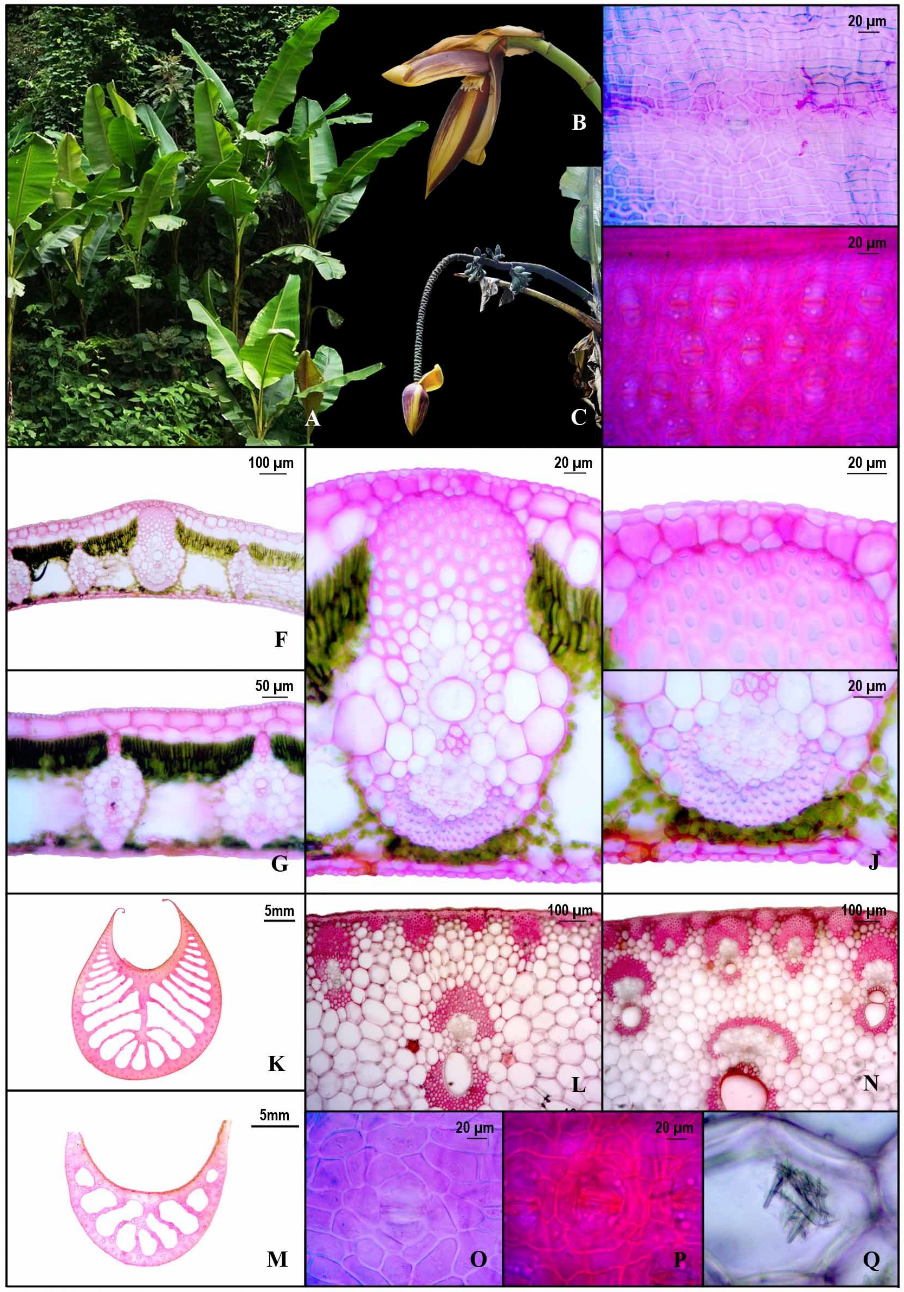


Fig. 36. ***Musa itinerans.*** **A.** habit; **B.** inflorescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

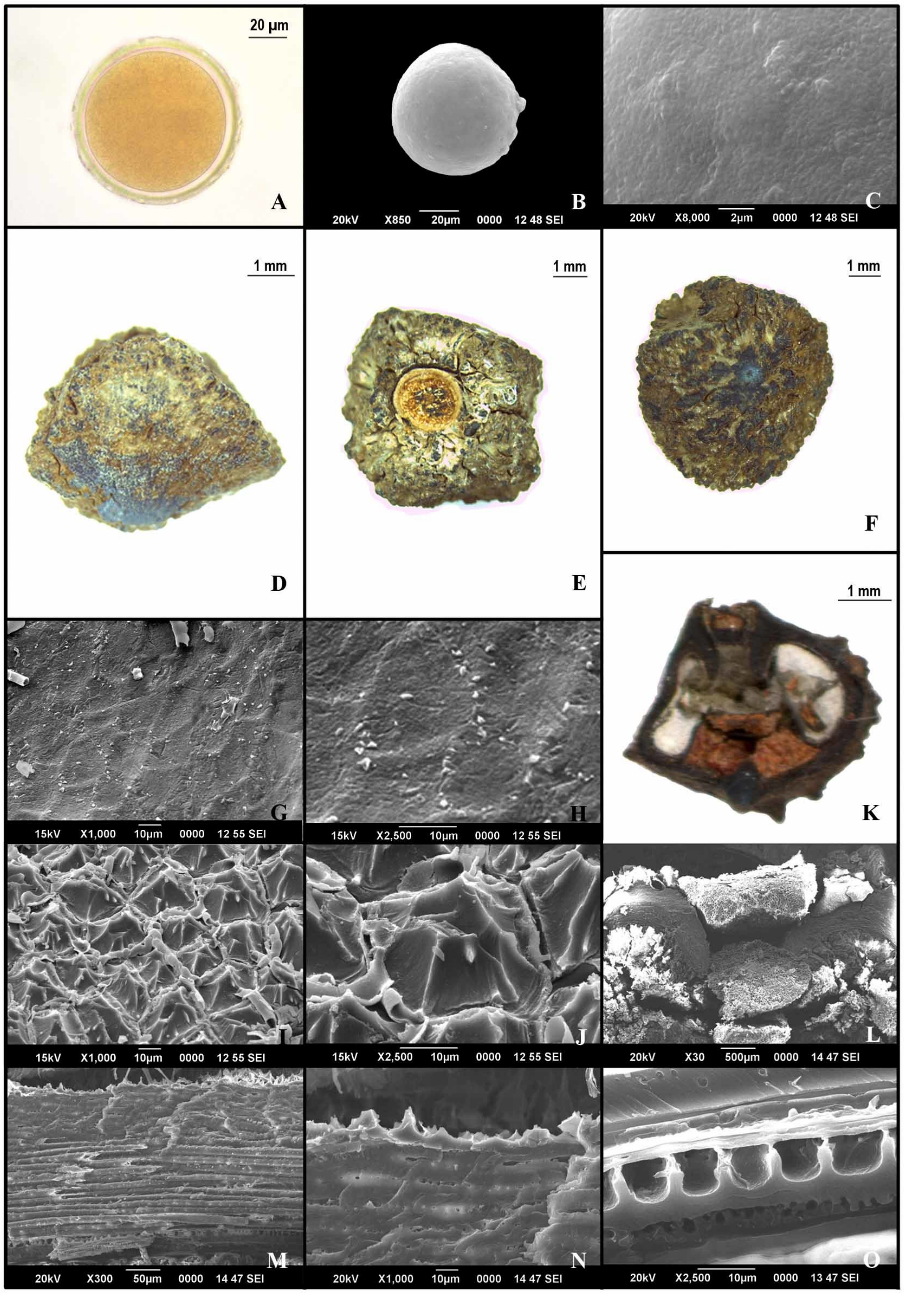


Fig. 37. ***Musa itinerans.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

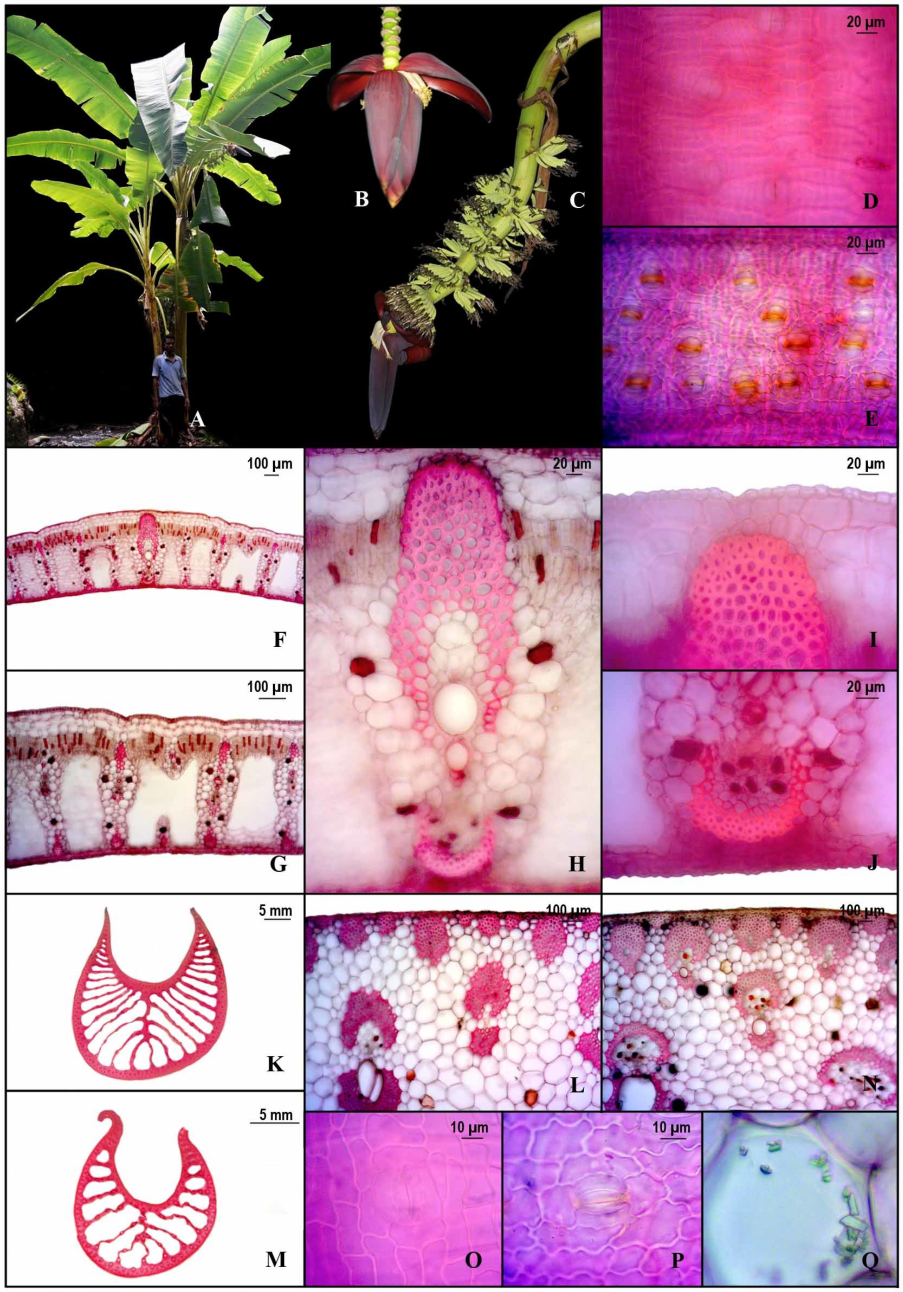


Fig. 38. ***Musa kattuvazhana.*** **A.** habit; **B.** male bud; **C.** infructescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**: F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

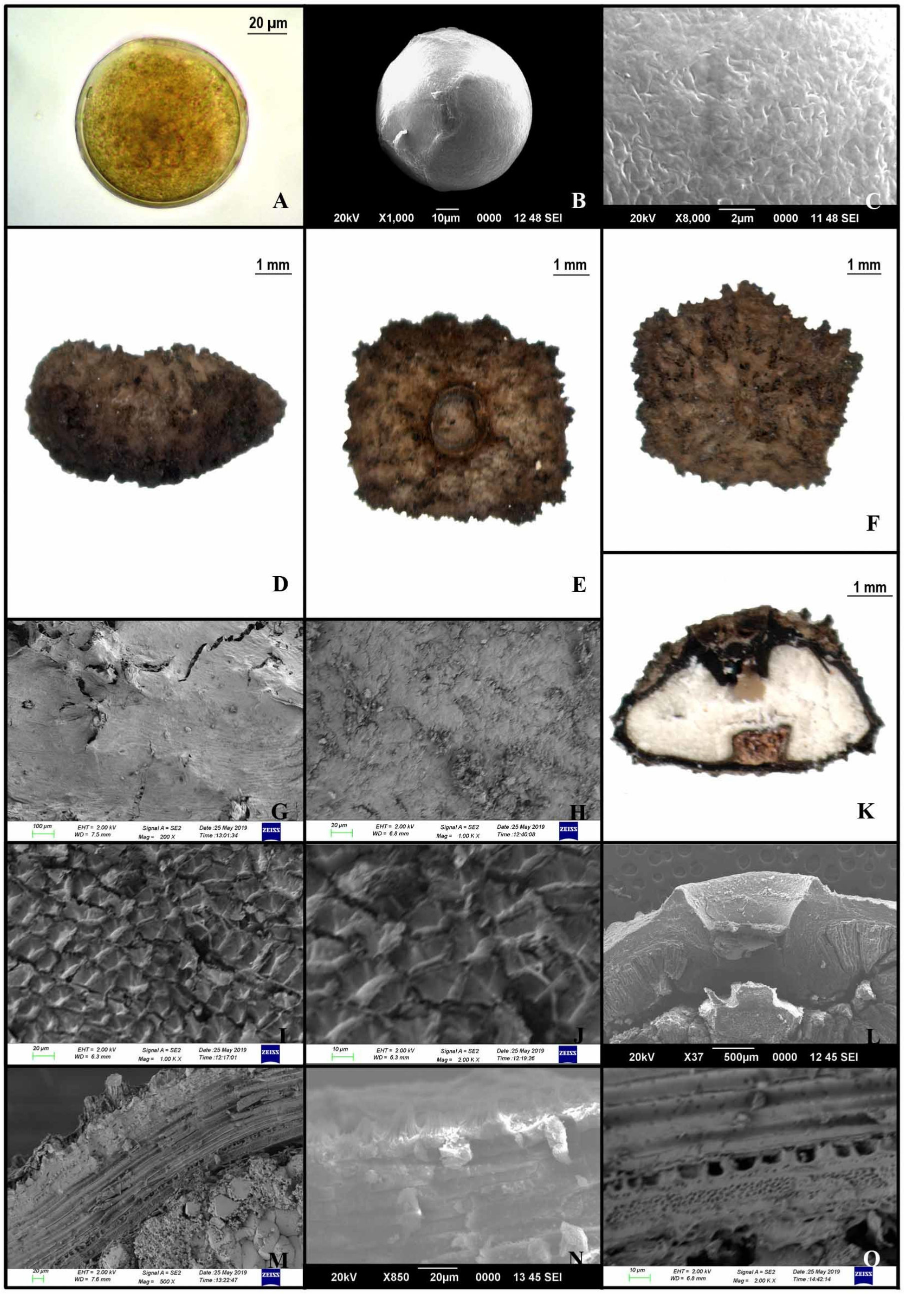


Fig. 39. ***Musa kattuvazhana.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

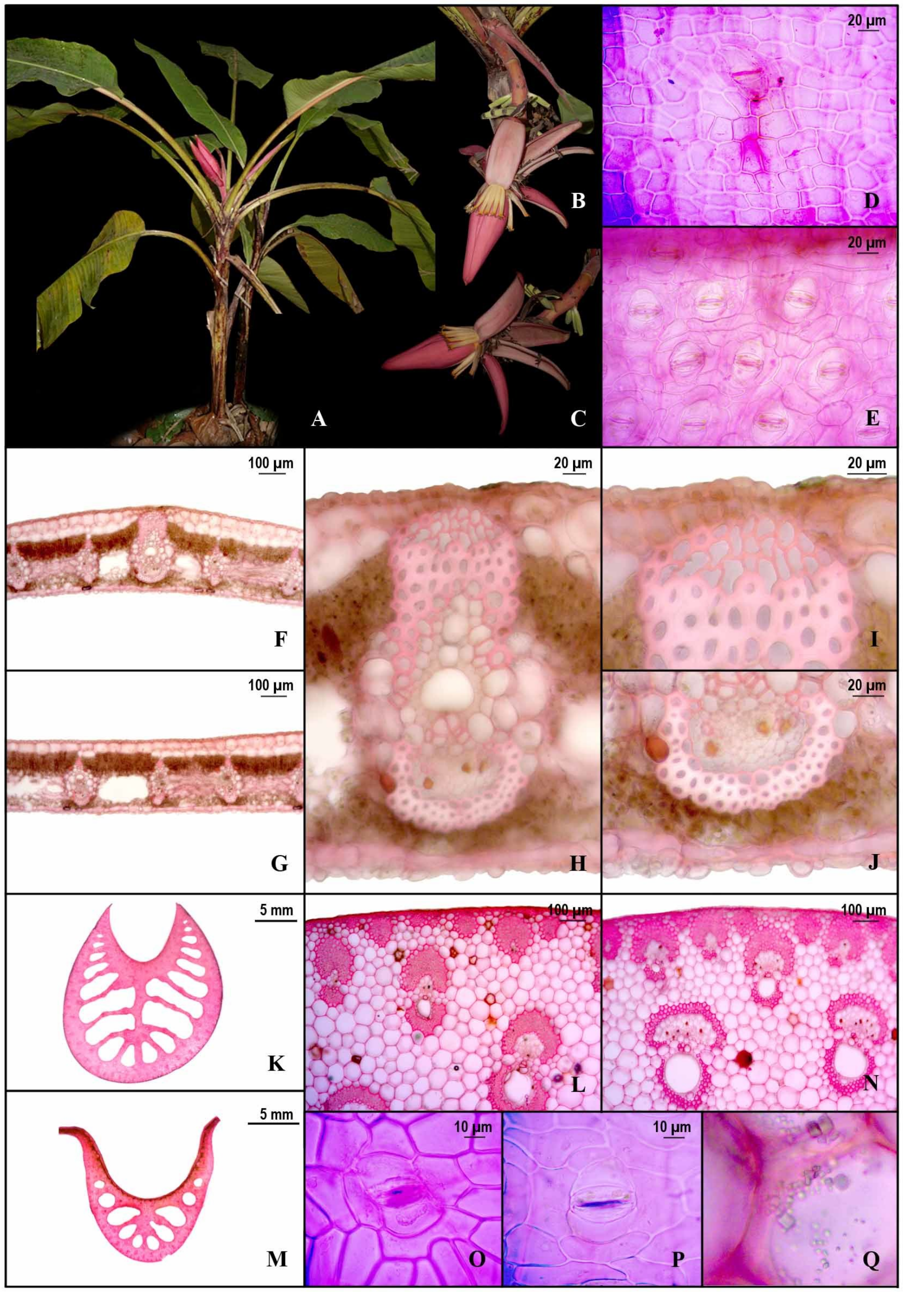


Fig. 40. ***Musa mannii.*** **A.** habit; **B & C.** inflorescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

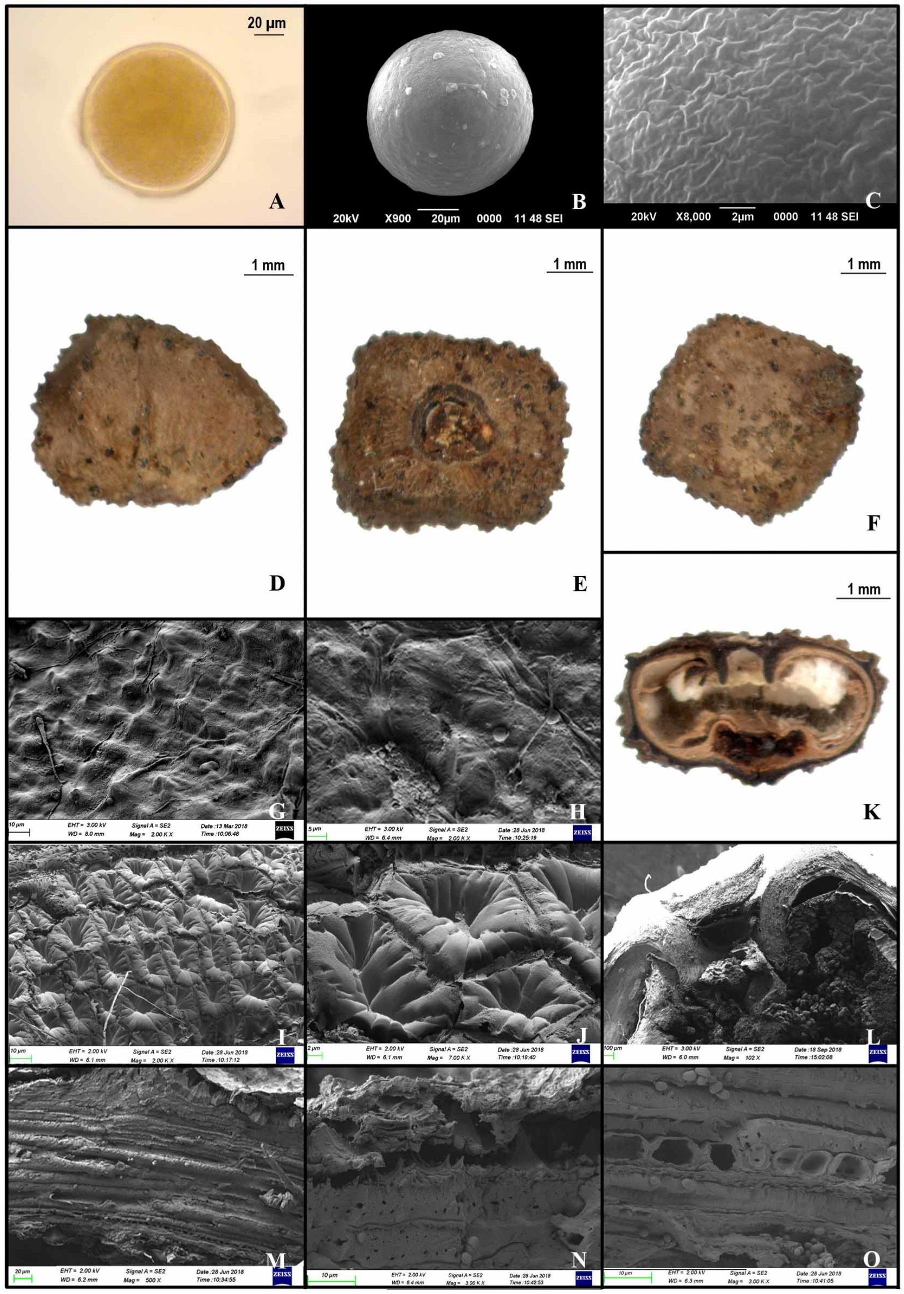


Fig. 41. ***Musa mannii.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

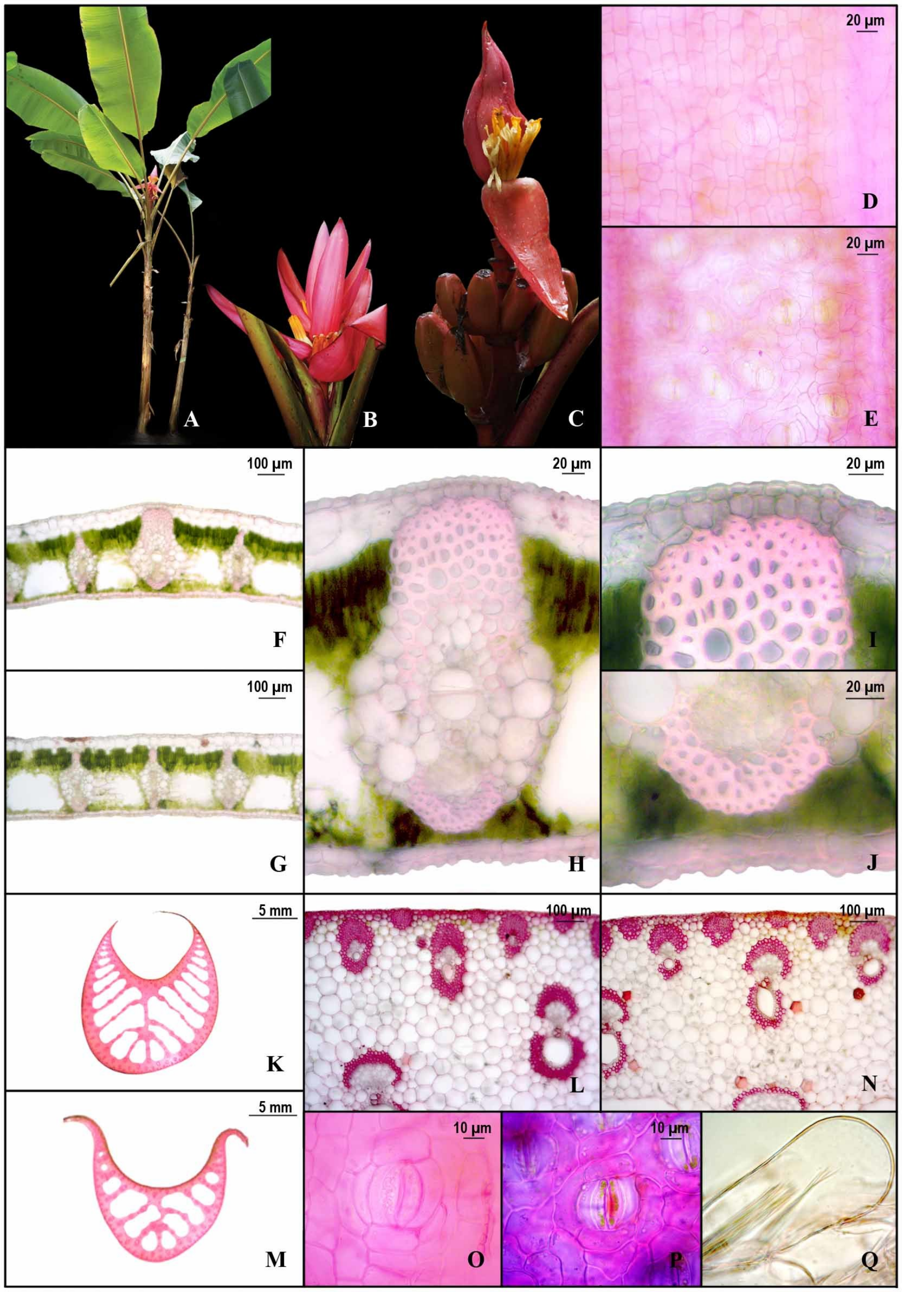


Fig. 42. ***Musa markkuana.*** **A.** habit; **B & C.** inflorescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

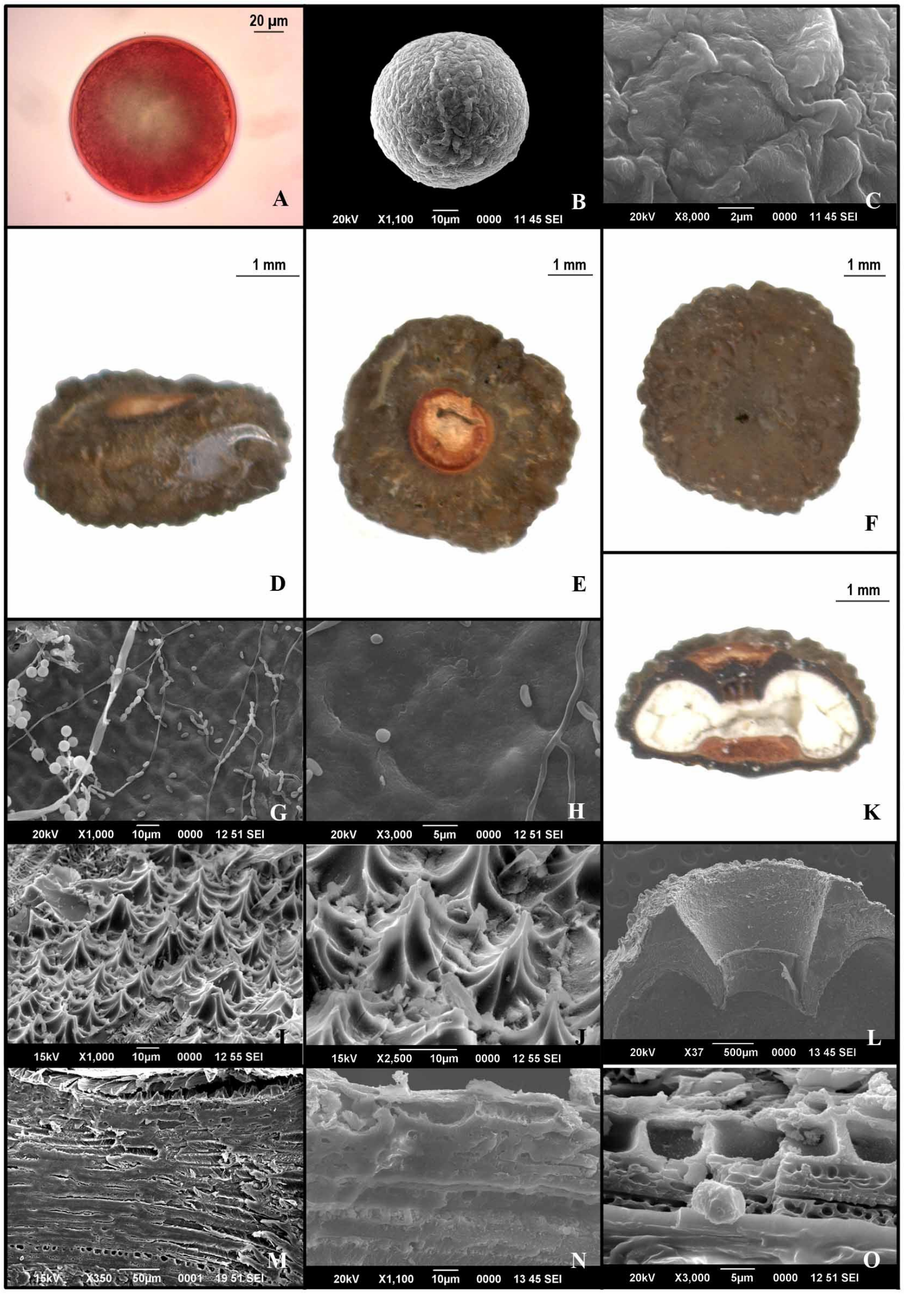


Fig. 43. ***Musa markkuana.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

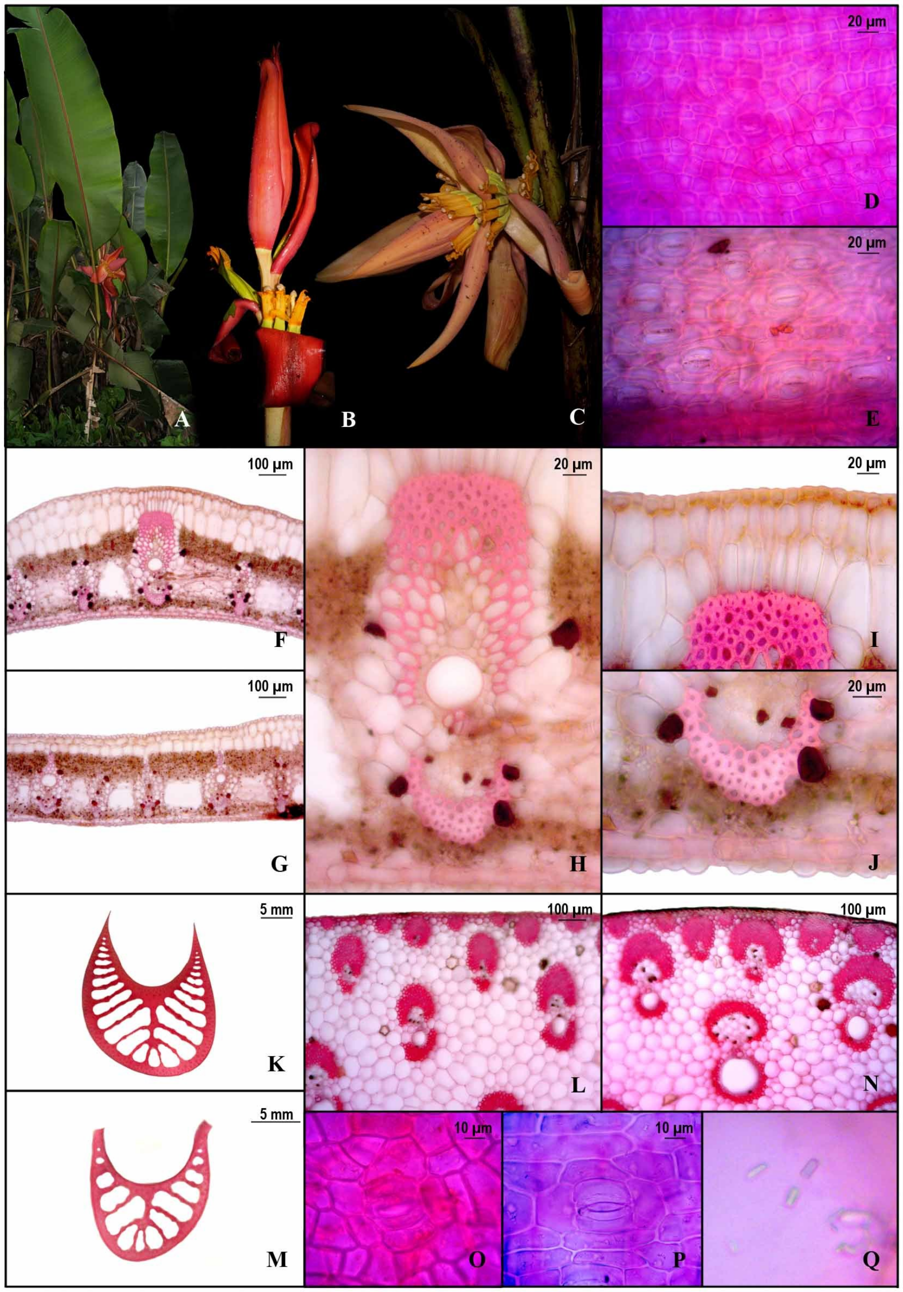


Fig. 44. ***Musa markkui.*** **A.** habit; **B & C.** inflorescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

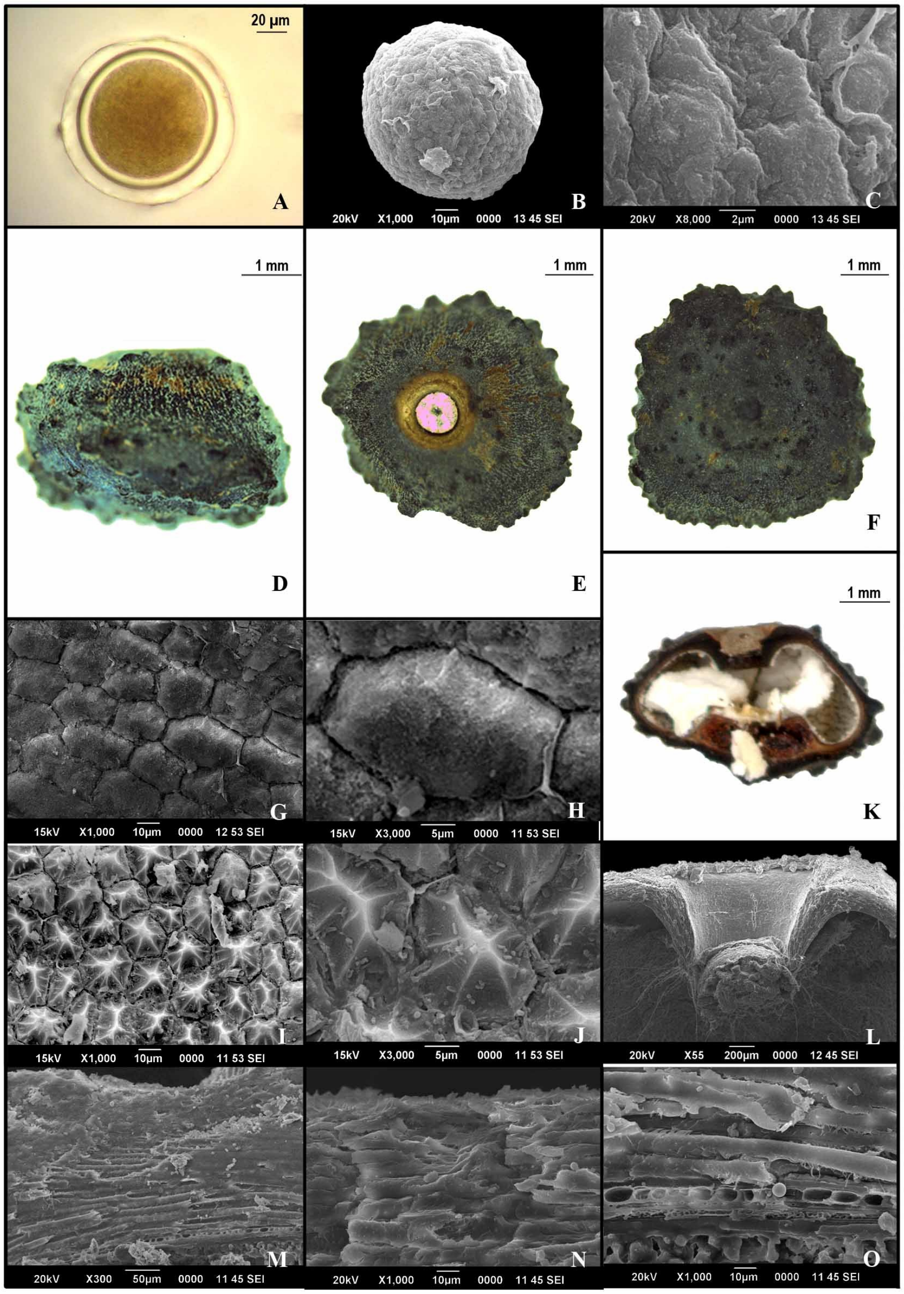


Fig. 45. ***Musa markkui.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

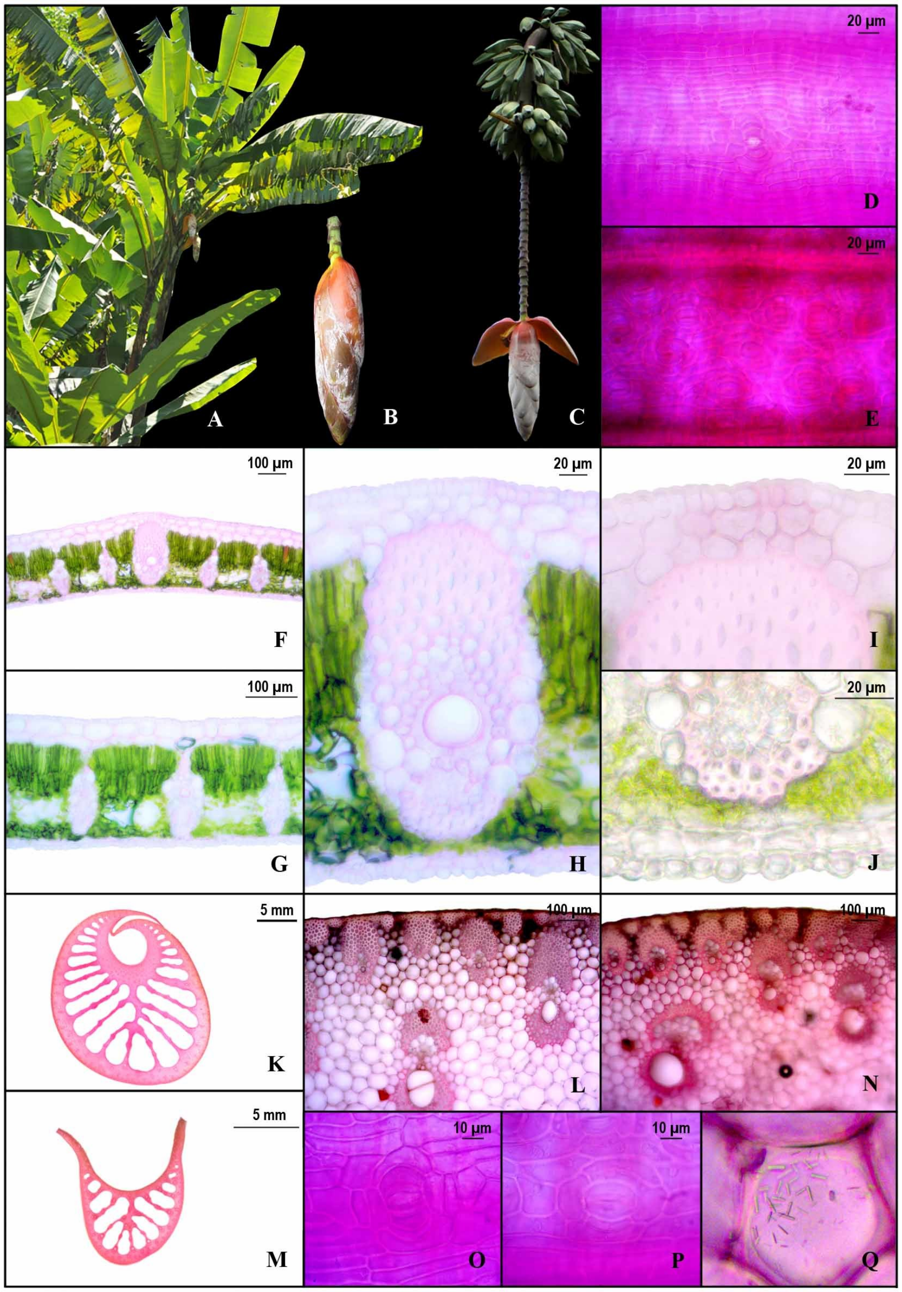


Fig. 46. ***Musa nagensium.*** **A.** habit; **B.** male bud; **C.** infructescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

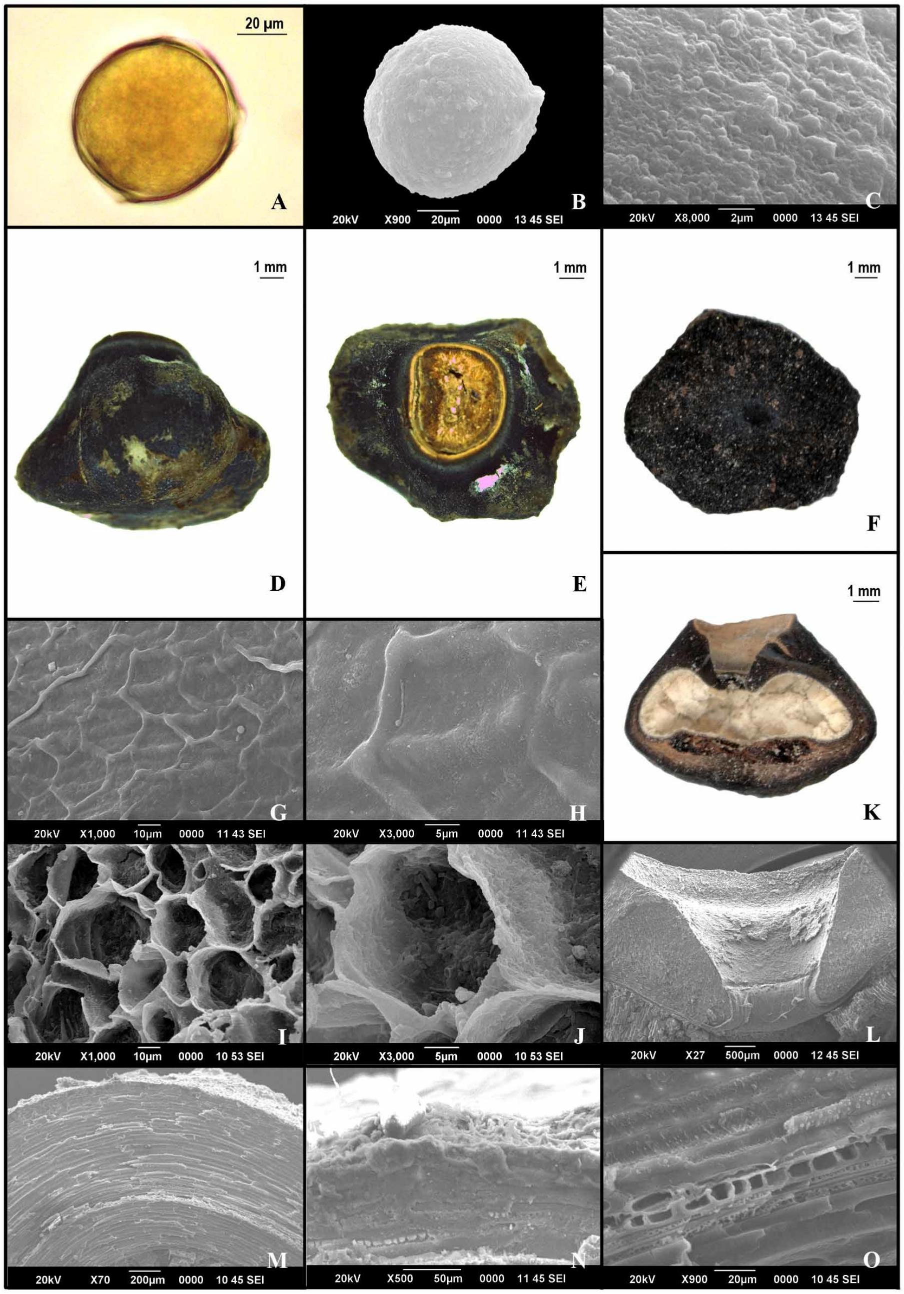


Fig. 47. ***Musa nagensium.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

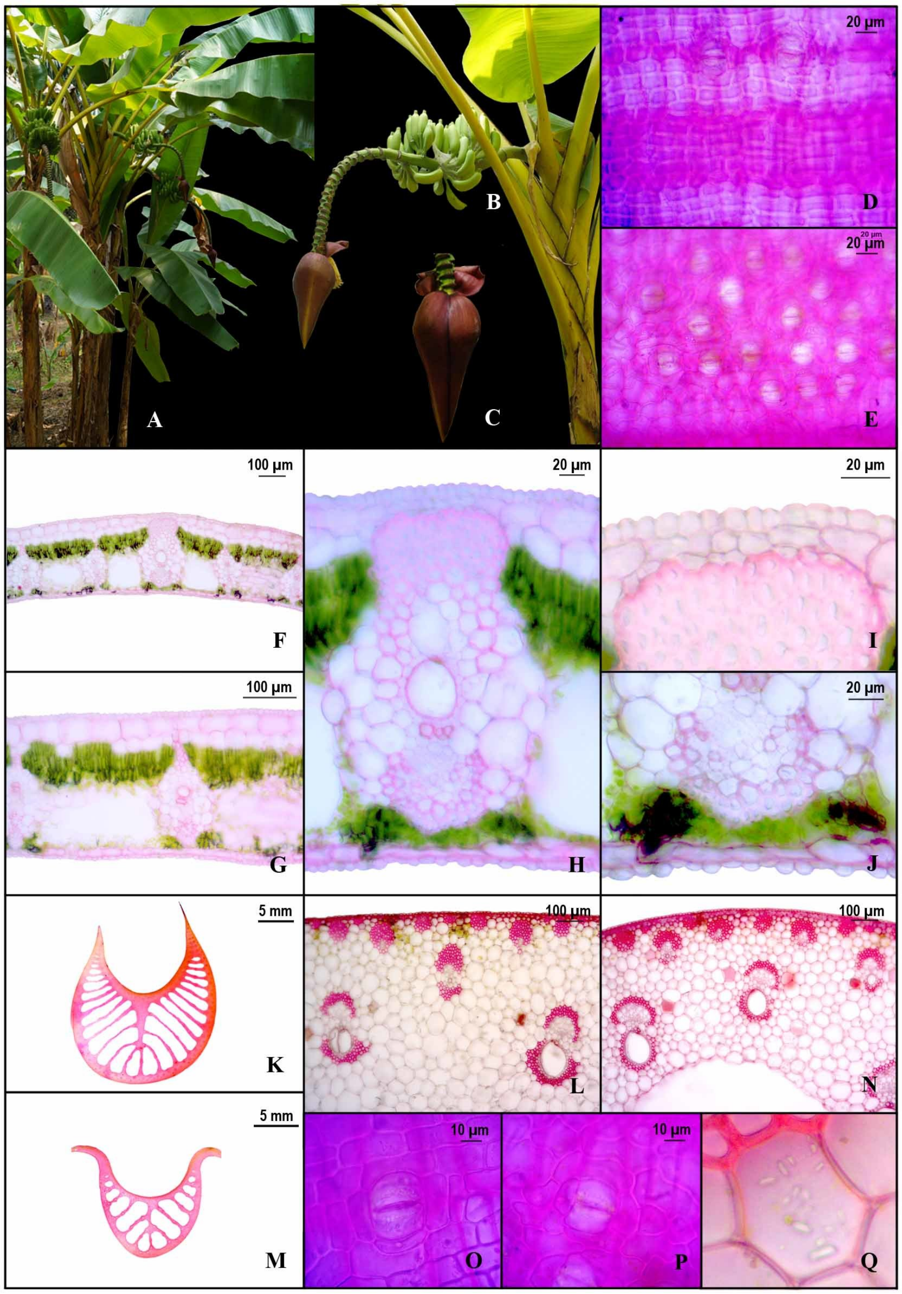


Fig. 48. ***Musa ochracea.*** **A & B.** habit; **& C.** male bud; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

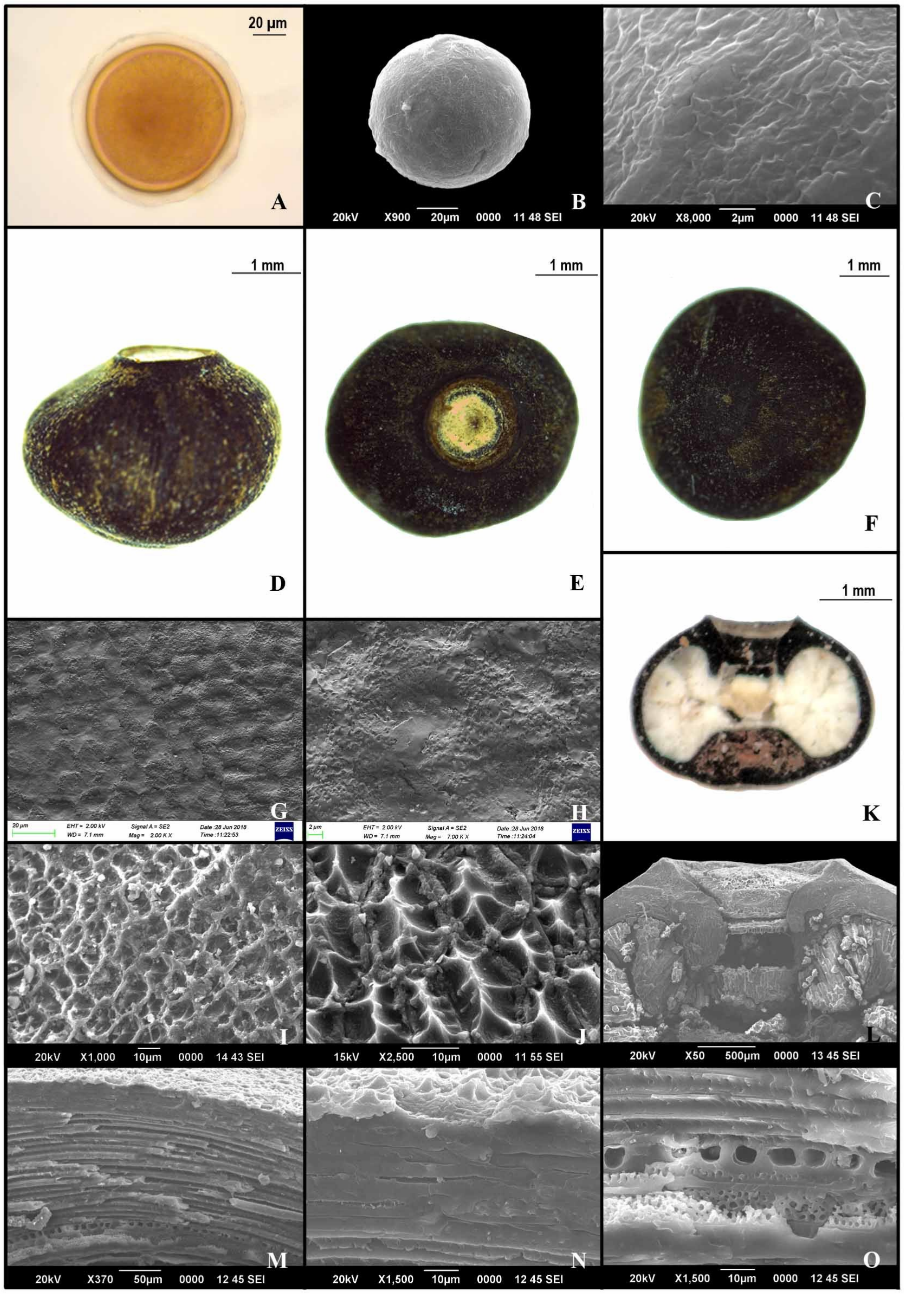


Fig. 49. ***Musa ochracea.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

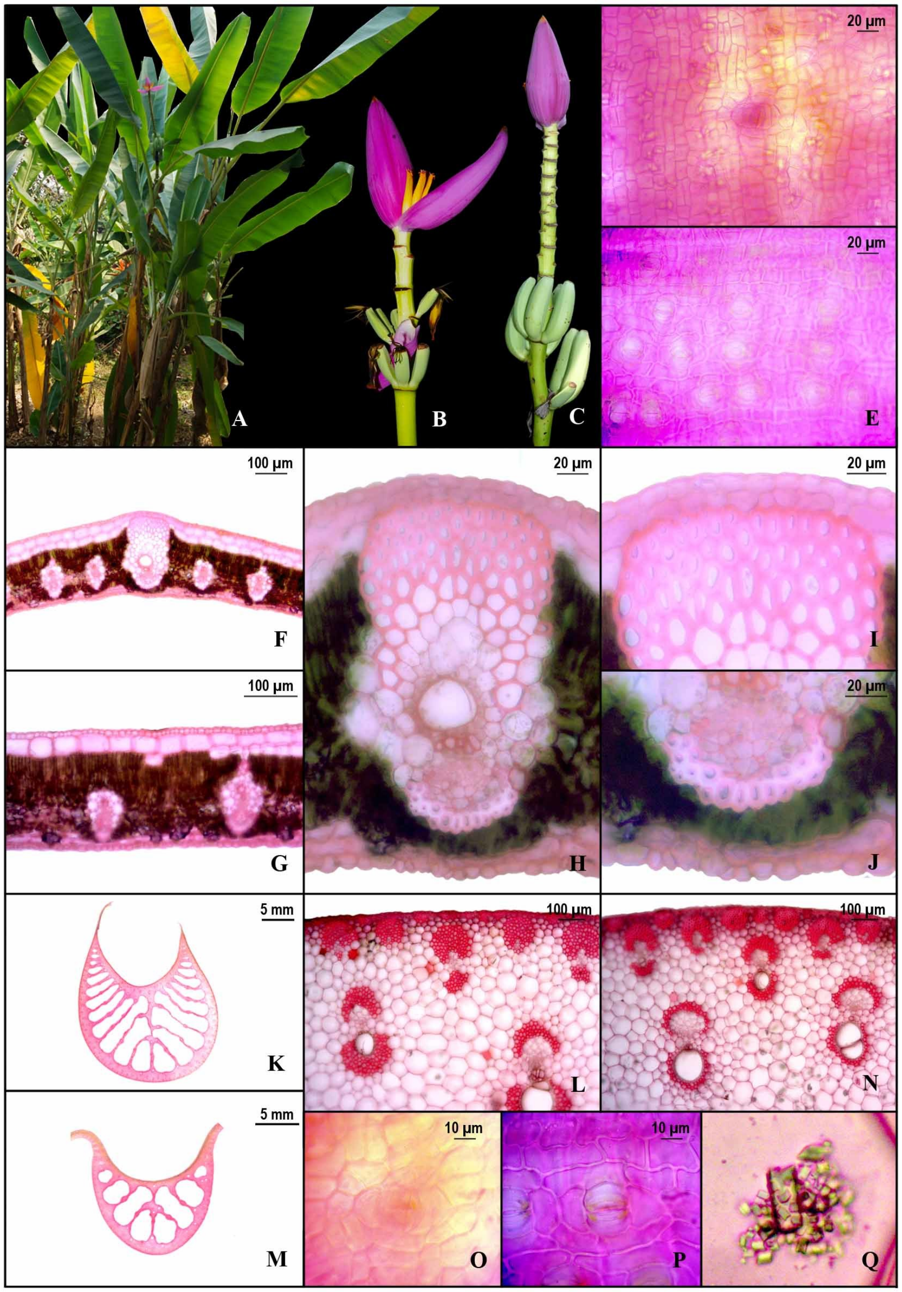


Fig. 50. ***Musa ornata.*** **A.** habit; **B.** inflorescence; **C.** infructescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

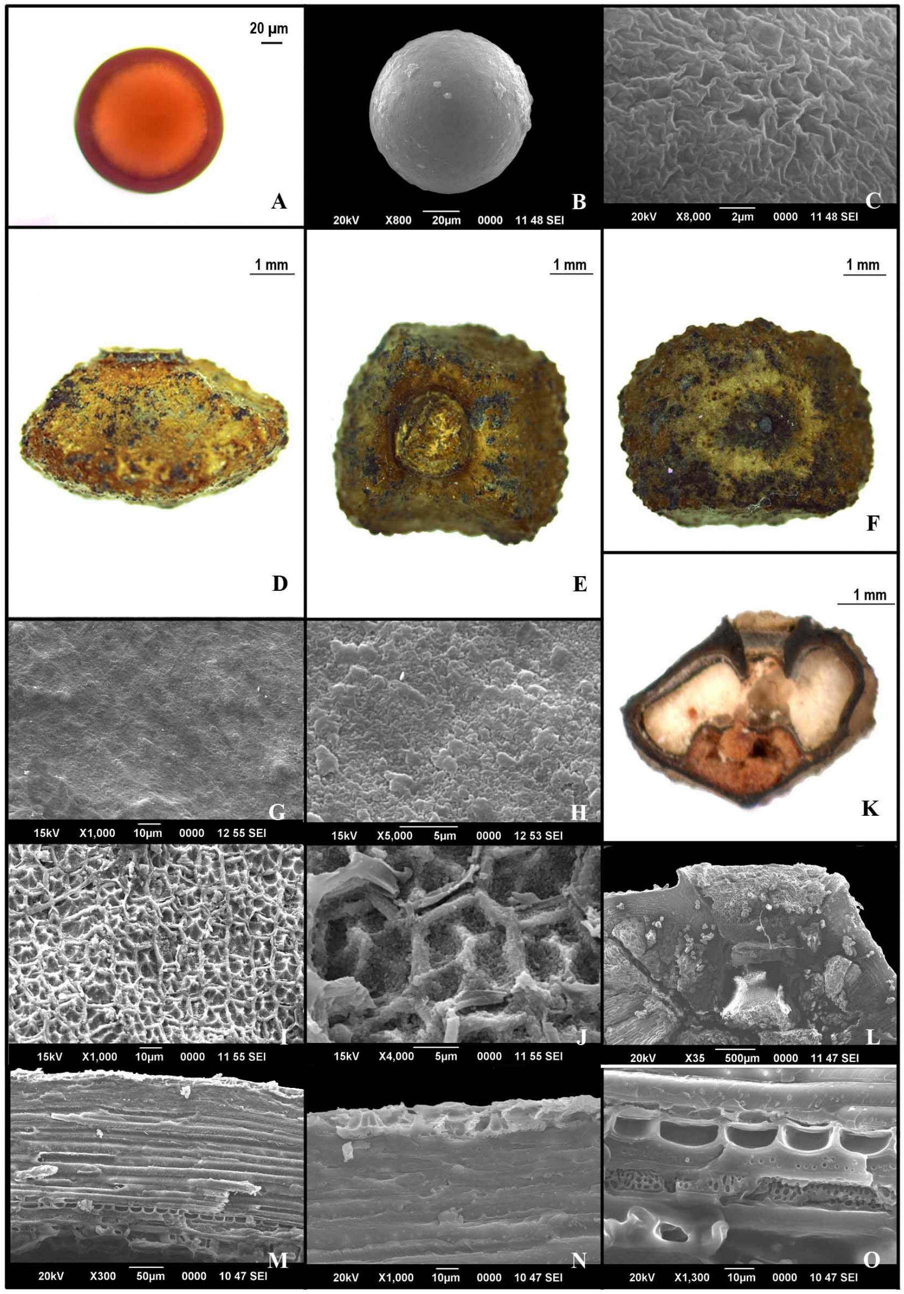


Fig. 51. ***Musa ornata.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

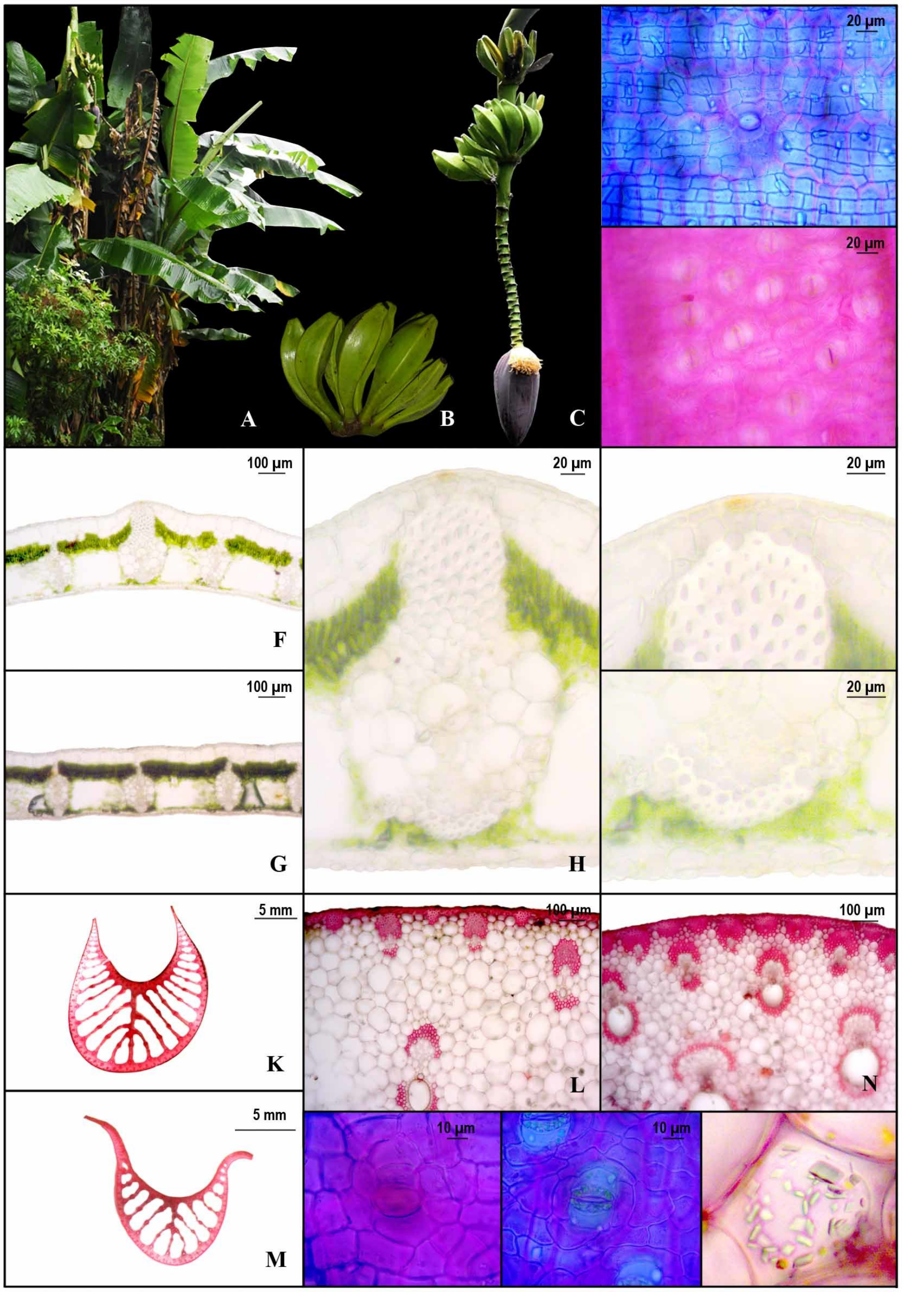


Fig. 52. ***Musa pradhanii.*** **A.** habit; **B.** fruit bunch; **C.** infructescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

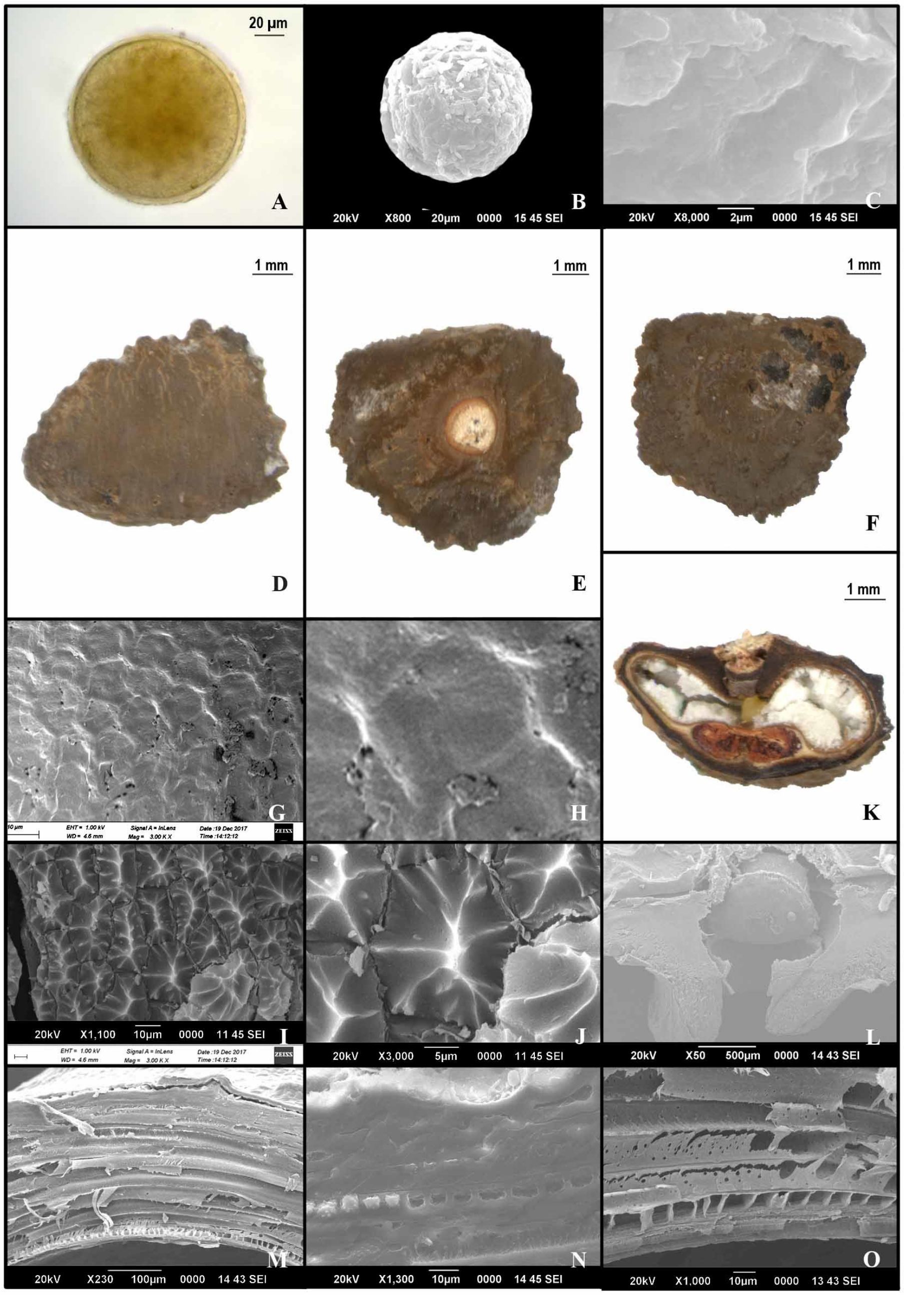


Fig. 53. ***Musa pradhanii.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

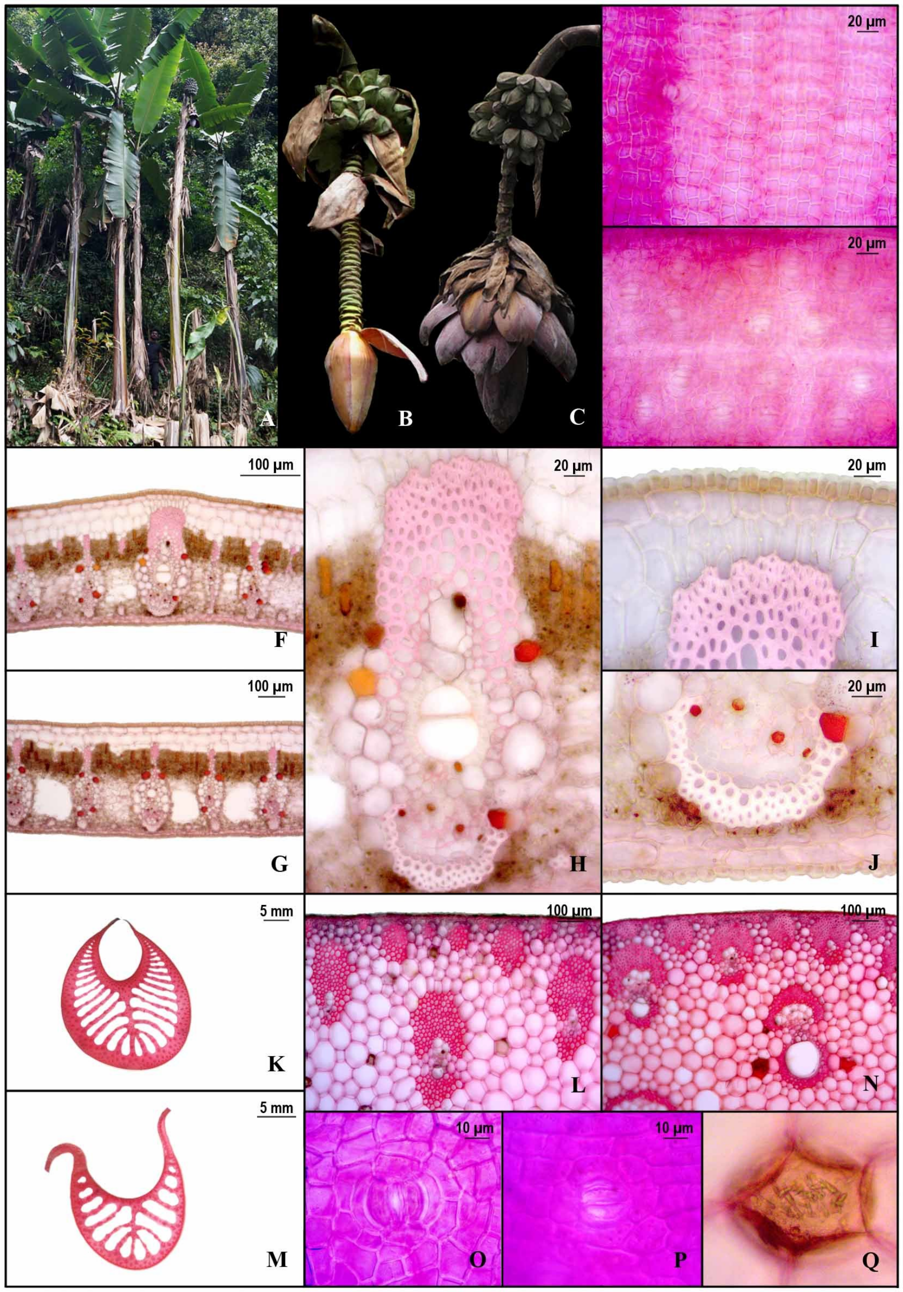


Fig. 54. ***Musa puspanjaliae.*** **A.** habit; **B & C.** infructescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

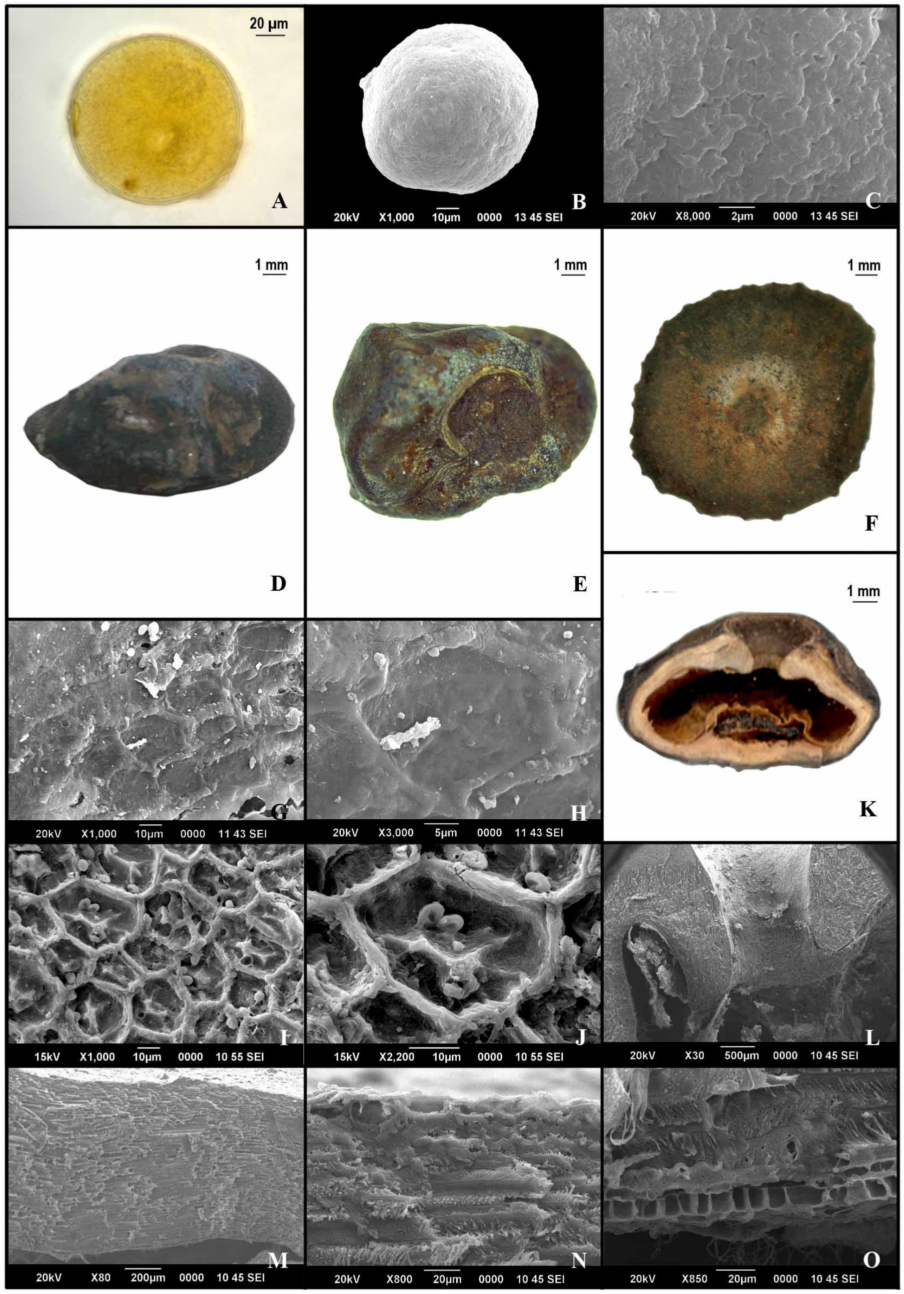


Fig. 55. ***Musa puspanjaliae.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

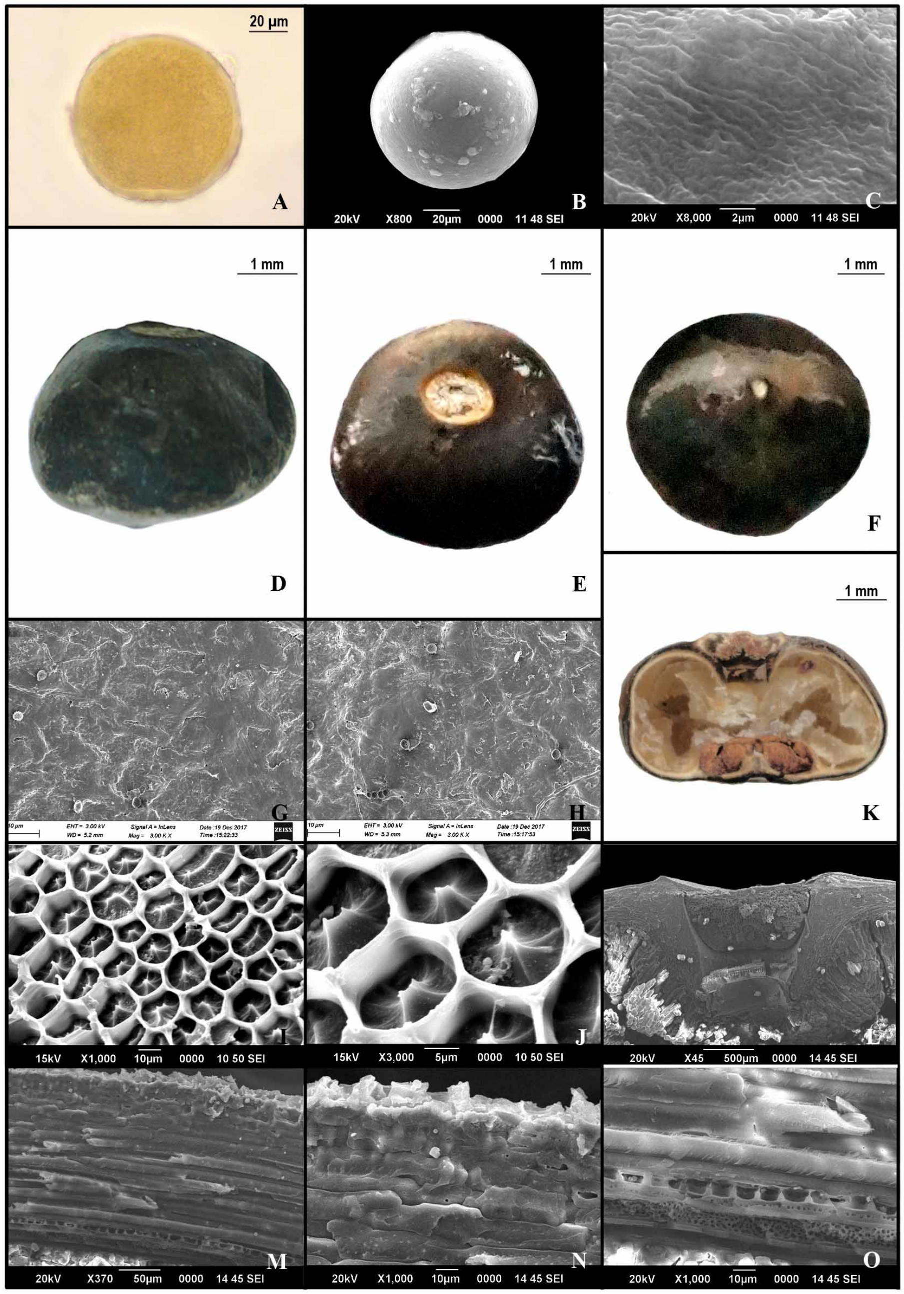


Fig. 57. ***Musa rubra.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

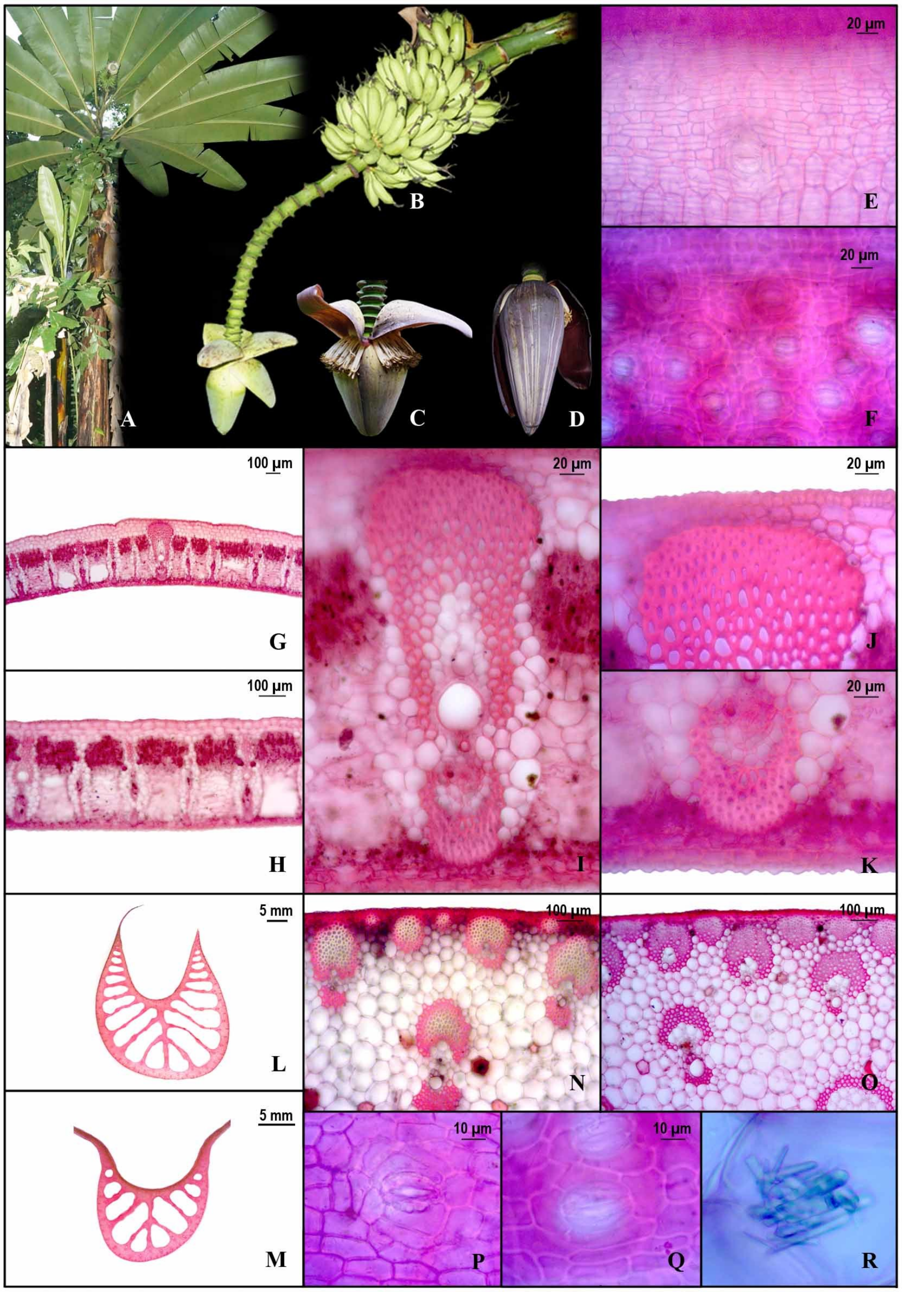


Fig. 58. ***Musa sabuana.*** **A.** habit; **B.** infructescence; **C & D.** male bud; **E.** adaxial epidermis; **F.** abaxial epidermis; **G-K.** cross section of lamina**:** **G.** lamina showing larger and smaller vascular bundles; **H.** lamina showing smaller vascular bundles; **I.** larger vascular bundle enlarged; **J.** adaxial hypodermis above larger bundle; **K.** abaxial hypodermis below the larger bundle; **L.** c.s. of petiole diagramatic; **M.** abaxial portion of petiole enlarged; **N.** c.s. of midrib diagramatic; **O.** abaxial portion of midrib enlarged; **P.** adaxial stoma; **Q.** abaxial stoma; **R.** crystals in petiole.

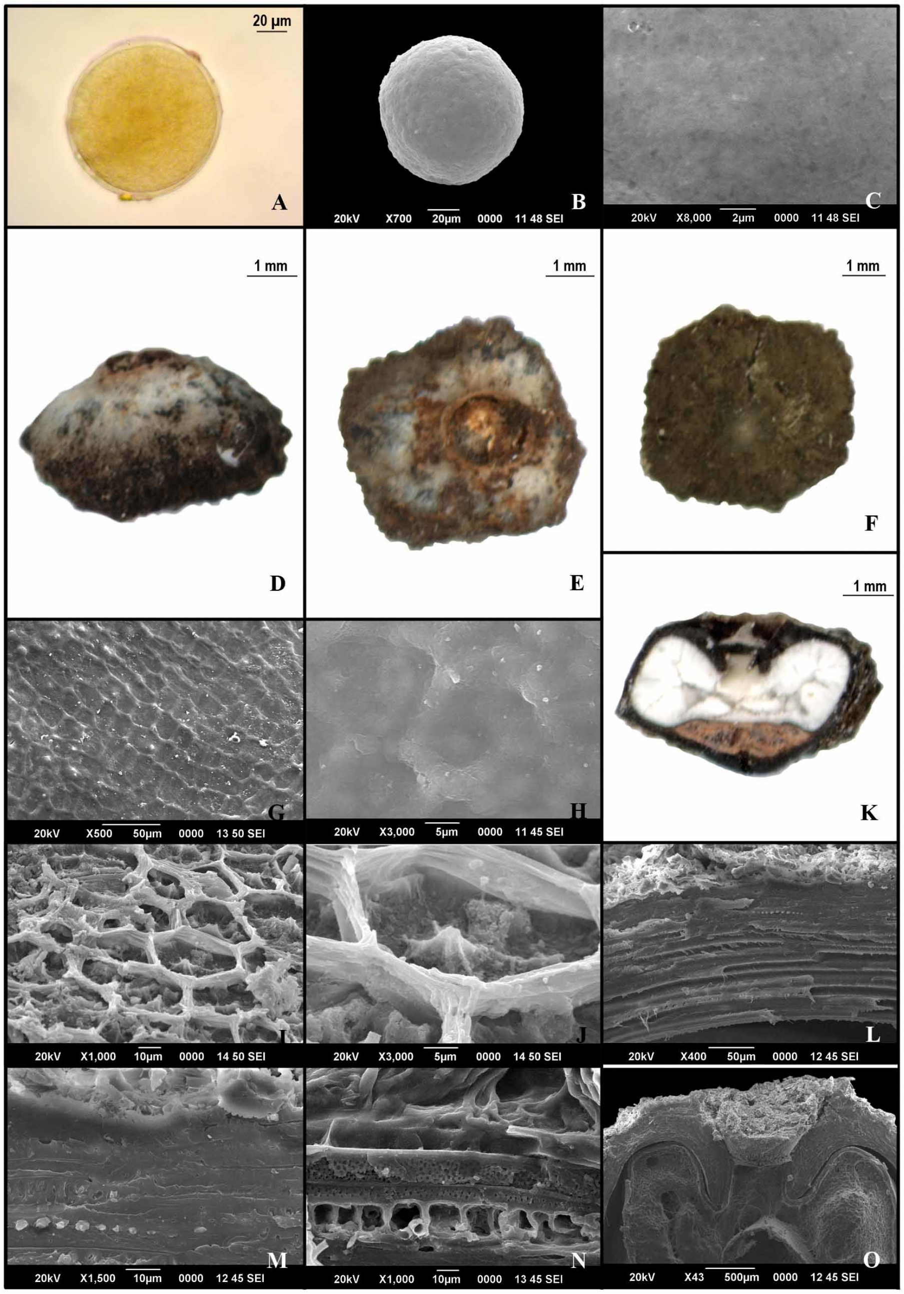


Fig. 59. ***Musa sabuana.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

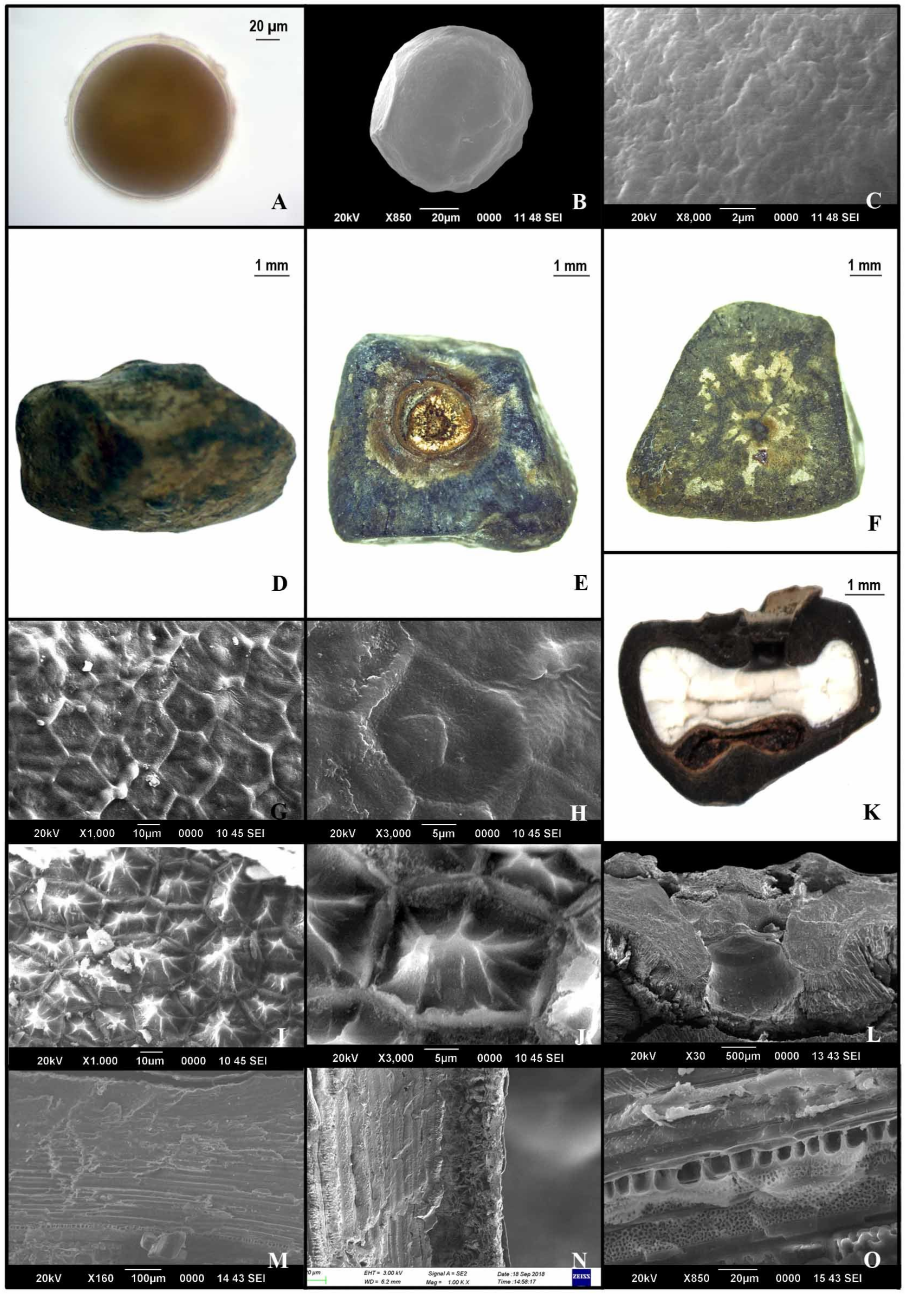


Fig. 61. ***Musa sikkimensis*** var. ***sikkimensis.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer

Fig. 62. ***Musa sikkimensis* var. *simmondsii.*** **A.** Habit; **B.** Fruit bunch. ***Musa velutina var. variegata.*** **A & B.** inflorescence.

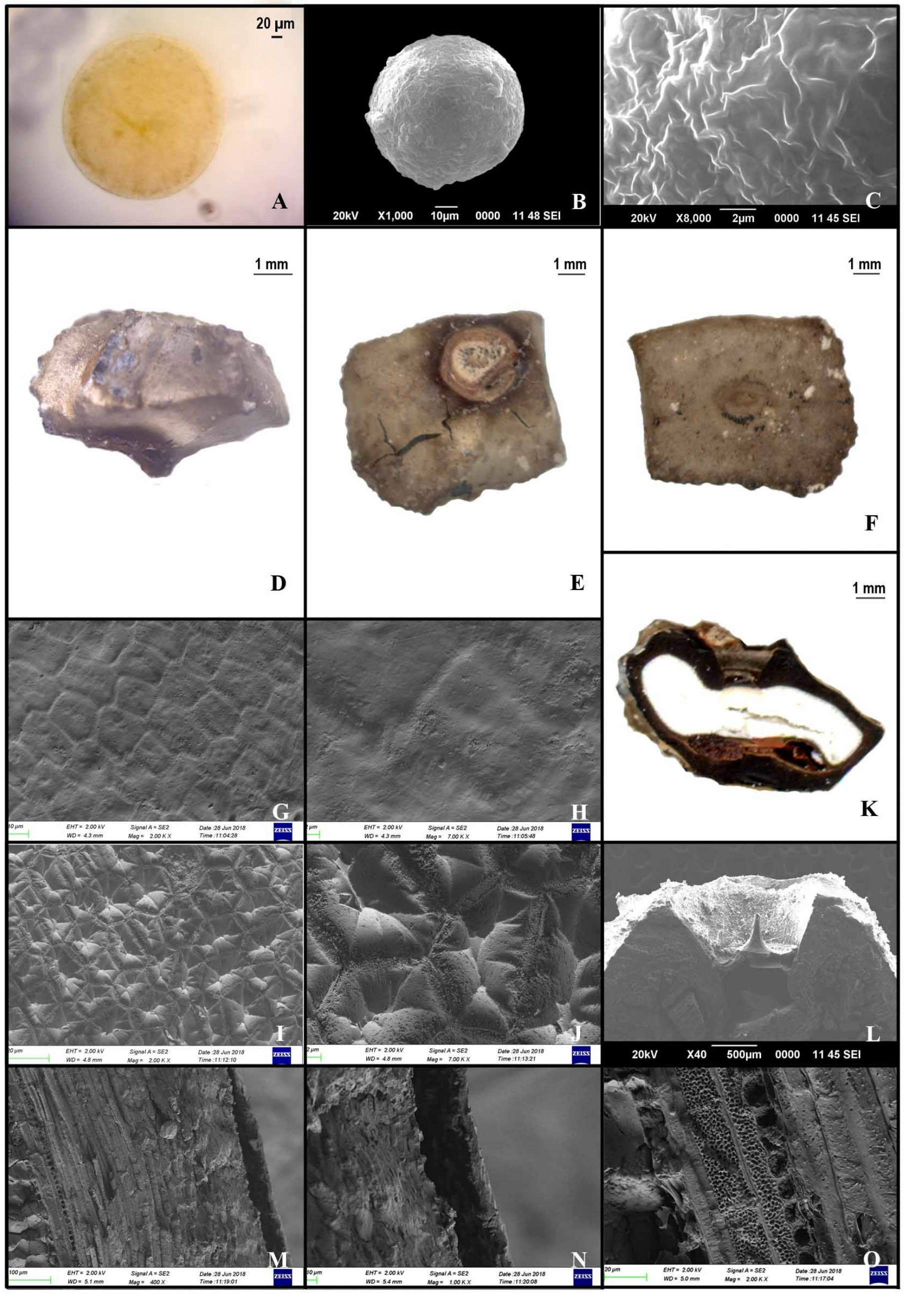


Fig. 63. ***Musa sikkimensis* var. *simmondsii.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micro-morphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone

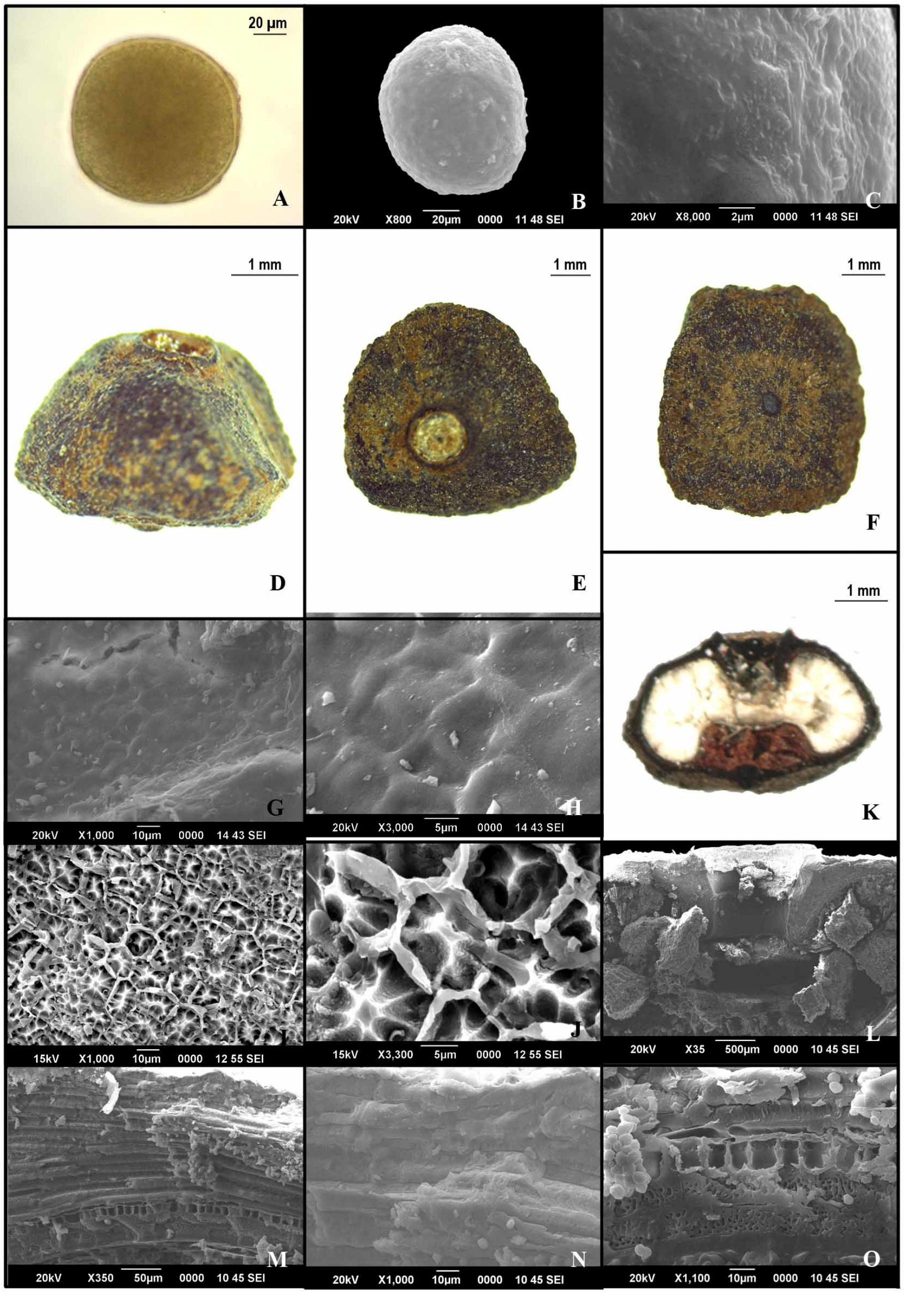


Fig. 65. ***Musa thomsonii.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

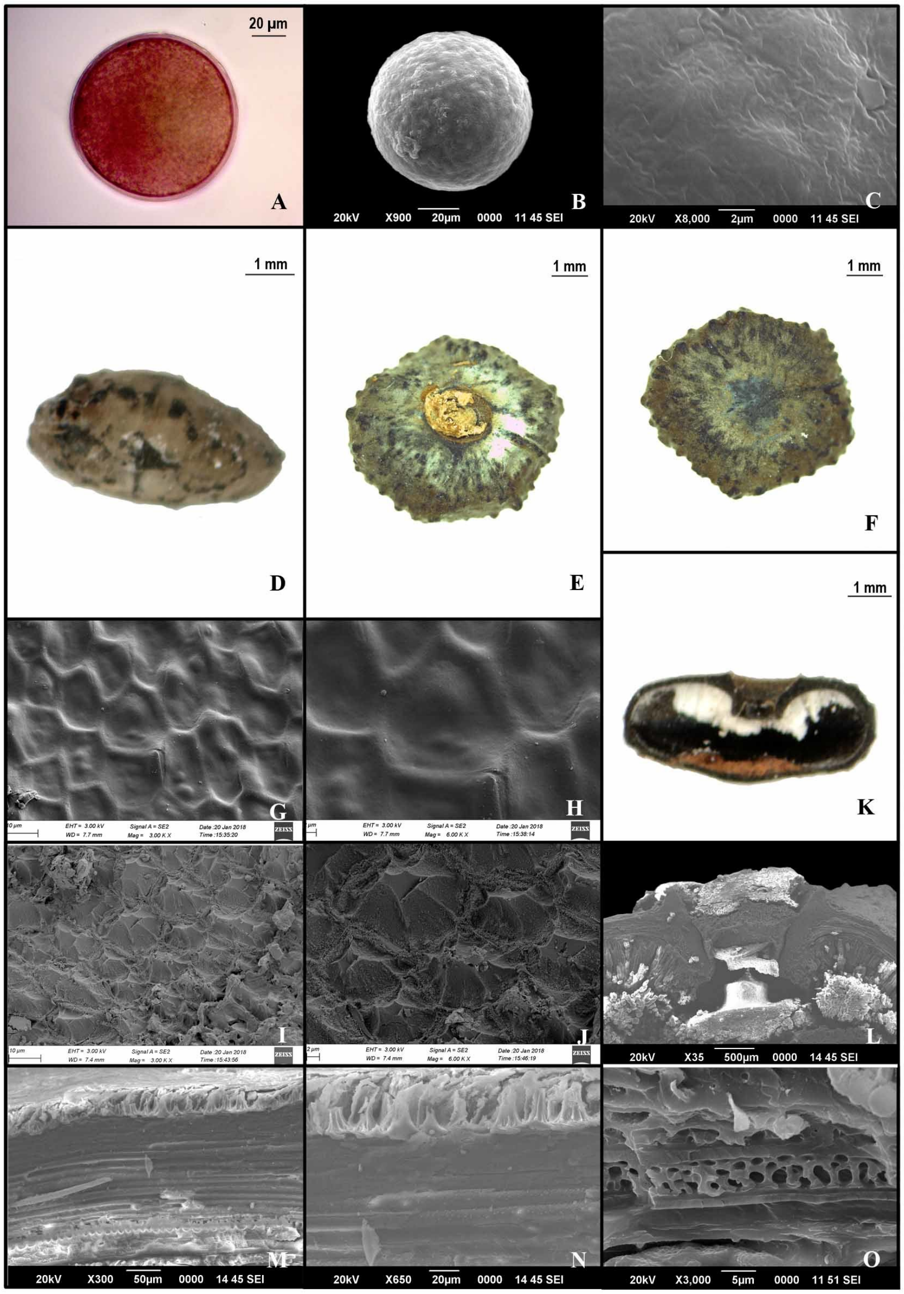


Fig. 67. ***Musa velutina* var. *velutina*. A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

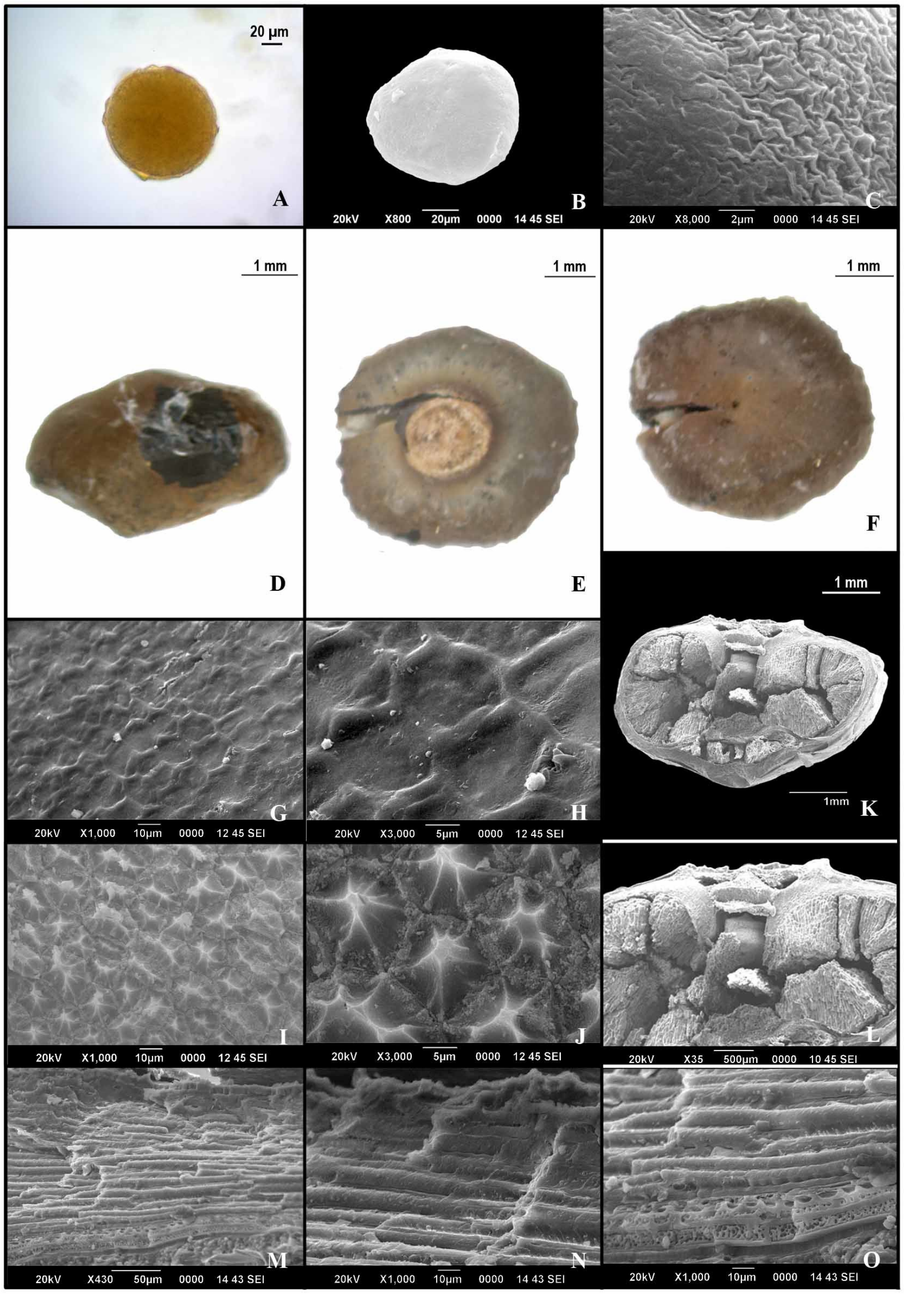


Fig. 68. ***Musa velutina var. variegata.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

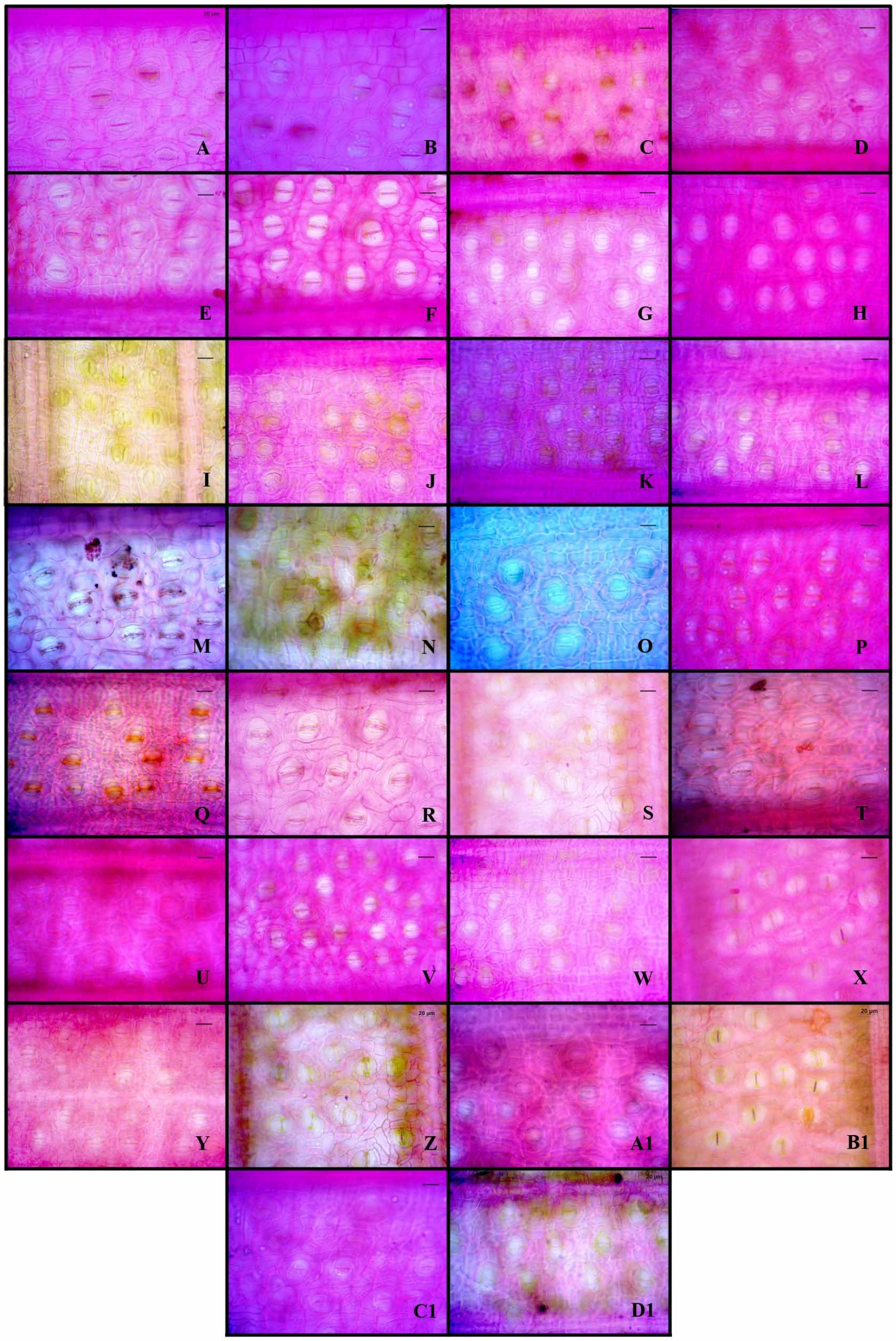


Fig. 70. **Comparative abaxial epidermal cells. A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis var. sikkimensis*; **C1.** *M. thomsonii;* **D1**. *M. velutina* var. *velutina*. (Scale = 20 μm).

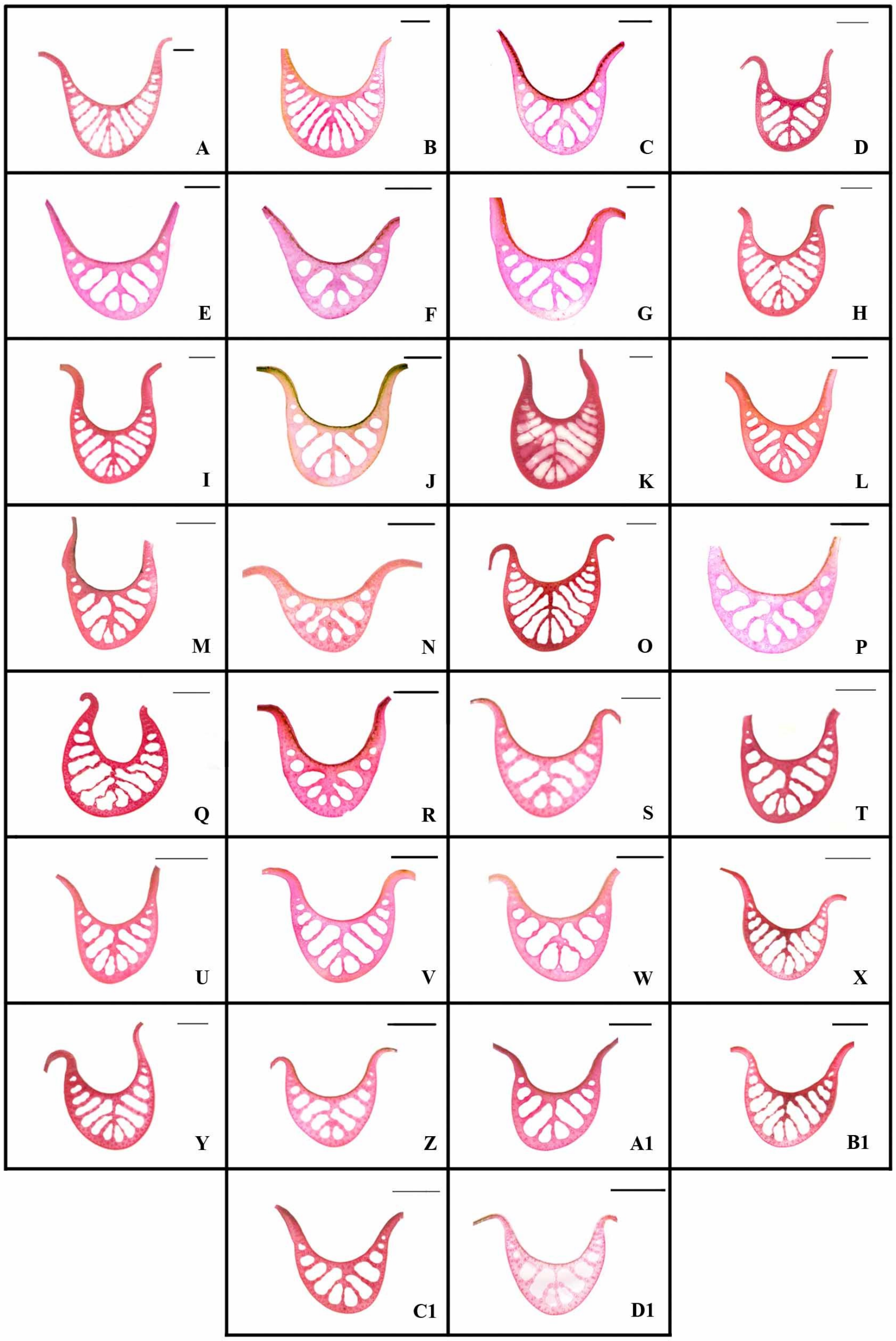


Fig. 76. **Comparative cross section of midrib. A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis* var. *sikkimensis*; **C1.** *M. thomsonii;* **D1**. *M. velutina* var. *velutina*. (Scale bar = 5 mm).

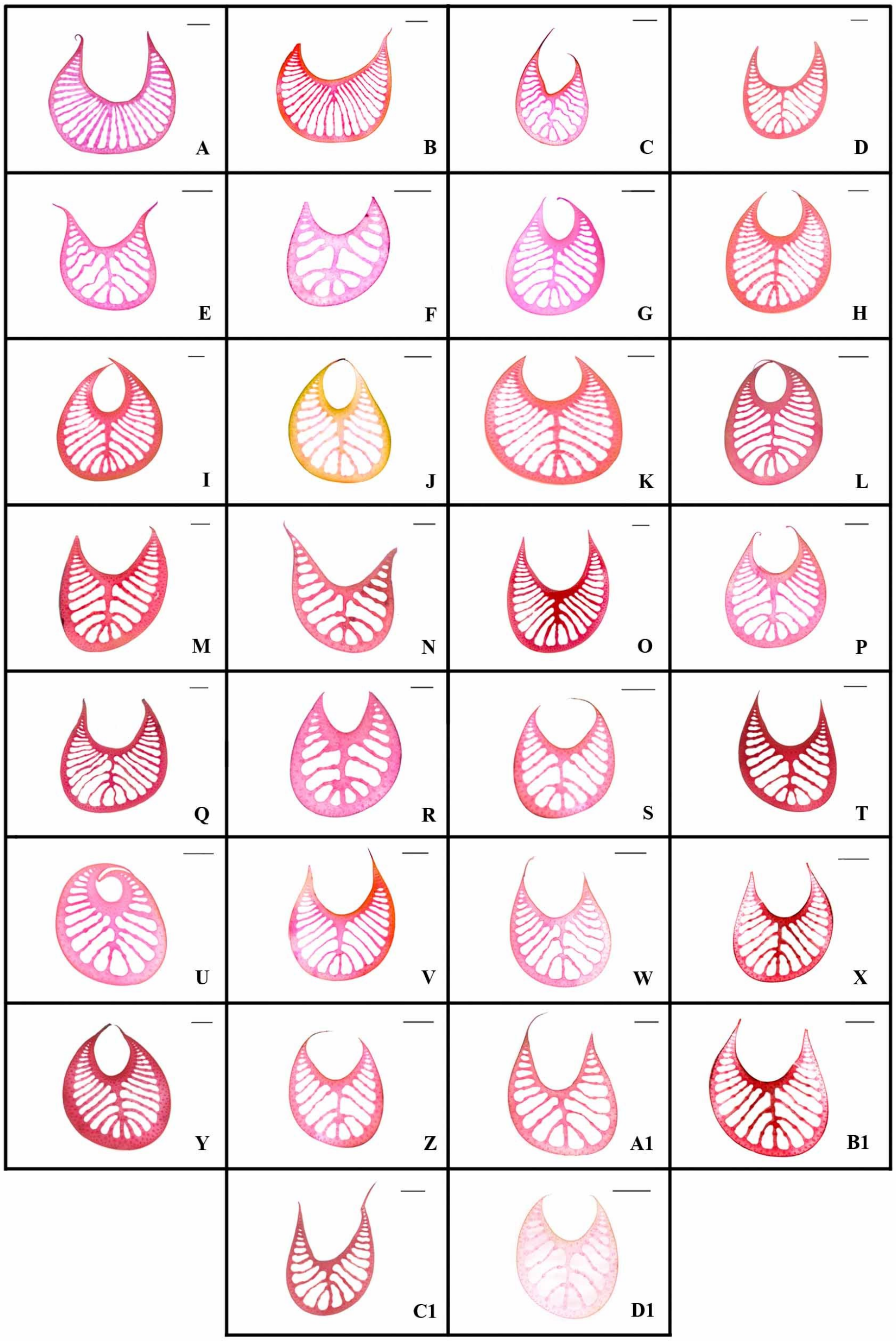


Fig. 75. **Comparative cross section of petiole. A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis* var. *sikkimensis*; **C1.** *M. thomsonii;* **D1**. *M. velutina* var. *velutina*. (Scale bar = 5 mm).

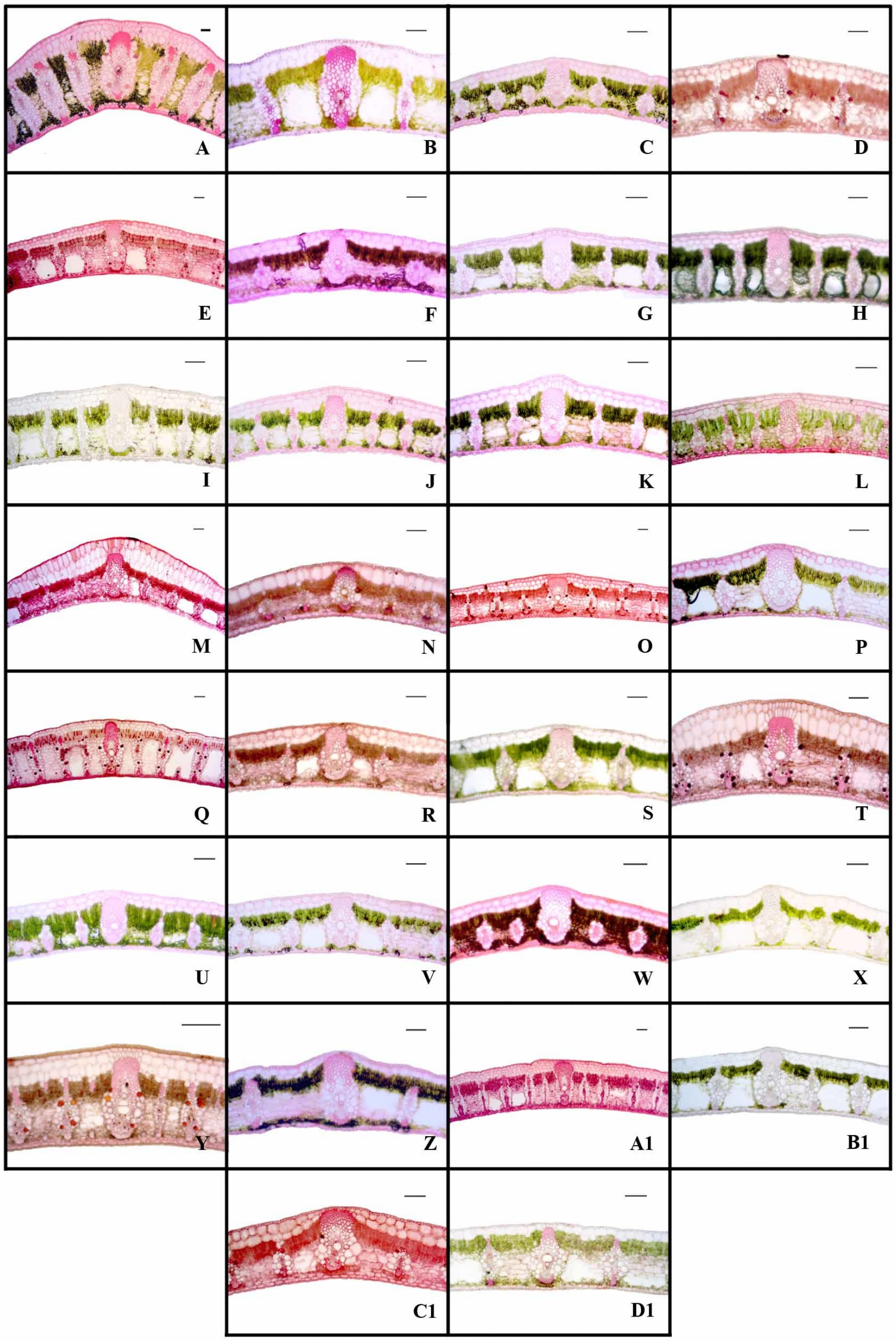


Fig. 71. **Comparative anatomy of c.s. of lamina. A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii***; E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazahi*; **K.** *M. balnisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis* var. *sikkimensis*; **C1.** *M. thomsonii;* **D1**. *M. velutina* var. *velutina*. (Scale bar = 20 µm).

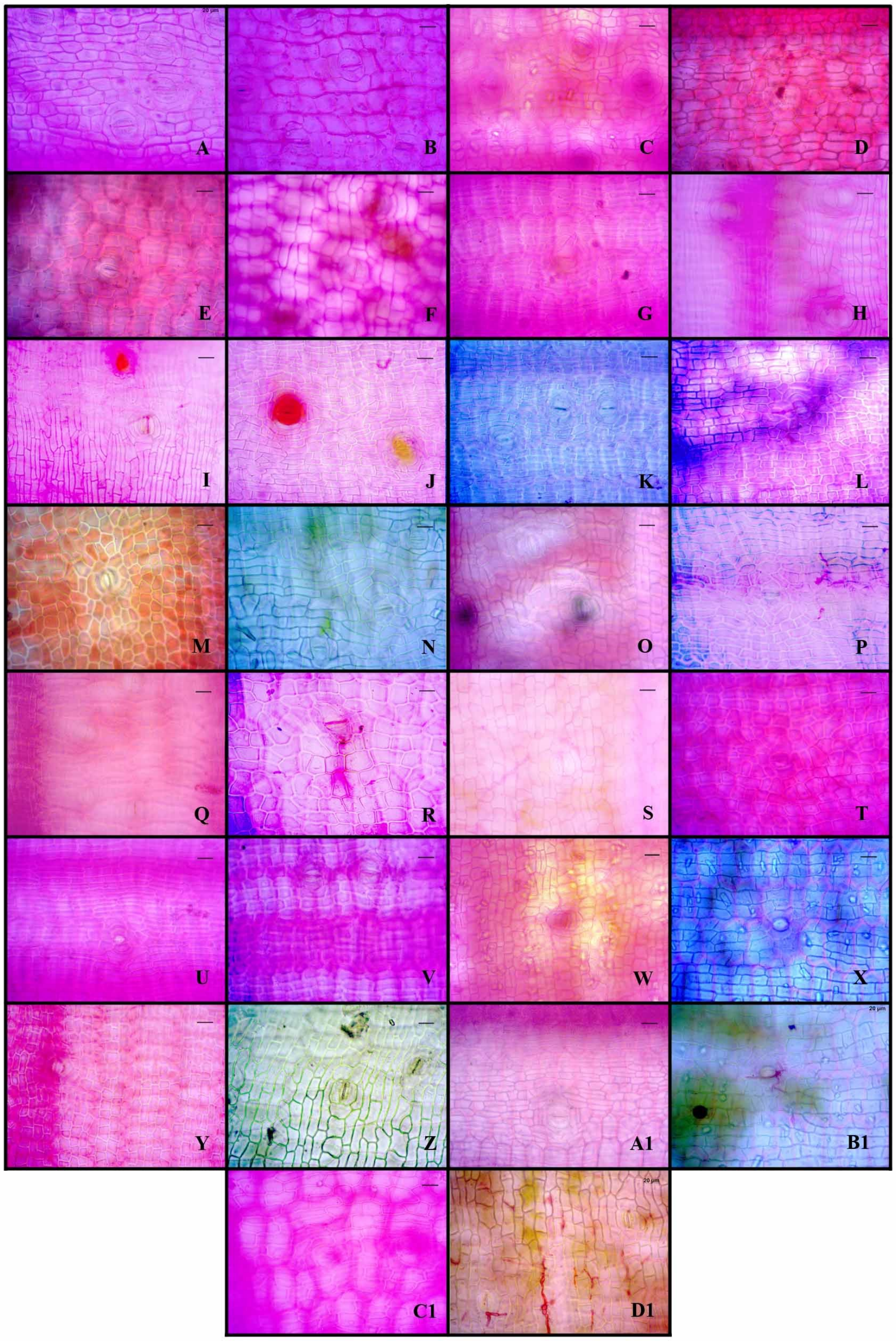


Fig. 69. **Comparative adaxial epidermal cells .** **A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis* var. *sikkimensis*; **C1.** *M. thomsonii;* **D1**. *M. velutina* var. *velutina*. (Scale = 20 μm).

Fig. 72. **Comparative anatomy of adaxial hypodermal cells above the larger vascular bundle.** **A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazahi*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. m*arkkui; U. M. nagensium; V. M. ochracea; W. M. ornata; X. M. pradhanii; Y. M. puspanjaliae; Z. M. rubra; A1. M. sabuana; B1. M. sikkimensis var. simmondsii; C1. M. thomsonii; D1. M. velutina var. velutina. (Scale bar = 20 μm).

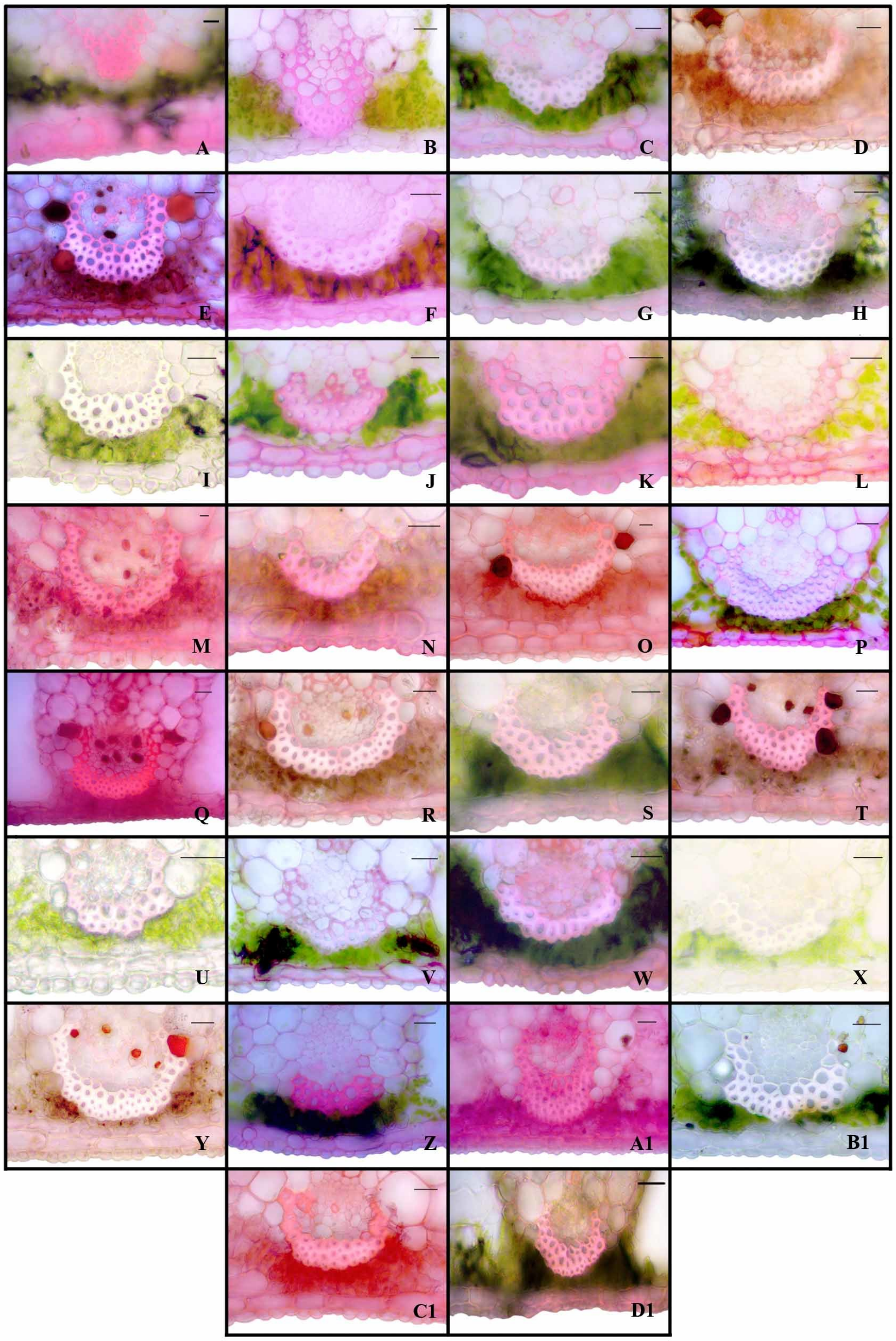


Fig. 73. **Comparative anatomy of abaxial hypodermis below the larger vascular bundle. A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazahi*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis* var. *sikkimensis*; **C1.** *M. thomsonii;* **D1**. *M. velutina* var. *velutina*. (Scale bar = 20 µm).

Fig. 74. **Differnt types of larger vascular bundle. A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii***; E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis* var. *sikkimensis*; **C1.** *M. thomsonii;* **D1**. *M. velutina* var. *velutina*.

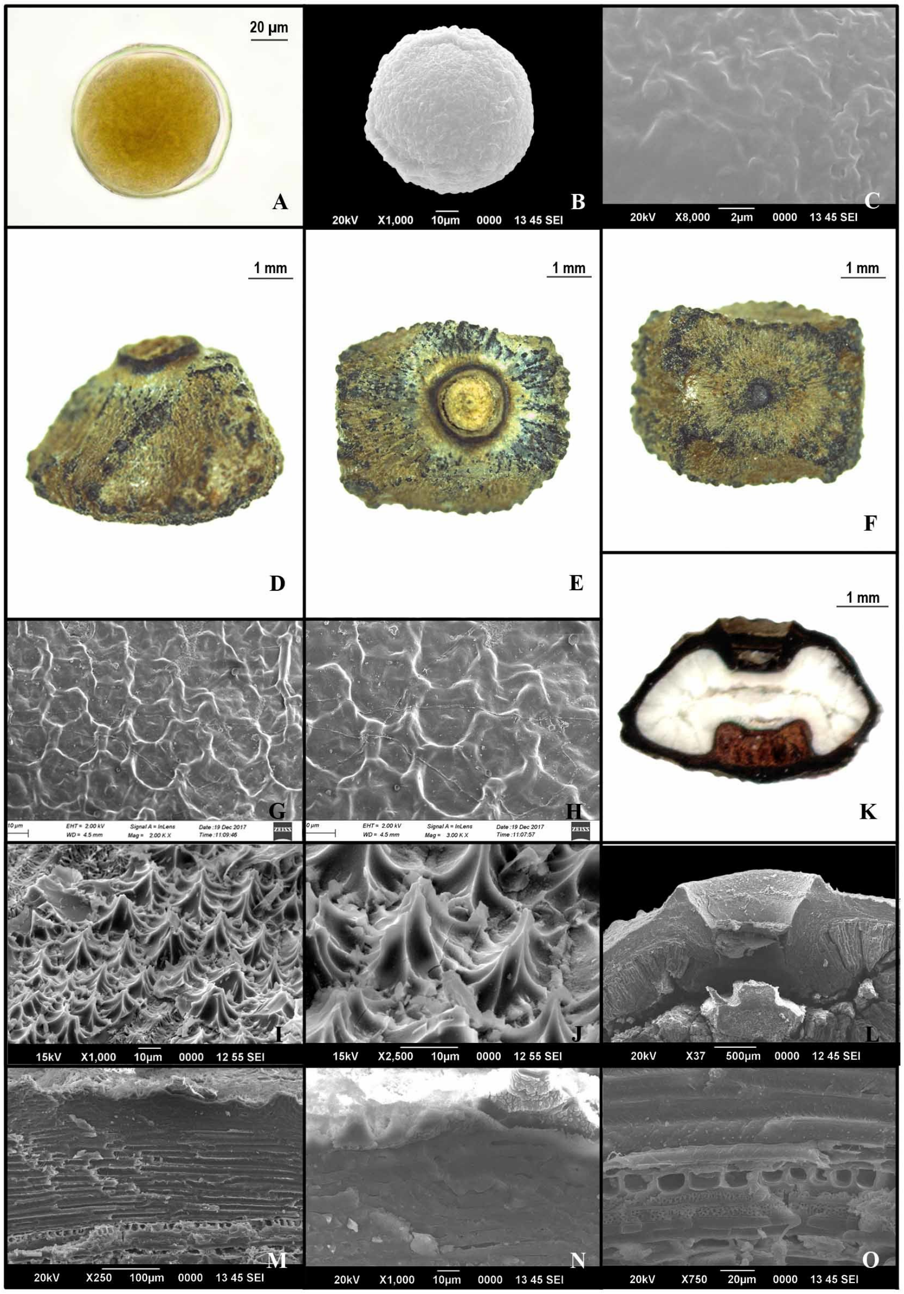


Fig. 11. ***Musa acuminata.*** **A-C.** Pollen morphology; **A.** entire (light microscopic); **B.** entire (SEM); **C.** portion enlarged; **D-F.** Seed morphology. **D.** lateral view; **E.** ventral view; **F.** dorsal view; **G-J.** Seed micromorphology; **G & H.** outer surface; **I & J.** inner surface; **K-O.** Seed anatomy. **K.** L.S. of seed; **L.** micropylar region; **M.** seed coat entire; **N.** outer layers of seed coat; **O.** inner layers of seed coat showing endotesta, tegmen and aleurone layer.

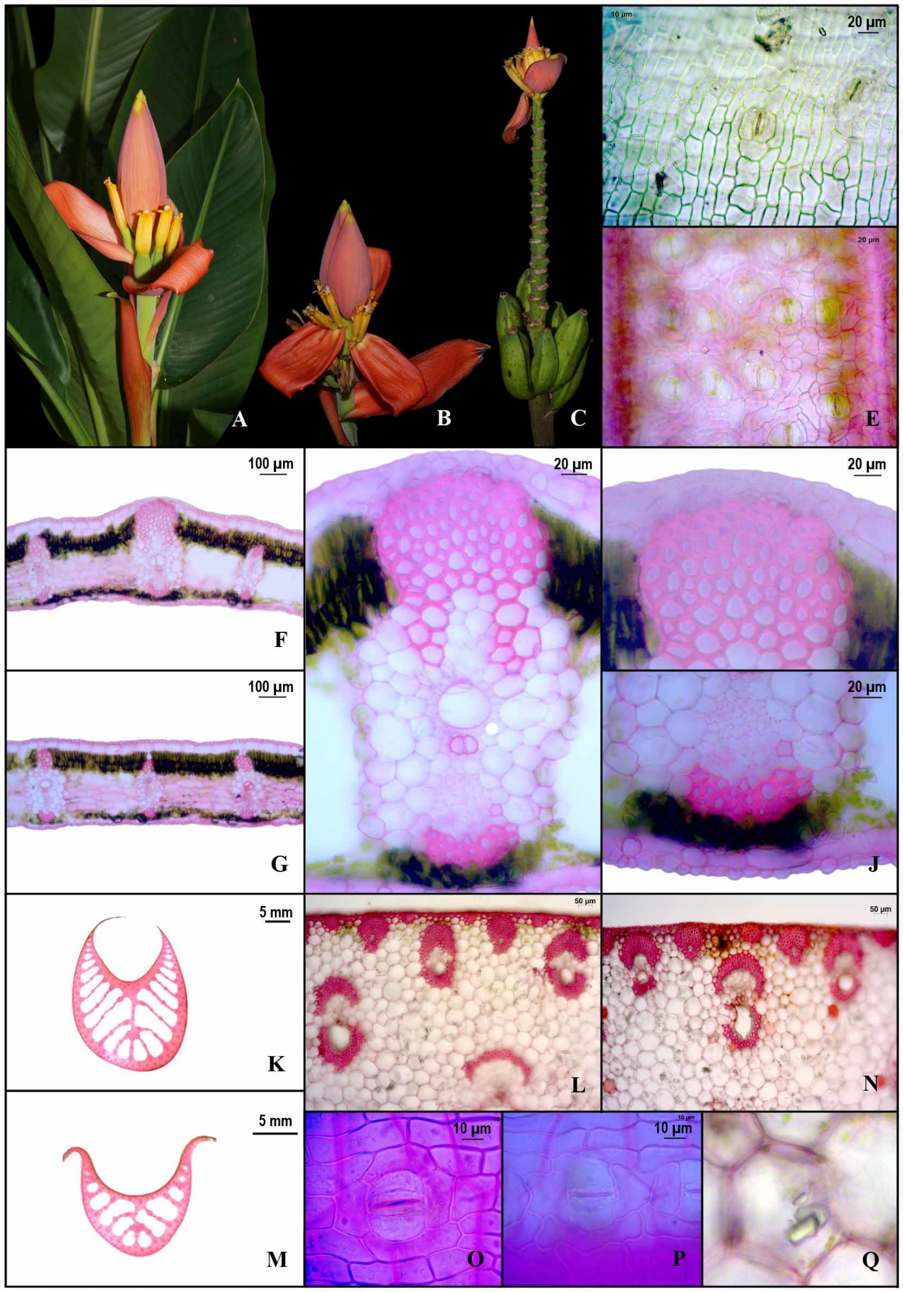


Fig. 56. ***Musa rubra.*** **A.** habit; **B.** inflorescence; & **C.** infructescence**; D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**: F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

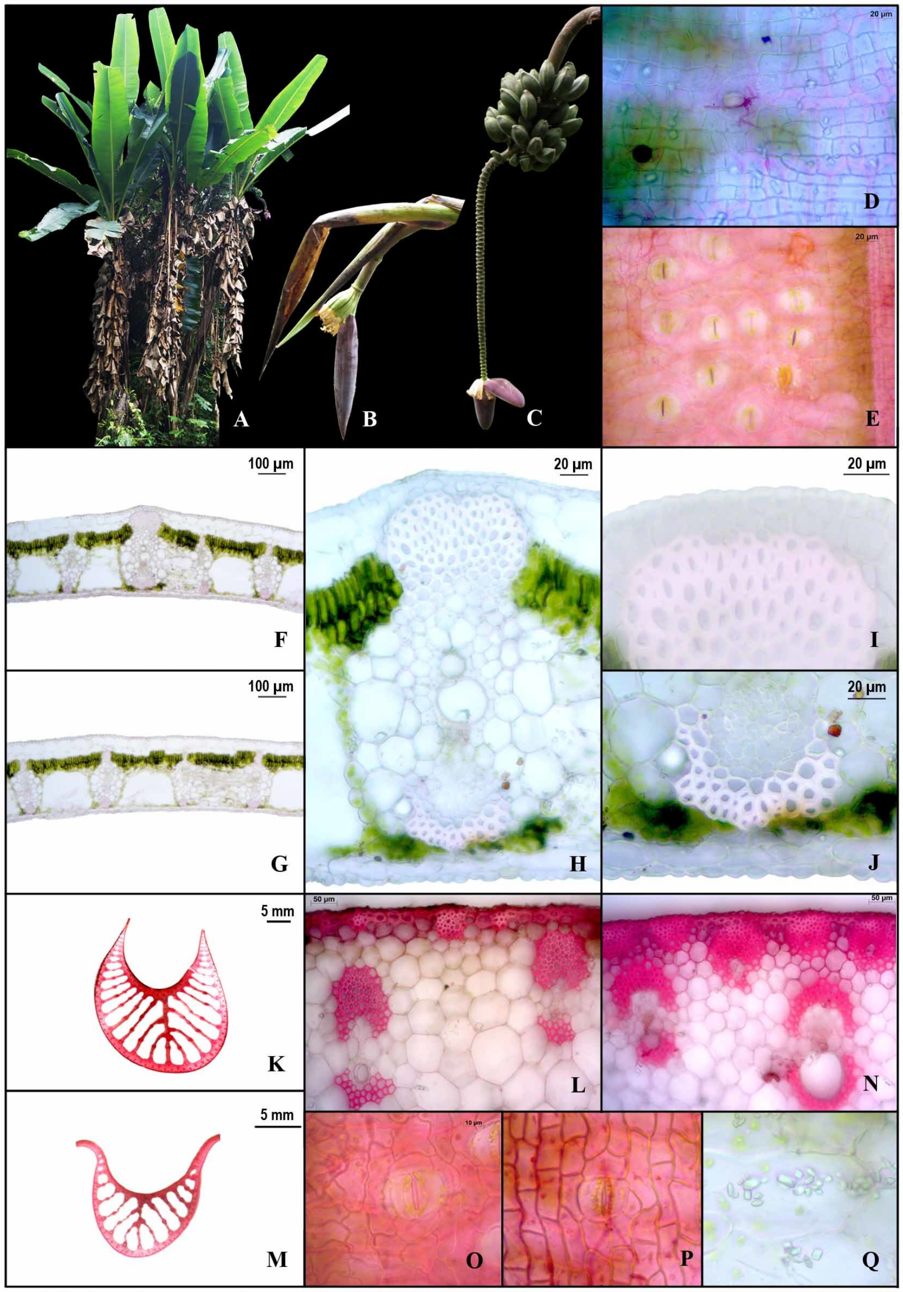


Fig. 60. ***Musa sikkimensis.*** **A.** habit; **B.** inflorescence; **C.** infructescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**: F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stomata; **Q.** crystals in petiole.

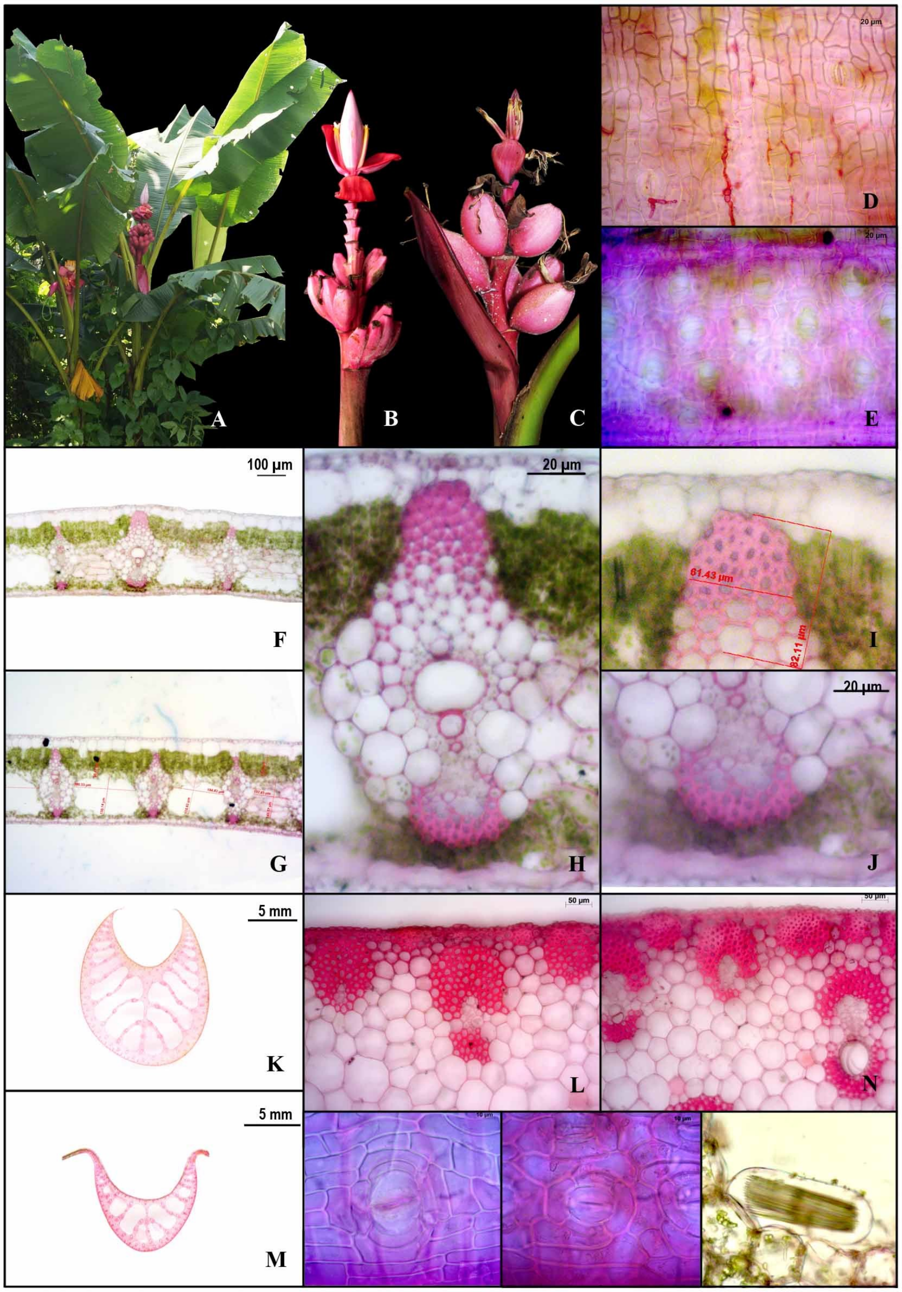


Fig. 66. ***Musa velutina.*** **A.** habit; **B & C.** infructescence; **D.** adaxial epidermis; **E.** abaxial epidermis; **F-J.** cross section of lamina**:** **F.** lamina showing larger and smaller vascular bundles; **G.** lamina showing smaller vascular bundles; **H.** larger vascular bundle enlarged; **I.** adaxial hypodermis above larger bundle; **J.** abaxial hypodermis below the larger bundle; **K.** c.s. of petiole; **L.** abaxial portion of petiole enlarged; **M.** c.s. of midrib; **N.** abaxial portion of midrib enlarged; **O.** adaxial stoma; **P.** abaxial stoma; **Q.** crystals in petiole.

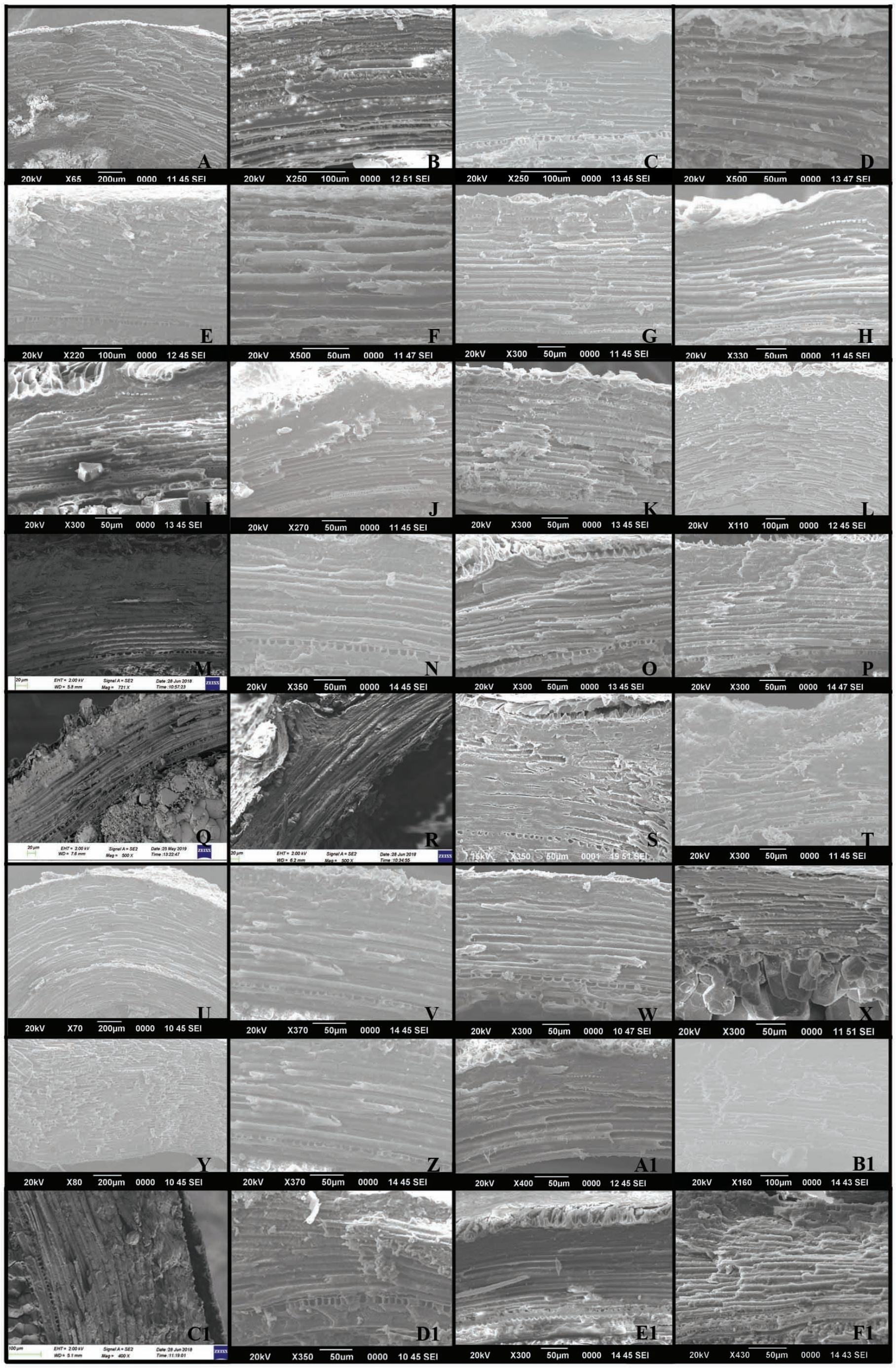


Fig. 84. **Comparative seed coat anatomy. A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M.** *M. chunii*; **N.** *M. cylindrica*; **O.** *M. flaviflora*; **P.** *M. itinerans*; **Q.** *M. kattuvazhana*; **R.** *M. mannii*; **S.** *M. markkuana*; **T.** *M. markkui*; **U.** *M. nagensium*; **V.** *M. ochracea*; **W.** *M. ornata*; **X.** *M. pradhanii*; **Y.** *M. puspanjaliae*; **Z.** *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis* var. *sikkimenis*; **C1**. *M. sikkimensis* var. *simmondsii*; **D1.** *M. thomsonii;* **E1**. *M. velutina* var. *velutina*; **F1.** *M. velutina* var. *variegata*.

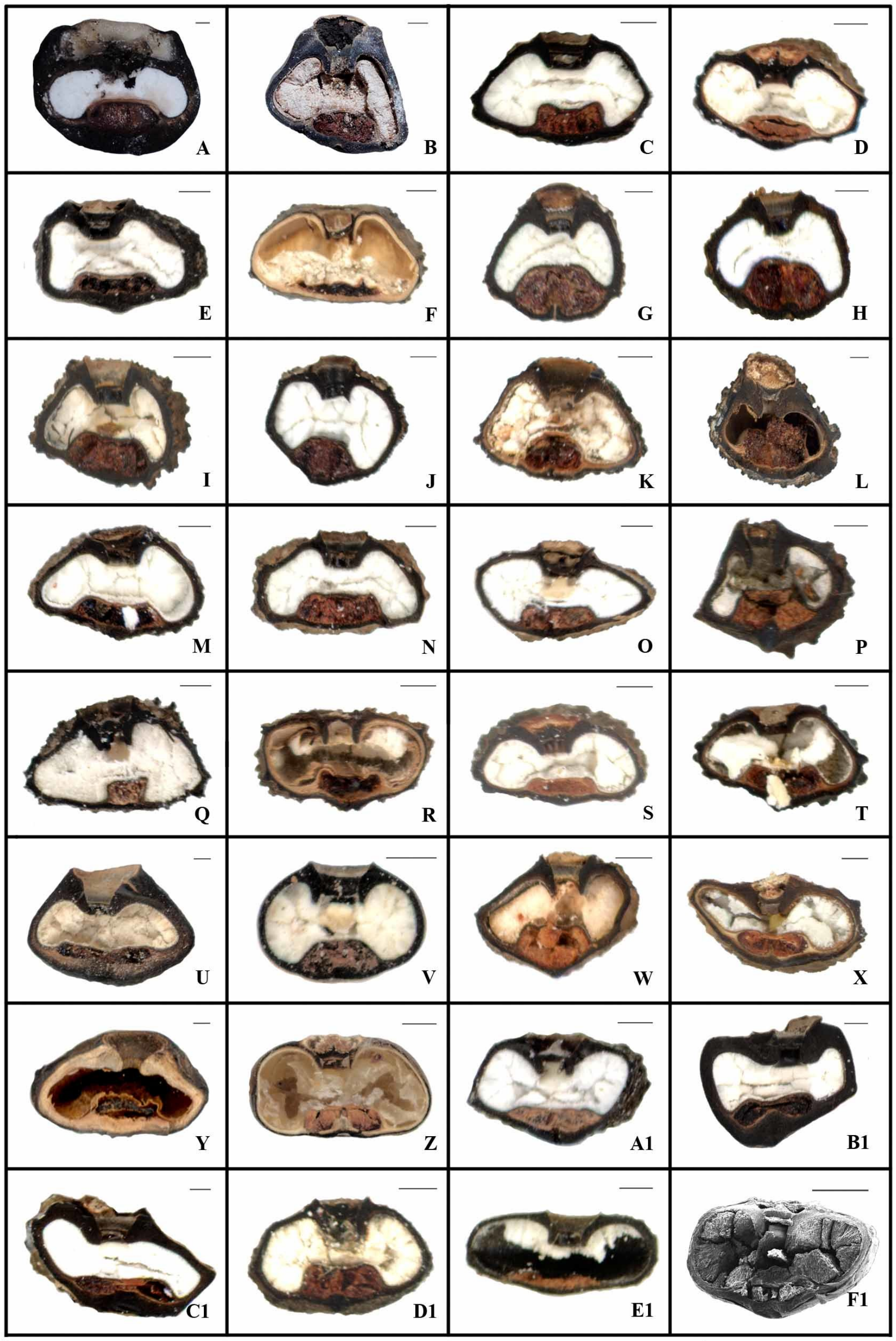


Fig. 83. **Comparative longitudinal section of seed.** **A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M.** *M. chunii*; **N.** *M. cylindrica*; **O.** *M. flaviflora*; **P.** *M. itinerans*; **Q.** *M. kattuvazhana*; **R.** *M. mannii*; **S.** *M. markkuana*; **T.** *M. markkui*; **U.** *M. nagensium*; **V.** *M. ochracea*; **W.** *M. ornata*; **X.** *M. pradhanii*; **Y.** *M. puspanjaliae*; **Z.** *M. rubra*; **A1.** *M. sabuana*; **B1.** *M. sikkimensis* var. *sikkimensis*; **C1.** *M. sikkimensis* var. *simmondsii*; **D1.** *M. thomsonii;* **E1.** *M. velutina* var. *velutina*; **F1.** *M. velutina* var. *variegata*. (Scale bar 1 = mm)

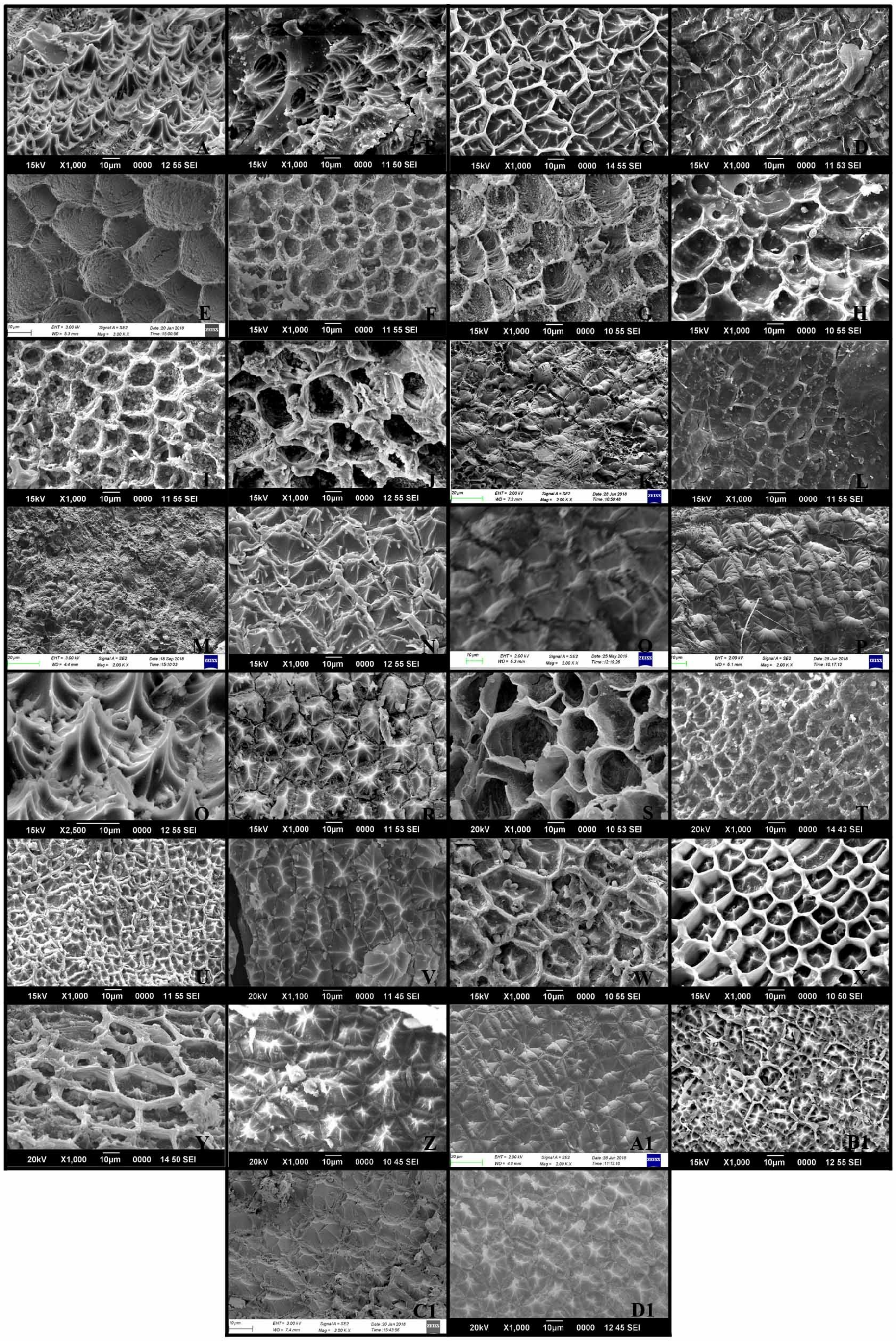


Fig. 82. **Comparative seed inner surface sculpturing. A.** *M. acuminata*; **B.** *M. argentii*; **C.** *M. arunachalensis*; **D.** *M. aurantiaca***; E.** *Musa balbisiana* var. *balbisiana*; **F.** *M. balbisiana* var. *andamanica*; **G.** *M. balbisiana* var. *bheem-kola*; **H.** *M. balbisiana* var. *elavazhai*; **I.** *M. balbisiana* var. *sepa-athiya*; **J.** *M. cheesmanii*; **K.** *M. chunii*; **L.** *M. cylindrica*; **M**. *M. flaviflora*; **N**. *M. itinerans*; **O**. *M. kattuvazhana*; **P**. *M. mannii*; **Q**. *M. markkuana*; **R**. *M. markkui*; **S**. *M. nagensium*; **T**. *M. ochracea*; **U**. *M. ornata*; **V**. *M. pradhanii*; **W**. *M. puspanjaliae*; **X**. *M. rubra*; **Y**. *M. sabuana*; **Z**. *M. sikkimensis* var. *sikkimensis*; **A1**. *M. sikkimensis* var. *simmondsii*; **B1**. *M. thomnsonii* ; **C1**. *M. velutina* var. *velutina*; **D1.** *M. velutina* var. *variegata*.

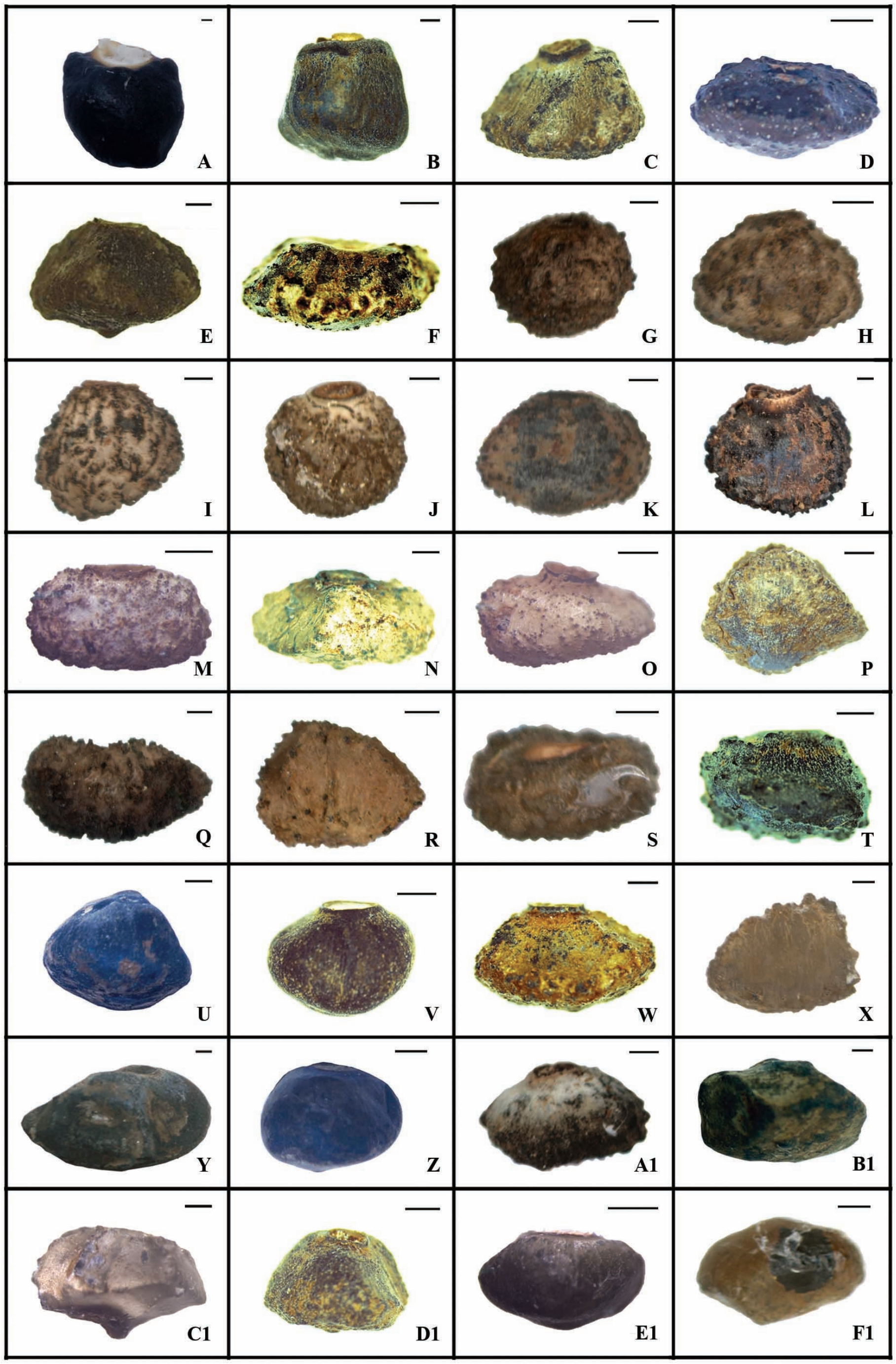


Fig. 80. **Comparative seed morphology.** **A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M.** *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis*; **C1**. *M. sikkimensis* var. *simmondsii*; **D1**. *M. thomsonii;* **E1**. *M. velutina* var. *velutina*; **F1**. *M. velutina* var. *variegata*. (Scale bar = 1 mm).

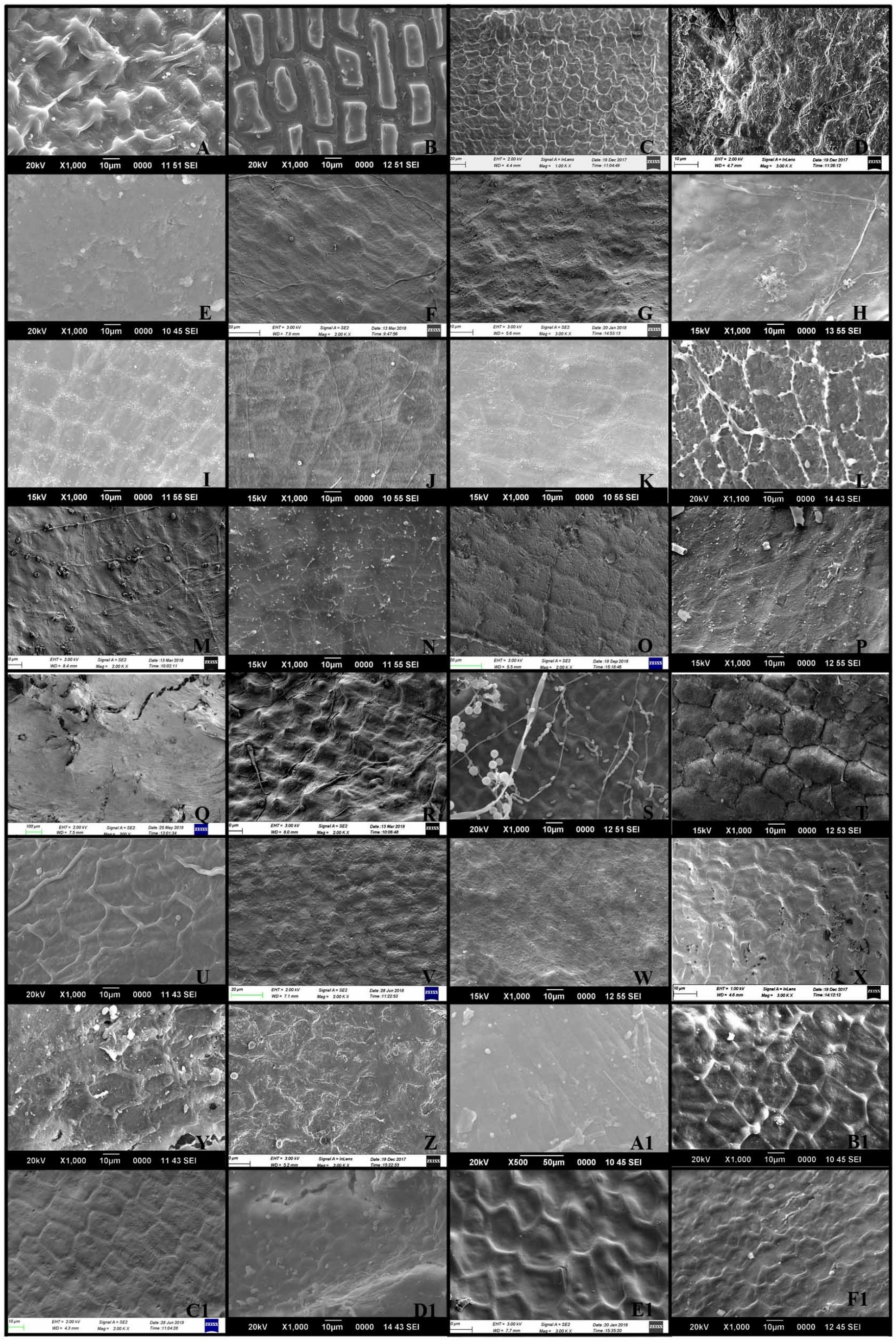


Fig. 81. **Comparative outer surface sculpturing of seed. A.** *E. glaucum*; **B.** *E. superbum*; **C.** *M. acuminata*; **D.** *M. argentii*; **E.** *M. arunachalensis*; **F.** *M. aurantiaca*; **G.** *Musa balbisiana* var. *balbisiana*; **H.** *M. balbisiana* var. *andamanica*; **I.** *M. balbisiana* var. *bheem-kola*; **J.** *M. balbisiana* var. *elavazhai*; **K.** *M. balbisiana* var. *sepa-athiya*; **L.** *M. cheesmanii*; **M**. *M. chunii*; **N**. *M. cylindrica*; **O**. *M. flaviflora*; **P**. *M. itinerans*; **Q**. *M. kattuvazhana*; **R**. *M. mannii*; **S**. *M. markkuana*; **T**. *M. markkui*; **U**. *M. nagensium*; **V**. *M. ochracea*; **W**. *M. ornata*; **X**. *M. pradhanii*; **Y**. *M. puspanjaliae*; **Z**. *M. rubra*; **A1**. *M. sabuana*; **B1**. *M. sikkimensis* var. *sikkimensis*; **C1**. *M. sikkimensis* var. *simmondsii*; **D1.** *M. thomsonii;* **E1**. *M. velutina* var. *velutina*; **F1.** *M. velutina* var. *variegata.*

Map 1. Map of India (Area of study).

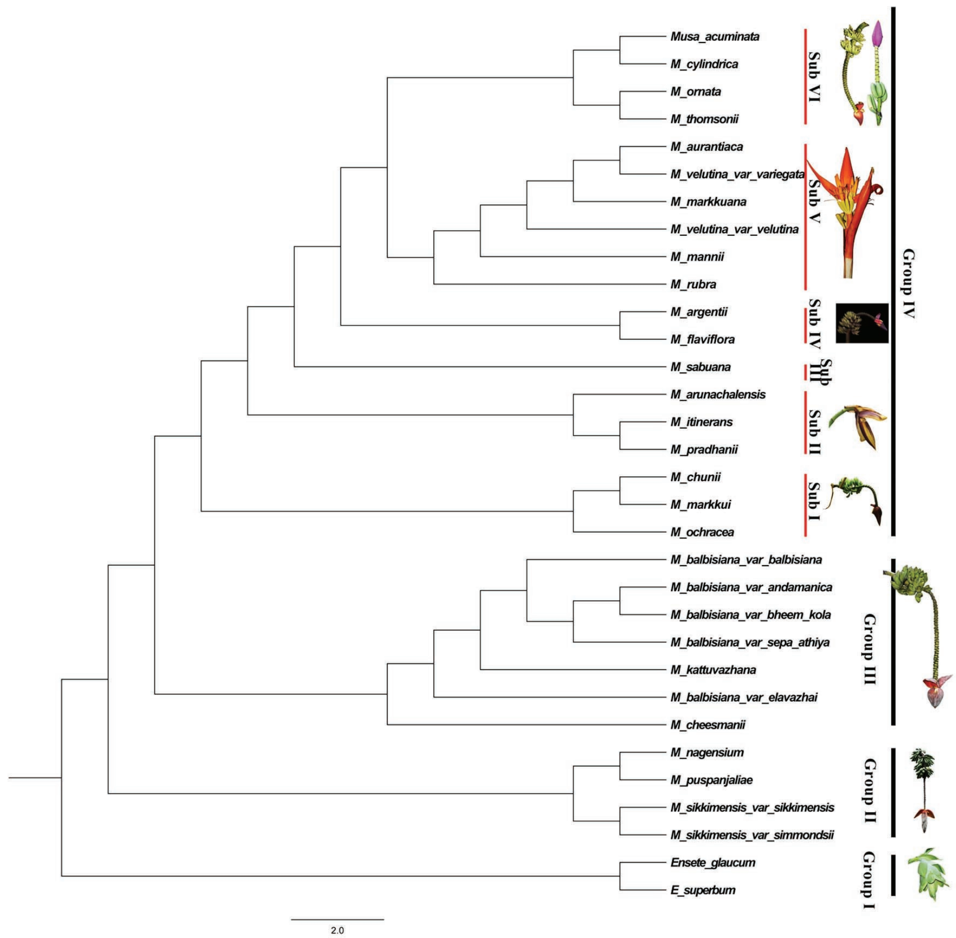


Fig. 86. **Phenogram of Indian Musaceae**.

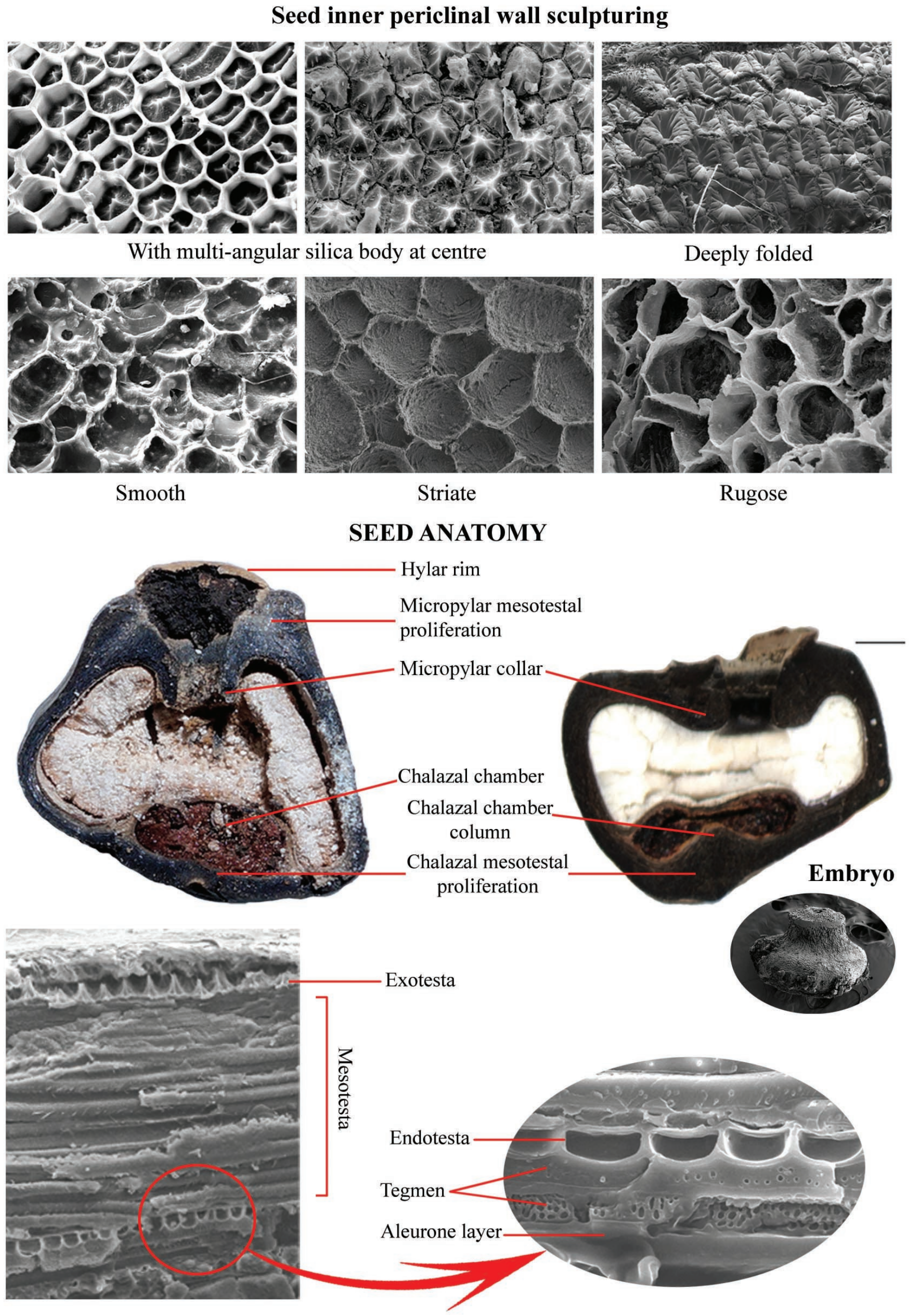


Figure 5. Seed inner surface sculpturing and Seed anatomy