DEVELOPMENTAL FRUIT ANATOMY OF SOME CORYPHOID PALMS*

G. N. REDDY AND A. R. KULKARNI

Ramnarain Ruia College, Matunga, Bombay-400 019

ABSTRACT

The developmental anatomy of six species of coryphoid palms, *Thrinax parviflora* Sw., *Coccothrinax argentea* Sargent., *Livistona chinensis* R. Br., *Licuala grandis* H. Wendl., *Pritchardia pacifica* Seem. & H. Wendl. and *Sabal* sp., is studied with special reference to the mature fruit anatomy. The development of subhypodermal sclerenchyma, endocarp, raphide sacs, idioblastic sclereids, seed coat and endosperm has been traced.

INTRODUCTION

The literature on fruit and seed anatomy on palms is meagre, the outstanding contributors being GUERIN (1949) and MURRAY (1973). LLOYD (1910) and LONG (1943) described the developmental anatomy of fruits of *Phoenix dactylifera*. JULIANO (1926) traced the development of endocarp in coconut. Recent investigation of MURRAY (1973) deals with endocarp development in 12 species of palms. In the comparative survey of fruit anatomy of palms, GUERIN (1949) has referred to the fruit structure in several palms studied by him. BIRADAR AND MAHABALE (1969), MAHABALE AND KULKARNI (1975) and ROBERTSON (1977) have described fruit and seed structure in *Phoenix*, *Livistona* and *Jubaeopsis caffra*, respectively. More recently, KULKARNI AND PANDEY (1978) have discussed the trends of organisation of endocarp in different groups of palms.

The present paper describes developmental anatomy of fruits in six species of coryphoid palms along with the structure of mature fruits and seeds. The species studied are—*Trithrinax* alliance *Thrinax* Unit—*Thrinax parviflora* Sw.; *Coccothrinax argentea* Sargent ; *Livistona* alliance *Livistona* Unit—*Livistona chinensis* R. Br.; *Licuala grandis* H. Wendl. and *Pritchardia pacifica* Seem. & H. Wendl.; *Sabal* alliance—*Sabal* sp.

OBSERVATIONS

Thrinax parviflora Sw.

Pl.1, Fig. 6

MATURE FRUIT ANATOMY

The *epicarp* of rectangular tangentially oriented epidermal cells with a layer of cuticle on the outer wall. Hypodermis not clearly distinguishable from the inner mesocarp.

Mesocarp of loosely arranged circular parenchyma cells with oval to circular raphide sacs, some filled with mucilage, some with thickened walls having pit canals.

Endocarp 3-4 layered sclerotic cylinder, consisting of alternate patches of brachy- and macrosclereids. Degenerating vascular strands seen adhered below the endocarp.

---

*Paper presented at the IV Indian Geophytological Conference, Lucknow, November 14-16, 1981.

Geophytology, **12**(2): 233-244, 1982.

Seed coat 4-5 layered, cells rectangular, tannin filled, walls pitted. Chalazal ingrowth prominently seen as tannin filled vasculated central cylinder in the endosperm. Endosperm of radial files of thick-walled cells converging in the centre of the seed.

DEVELOPMENTAL ANATOMY

One seeded drupe develops from one of the three carpels of a tricarpellate apocarpus gynoecium.

The initials of the endocarp are seen as a cylinder of radially elongated cytoplasmic cells (Pl. 1, Fig. 1, *Ei*) extending from the top of the ovary towards base dividing the ovary tissues into an outer 10-12 layered zone of densely cytoplasmic polygonal cells and an inner extensive zone extending upto locular epidermis of large vacuolated cells containing large thick-walled raphide sacs (Pl. 1, Fig. 2, *Rs*) and a row of procambial strands situated just below the differentiating cylinder of endocarp. Sclerosis in endocarp initials is already set-in at the mature ovary level and appears to progress from the top of the ovary towards base. As the fruits develop, the sclereids of the endocarp cylinder get separated into tangential strands in which the surrounding parenchyma intrudes and its cells undergo sclerosis (Pl. 1, Figs. 3-5). This process in turn continues until late free nuclear stage of endosperm, when fruits attain the maximum size. During maturation of the fruits, endocarp sclereids undergo full sclerification and the alternating strands of round and radially elongated sclereids become more conspicuous (Pl. 1, Fig. 7).

The zone of ovary wall situated between the epidermis and endocarp retains cytoplasmic nature upto late free nuclear stage of the endosperm (Pl. 1, Fig. 4). Some cells in it enlarge to develop into raphide sacs (Pl. 1, Fig. 5). As the endosperm matures, many of these raphide sacs develop thick walls and their content gelatinises. The ground parenchyma cells enlarge and become vacuolated. The epidermal cells get tangentially stretched and develop cuticle over their outer tangential walls.

The tissues of ovary wall situated between the endocarp and locular epidermis progressively get degenerated and compressed (Pl. 1, Figs. 3—6) as the fruits develop.

During early free nuclear endosperm stage (Pl. 1, Fig. 3), the raphide sacs in this zone tend to enlarge; very often their walls dissolve to form lysigenous cavities. During further development of the fruits, some of the ground tissue cells also tend to degenerate to form irregular lysigenous cavities (Pl. 1, Fig. 5). By the time the endosperm becomes cellular, this entire tissue gets compressed between the seed coat and the endocarp.

A single ring of vascular bundles is seen just below the differentiating cylinder of endocarp initials at mature ovary stage (Pl. 1, Fig. 1, *Vs*). At this stage, the vascular tissue is merely represented by provascular strands. Differentiatoin of vascular elements starts just after fertilisation. At late free nuclear endosperm stage, sclerosed xylem elements can be seen in each vascular bundle (Pl. 1, Fig. 5, Vs). The fibrous sheath is poorly differentiated and stegmata are not seen. In the mature fruits, remnants of vascular strands remain attached to the inner surface of the endocarp.

Seed coat—The ovule is bitegmic, the outer 5-6 layered and the inner 3-4 layered integuments are free up to chalaza. As the seeds develop, the integumentary tissue thins out ; its cells get tannin filled (Pl. 1, Figs. 3, 4). The chalazal ingrowth starts its activity during early free nuclear endosperm stage. At the late free nuclear endosperm stage, a column of chalazal tissue supplied by a ring of vascular bundles is seen projecting into the seed cavity (Pl. 1, Fig. 4, *Ci*).

Coccothrinax argentea Sargent
Pl. 1, Figs. 7-11

The Developmental anatomy of the pericarp typically resembles that of *Thrinax* (Pl. 1, Figs. 7, 8). However, the thick-walled raphide sacs found in the pericarp of *Thrinax* are wanting in *Coccothrinax*. The seed in *Coccothrinax* is variously lobed which divide the endosperm into a number of compartments at the base.

The pattern of seed development in *Coccothrinax* is radically different from that of *Thrinax*. During early stages of seed development when the endosperm is in free nuclear stage, the integuments develop number of infoldings which protrude in the seed cavity (Pl. 1, Figs. 9-11). These infoldings are very deep at the base and practically meet the central chalazal intrusion dividing the seed cavity into a number of compartments (Pl. 1, Fig. 12). The infoldings are very shallow at the top of the seed.

Livistona chinensis R. Br.
Pl. 2, Figs. 13-18

MATURE FRUIT ANATOMY

Epicarp consists of rectangular epidermal cells with highly cutinised outer walls followed by 3-5 layered tannin filled hypodermis of tangentially oriented rectangular to hexagonal cells.

Distributed in the ground parenchyma of the *mesocarp* are found number of vascular bundles, raphide sacs, idioblastic sclereids and tannin cells (Pl. 2, Fig. 20). Vascular bundles have well differentiated patch of polygonal xylem elements capped by phloem. The fibrous sheath associated with stegmata is poorly developed and unsclerosed. Raphide sacs are large, round and thin-walled. Tannin sacs are numerous, variable in size and mostly distributed singly. Idioblastic sclereids are also numerous, ovoid and scattered singly.

Endocarp consists of a cylinder of 4-6 layered irregularly lobed brachysclereids, invested on the outer side by a dense sheath of silica crystals (Pl. 2, Fig. 18), which are also found in the lumen of several peripheral sclereids.

The cell layers situated between locular epidermis and the endocarp are highly radially compressed and consist of compactly arranged rectangular cells. The locular epidermal cells have a thin layer of cuticle on their inner face.

The seed coat is single zoned, 8-10 layered and tanniferous (Pl. 2, Fig. 18, *Sec*). The cells are hexagonal and tangentially flattened. The chalaza has a group of prominent vascular bundles ; chalazal tanniferous ingrowth is prominent, vasculated and extends deep into the endosperm. The endosperm has radial files of thick-walled cells. These are rectangular with conspicuous plasmodesma strands.

DEVELOPMENTAL ANATOMY

One seeded drupe develops from one of the three locules of a tricarpellate, syncarpous, trilocular gynoecium with one ovule in each locule (Pl. 2, Fig. 13).

All the three locules appear separate at the ovary level. The epidermis of the ovary has radially elongated cytoplasmic cells with a thin layer of cuticle on the outer face. The cells continue to be radially extended and cytoplasmic until late free nuclear endosperm stage. As the endosperm starts becoming cellular, the epidermal cells undergo tangential stretching, their cytoplasm is reduced and the cuticle on the outer surface becomes successively thicker.

The hypodermis is filled with granular tanniferous material right from the ovary level (Pl. 2, Fig. 13). By the time the fruits reach the free nuclear endosperm stage, these granular deposits condense to form dense amorphous tannin mass in the cells (Pl. 2, Fig. 16). The vascular bundles at the ovary level are represented by provascular strands ; the xylem elements become recognisable at early free nuclear endosperm stage. At late free nuclear stage, they are seen as lignified elements. The stegmata associated with poorly developed fibrous sheath become apparent at free nuclear endosperm stage. The tannin cells and raphide sacs are seen right from the ovary level. As the fruits develop, they increase in number as well as in the size ; the content of tannin cells becomes more and more dense as the fruits mature.

Idioblastic sclereids first make their appearance in the ovary wall just after fertilization. At this stage, several cells of the mesocarp are seen enlarged and slightly sclerosed. The addition of new sclereids and the sclerosis of the existing ones continues during developmental stages of fruit. They reach peak level of development at the early cellular endosperm stage (Pl. 2, Fig. 17).

No trace of endocarp is seen at ovary level, though just after fertilization the ovary wall shows number of enlarged cells distributed in a zone 3-4 cells removed from locular epidermis (Pl. 2, Fig. 14). During further developmental stages, as these cells get sclerosed new cells situated in between also enlarge and get sclerosed. At early free nuclear endosperm stage almost continuous cylinder of 3-4 layered sclerotic endocarp is seen (Pl. 2, Figs. 15, 16). Further increase in volume of the fruit is accompanied by the separation of originally formed sclereids and the intrusion of adjacent parenchyma cells in these spaces which also subsequently get sclerosed. These later formed sclereids generally contain silica crystals in their lumen. As the fruits mature, the cells immediately lying over the endocarp produce an additional cylinder of silica granules.

The locular epidermis and the layers of cells situated between it and the endocarp undergo progressive radial compression as the fruit develops followed by slight sclerosis of their walls (Pl. 2, Figs. 14-18).

The ovules are bitegmic. The tannin starts accumulating in the cells of the outer integument just after fertilization (Pl. 2, Fig. 14). Upto the young free nuclear endosperm stage both outer and inner integuments are clearly seen but during later stages of development the inner integument is absorbed. The chalazal activity starts at the late free nuclear stage of endosperm and the chalazal ingrowth rapidly extends into the developing endosperm and reaches maximum stage of development before sclerosis of endosperm cells begins.

Licuala grandis H. Wendl.

Pl. 2, Figs. 19-24

Mature fruit anatomy

Mature fruit has an *epicarp* consisting of papillate epidermal cells with cutinized radial and outer tangential walls and 2-4 layered hypodermis of rectangular, tangentially oriented, compactly arranged thick-walled cells. The sub-hypodermal zone has a continuous 1-3 layered sclerotic cylinder consisting of highly sclerosed irregular brachysclereids. Distributed in the ground tissue of the mesocarp are two rows of vascular bundles and a few raphide sacs. The vascular bundles have poorly sclerosed fibrous sheath associated with a ring of stegmata (Pl. 2, Fig. 24, *Vs*). The raphide sacs are oval to circular. They get filled with mucilage as the fruits ripen. The ground tissue has loosely arranged oval to circular cells. The endocarp is two zoned ; inner sclerotic and outer crystalliferous. Sclerotic zone has a 2-3 layered cylinder of brachysclereids. The massive crystalliferous zone has small polygonal cells with silica crystals in the lumen.

Seed coat 4-5 layered ; cells rectangular, compactly arranged and tannin filled. Chalazal tanniferous ingrowth massive, many layered, extending deep in the endosperm. Endosperm of radial files of thick-walled cells converging in the centre of the seed.

Developmental anatomy

The fleshy one-seeded drupe develops from one of the three carpels of a tricarpellate syncarpous gynoecium with one ovule in each locule (Pl. 2, Fig. 19).

Epidermal cells from the ovary level to young endosperm stage are prominently nucleate without cuticle on the outer walls. At late free nuclear stage of endosperm, when fruits reach the maximum diameter, cells develop cuticle on the outer tangential walls. Apparently, division activities in epidermal cells lessen considerably after this stage leading to the development of cutinised papillate cells with thickened radial walls at mature endosperm stage.

Hypodermis becomes well defined from inner tissues of the ovary wall only at free nuclear endosperm stage, when the initials of sub-hypodermal sclerotic cylinder also become evident (Pl. 2, Fig. 20, *Si*). At this stage, the hypodermis is 3-5 layered with prominently nucleate cells. The thickening of cell walls becomes apparent at late free nuclear stage of the endosperm. Even at mature endosperm level, this tissue remains 4-5 layered indicating that the cells mainly undergo radial divisions during the development of the fruits.

The initials of sub-hypodermal sclerotic cylinder become noticeable as distantly placed ring of brachysclereids just after fertilization (Pl. 2, Fig. 20 *Si*) at early free nuclear endosperm stage. Differentiation of sclereids begins at the base of the ovary but rapidly proceeds towards the top during early post fertilization development. As the fruit wall increases in size, several sub-hypodermal cells of mesocarp situated inbetween successive sclereids are seen enlarged which also later get sclerosed thus giving rise to 2-3 layered continuous sclerotic cylinder. The cylinder is prominently organised at late free nuclear stage of the endosperm.

At ovary level, the vascular bundles are represented by provascular strands. The vascular tissues get differentiated at early free nuclear stage of the endosperm when each vascular bundle is also seen surrounded by a ring of stegmata containing circular silica bodies (Pl. 2, Figs. 21-23, *Vs*). The lignification in xylem elements is completed by late free nuclear endosperm stage. The fibrous tissue is meagrely developed even in mature fruits (Pl. 2, Fig. 24).

The raphide sacs distributed in the mesocarp are apparent at ovary level (Pl. 2, Fig. 19). They become distantly placed as the fruit develops. In ripened fruits many of them get filled with mucilage.

Endocarp makes its appearance at early free nuclear endosperm stage (Pl. 2, Fig. 20, *Ei*), when it is represented by a ring of distantly placed sclereids 2-3 layers above the locular epidermis overlain by a clylinder of meristematic zone consisting of small cubical cells. During further development, several cells situated in between successive sclereids also enlarge and get sclerosed. The locular epidermis and cell layers lying just above it undergo tangential flattening. While the former degenerates leaving a layer of cuticle, the cells of the latter become thick-walled. A few derivatives of the meristem intrude and enlarge irregularly in between earlier formed sclereids and undergo sclerosis. These later formed sclereids contain silica crystals in their lumen. At late free nuclear endosperm stage most of the cells of the meristematic zone secrete silica crystals to form a siliceous external cover over the sclerotic cylinder of the endocarp.

The ovule is bitegmic; the inner integument is 2-3 layered and tannin filled; the outer is massive and non-tanniferous (Pl. 2, Fig. 19). Vascular bundles are restricted to chalaza. The entire seed coat almost completely becomes tannin filled by the time the endosperm reaches early free nuclear stage. The chalazal ingrowth starts its activity during free nuclear phase of endosperm and reaches maximum level of development during early cellular phase.

Pritchardia pacifica Seem & H. Wendl.

Pl.3, Figs. 25-30

Mature fruit anatomy

The *epicarp* 7-10 layered is tannin filled. The epidermal cells are rectangular, cutinised with cuticular deposition on the outer wall. The hypodermal cells are rectangular to hexagonal, compactly arranged and tangentially oriented. The hypodermis is interrupted by a ring of macrosclereid patches, each patch containing 2-3 sclereids.

The *mesocarp* has two rows of vascular bundles one each on outer and inner sides. Vascular bundles have poorly developed fibrous sheaths. Large, round, thick-walled raphide sacs are abundant in the mesocarp. The ground parenchyma has loosely arranged mostly thin-walled cells of various shapes. Many of them are tangentially elongated.

The *endocarp* is two-zoned, the outer zone is massive with sclereids of irregular shape ith a central ring of silica crystals. The inner thin zone has 2-4 layered tangentially stretched thick-walled pitted cells.

The *seed coat* is massive; its cells are tannin filled. The endosperm has radial files of rectangular thick-walled cells converging in the centre of the seed. Chalazal ingrowth is prominent, deep and tannin filled.

Developmental anatomy

The one-seeded drupe develops from one of the three carpels of a tricarpellate gynoecium with carpels connated by styles only (Pl. 3, Fig. 25). The hypodermis is not sharply defined from the inner tissues of the ovary wall at the mature flower stage. The epidermal cells lining the stylar canal are more cytoplasmic and prominently nucleate than those on the outer side.

The hypodermis becomes sharply defined, 2-3 layered tissue of polygonal cells just after fertilization. At this stage, the epidermis also develops a layer of cuticle on its outer wall. By the time the fruits reach late free nuclear endosperm stage, the hypodermis becomes 5-6 layered; its cells undergo tangential stretching and get filled with tannin (Pl. 3, Fig. 27). The initials of sub-hypodermal cylinder of sclereids become apparent in just fertilized ovary as an almost continuous sub-hypodermal cylinder of radially elongated cells. The initiation appears to start from the base of the style and progressively extends towards the base of the ovary. The sclerosis soon sets in the cells of this cylinder. As the fruits grow in girth, the maturing sclereids of the cylinder get separated by intrusion of surrounding parenchyma giving rise to the discontinuous cylinder of sclereids seen at late free nuclear stage of the endosperm (Pl. 3, Fig. 27).

As the endosperm becomes cellular, these intervening parenchyma cells also become filled with tannin along with hypodermal cells (Pl. 3, Figs. 27-29).

Mesocarp at ovary level is of homogeneous thin-walled oval cells with numerous raphide sacs distributed in the middle part (Pl. 3, Fig. 25). As the fruits grow, the raphide sacs enlarge in size and their walls get sclerosed. The sclerosis of their wall begins at late free nuclear stage only (Pl. 3, Figs. 27-28). During further course of development of the fruits, the ground tissue cells get stretched in various ways specially in radiating fashion around thick-walled raphide sacs and vascular bundles. A few of the parenchyma cells also undergo sclerosis as the fruits ripen (Pl. 3, Figs. 29, 30).

At ovary level, the vascular bundles are seen merely as provascular strands. Xylem and phloem elements get differentiated as the fruits reach late free nuclear endosperm stage (Pl. 3, Fig. 28, *Vs*). The fibres surrounding vascular tissue remain unsclerosed throughout though the peripheral ones are associated with stegmata.

The endocarp is initiated as a cylinder of radially enlarged cells, 3-4 layers removed from the locular epidermis in the ovary just after fertilization (Pl. 3, Fig. 26). Initiation starts below the stylar region and rapidly progresses towards the base of the ovary. Soon, the cells start sclerosing though some may undergo one or two radial divisions before getting sclerosed. As the fruits develop, these sclerosing cells get separated and the cells of the adjoining parenchyma intrude in the separated space. These intruded cells undergo irregular enlargement and finally get sclerosed to add to the endocarp. At late free nuclear endosperm stage, the endocarp is 4-5 layered and almost continuous (Pl. 3, Figs. 27, 28). The earlier formed sclereids are free from silica crystals while the later formed ones contain the silica granules in them. Sclerosis of the cells continues further and finally involves 2-3 layers of cells immediately lying below the sclerotic cylinder which also get thick-walled and pitted.

The locular epidermis has rectangular, prominently nucleate cells at the ovary level with a thick layer of cuticle on its inner face. Radial divisions in its cells could be traced up to late free nuclear stage of endosperm. During further course of fruit development, however, they become tangentially flattened and finally get crushed by the pressure of growing seed of the locule (Pl. 3, Figs. 26, 27).

The ovules are bitegmic; the two integuments are free only in the micropylar region. The transection of ovular body shows two-zoned integument, the outer being massive and non-tanniferous and the inner delicate and tanniferous (Pl. 3, Fig. 25). A group of vascular bundles is seen ending at chalaza.

As the seed development proceeds, the inner zone gets progressively narrowed out, while the cells of the outer zone show deposition of tanniferous material. The chalazal activity starts during early free nuclear endosperm stage. By the time the seeds reach late free nuclear endosperm stage, a prominent tannin filled chalazal ingrowth is seen invaginated in the endosperm. The wall formation in endosperm is centripetal. As the endosperm matures, the cells become highly thick-walled with numerous plasmodesma connections between adjacent cells.

Sabal sp.

Pl. 3, Figs. 31-35

Mature fruit anatomy

Epicarp has rectangular epidermal cells having cutinised outer tangential and radial walls and with a heavy layer of cuticle on the outer face. The hypodermis is 4-6 layered tissue with outer two layers having tangentially oriented rectangular cells and inner 2-4 layers with polygonal compactly arranged cells.

The sub-hypodermal sclerotic cylinder is continuous, mostly single layered and consists of brachy-to macro-sclereids.

Numerous vascular bundles and raphide sacs are seen distributed in the massive mesocarp consisting of thin-walled cells. The tissue immediately lying over locular epidermis shows large irregular lysigenous spaces.

Vascular bundles have well differentiated vascular tissue but not fibrous sheath. The raphide sacs are large, circular and thin-walled. The *endocarp* is limited to locular epidermal cells, which are rectangular, tangentially oriented with slightly thickened walls having a thick layer of cuticle over the outer as well as inner tangential walls.

Developmental anatomy

A single-seeded berry develops from one of the three carpels of a tricarpellate syncarpous gynoecium (Pl. 3, Fig. 31).

The initials of sub-hypodermal sclerotic cylinder could be recognised in the ovary just after fertilization as a cylinder of radially elongated cells (Pl. 3, Fig. 34, *Si*) differentiating from base and progressing towards the apex of the ovary. The sclerosis of the initials follows rapidly in the acropetal fashion. As the fruits develop, the hypodermal parenchyma intrudes inbetween the developing sclereids and its cells also get sclerosed. In this way the sub-hypodermal sclerotic cylinder maintains its completeness throughout the growth stages of the fruit. Till the late free nuclear stage of the endosperm, the epidermal and hypodermal cells retain their cytoplasmic nature and divide actively. As the endosperm starts becoming cellular, a layer of cuticle develops over the epidermal surface and its cells start getting thick-walled.

The entire ground tissue of mesocarp is homogeneous at the ovary level with densely cytoplasmic polygonal cells. At this stage a ring of vascular bundles and raphide sacs is seen in the ovary wall. Lignification of the xylem elements of the vascular bundles commences immediately after fertilization. As the fruits develop further, the number of vascular bundles in the fruit wall increases by branching of original bundles (Pl. 3, Figs. 32, 33, *Vs*). Fibrous sheath with associated stegmata are not seen around the vascular bundles. The raphide sacs also increase in number as well as size.

Before commencement of cell formation in the endosperm, inner mesocarp develops lot of intercellular spaces which further increase in size lysigenously as the fruit matures.

At ovary level, the locular epidermis has rectangular, prominently nucleate cells. Even at this stage the inner face of locular epidermis has a layer of cuticle. Locular epidermal cells divide radially and increase in number until the stage of initiation of wall formation in the developing endosperm. During further growth, the locular epidermal cells undergo tangential stretching and their walls get slightly thickened with the development of an additional layer of cuticle on their outer face also (Pl. 3, Fig. 32, *e*).

GENERAL COMPARSIONS AND DISCUSSIONS

Six species of coryphoid palms representing six genera could be readily distinguished on the stable anatomical characters of their mature pericarp as indicated below :

A. Endocarp single layered, represented by slightly modified locular epidermis. . *Sabal.*
AA. Endocarp of multilayered sclereids.
B. Endocarp crystalliferous, mesocarp with vascular bundles.
C. Sub-hypodermal sclerotic cylinder present, continuous or discontinuous.
D. Mesocarp with many idioblastic sclereids .... *Pritchardia.*
DD. Mesocarp without sclereids.. *Licuala.*
CC. Sub-hypodermal sclerotic cylinder absent.............................. *Livistona.*
BB. Endocarp noncrystalliferous, mesocarp without vascular bundles.
E. Idioblastic sclereids present in the mesocarp, seeds nonruminate........ *Thrinax.*
EE. Idioblastic sclereids absent, seeds deeply ruminate................ *Coccothrinax.*

The nature of endocarp, the presence or absence and the nature of organisation of sub-hypodermal sclerotic cylinder, the presence or the absence of vascular bundles, the nature and distribution of idioblastic sclereids, raphide sacs, tannin cells etc. serve as important characters for distinction.

Among six main types of endocarp recognised by Kulkarni and Pandey (1978), the species studied here could be grouped into first two types; *Sabal* is the sole representative of type-I endocarp where it is solely constituted by locular epidermis. Amongst other coryphoid palms investigated, *Raphis* (Guerin, 1949) has also this type of endocarp. The other species fall in type-II, where the endocarp is many layered, solely composed of sclereids. According to Kulkarni and Pandey (1978), this type of endocarp is restricted to coryphoid stock of palms and is found in majority of its species. Based on presence or absence of crystals in it, this type could further be divided into two sub-types. In *Livistona, Licuala* and *Pritchardia* many endocarp sclereids contain silica crystals, while in *Thrinax* and *Coccothrinax* these are absent. In addition, in the two latter genera, the mesocarp of mature fruits is free from vascular bundles. These features justify the inclusion of these two genera in *Thrinax* unit of *Trithrinax* alliance of coryphoid palms by Moore (1973).

The pericarp of the fruit is further mechanically strengthened by the organisation of sub-hypodermal sclerotic cylinder in *Sabal, Licuala* and *Pritchardia.* In *Sabal* sp. and *Licuala grandis* the cylinder is continuous, while in *Pritchardia* it consists of a ring of sclereid strips. Sub-hypodermal sclerotic cylinder, continuous or discontinuous, has also been reported to be present (Guerin 1949; Pandey 1979) in other coryphoid genera, like *Raphis* and *Corypha.*

In none of the species studied here, the vascular bundles of the pericarp are accompained by sclerosed fibrous sheaths, which appears to be a universal feature of coryphoid palms studied so far. In addition, in phoenicoid, caryotoid and lepidocaryoid palms also, the fibrous sheaths accompanying vascular bundles are either absent or remain unsclerosed (Guerin 1949; Pandey 1979). In *Thrinax* and *Coccothrinax*, on the other hand, the vascular bundles tend to degenerate along with the part of the pericarp situated below the endocarp. In mature fruits, the remnants of these could often be recognised adhering to the inner surface of the endocarp in these genera.

The syncarpae is not fully manifested in any of these species studied. In *Thrinax* and *Coccothrinax,* the carpels are completely free; in others, the connation is restricted only to the styles. Consequently, the three locules appear to be free. Similar situation has also been observed by Rao (1959), and Uhl and Moore (1971), who have described gynoecial morphology of many species of this group indicating its primitive status within the family.

The endocarp type-II shows two distinct modes of origin in the species studied. In *Licuala*, *Livistona* and *Pritchardia*, the endocarp initials are situated 3-4 layers above the locular epidermis. In *Thrinax* and *Coccothrinax*, an extensive zone of ovary tissue including several vascular bundles and raphide sacs is seen between them and the locular epidermis.

In *Licuala* and *Livistona*, the endocarp initials become apparent as a discontinuous ring of enlarged sclerotic cells. They do not form a distinct unilayered palisaded tissue as seen in *Thrinax*, *Coccothrinax* and *Pritchardia*.

During further development, the endocarp in both these types maintains its continuity by separation of already existing sclereids and the intrusion of surrounding parenchyma into the separated spaces and their subsequent sclerosis as observed by MURRAY (1973). In *Pritchardia*, an additional zone of densely cytoplasmic cells was found to overlay the developing endocarp as reported by MURRAY (1973) in *Livistona*. A few derivatives of this tissue were also found to intrude inbetween the spaces of separated sclereids followed by sclerosis. In *Pritchardia* almost all the cells of this zone become crystalliferous in mature fruits.

The origin and differentiation of sub-hypodermal sclerotic cylinder takes place typically in the same manner as that of the endocarp. In *Thrinax*, *Coccothrinax* and *Pritchardia* it is initiated as a sub-phypodermal unilayered cylinder of palisaded cells. In *Licuala*, it consists of a ring of sub-hypodermal enlarged sclerotic cells. The continuity of this cylinder is maintained during further growth of the fruits by separation of existing sclereids and by subsequent intrusion and sclerosis of adjoining parenchyma into the spaces. This mode of development was also reported by LLOYD (1910) and LONG (1943) in *Phoenix dactylifera*. Similar mode of initiation and differentiation of sclerotic zone in phoenicoid and coryphoid palms probably suggests the relationship between these two groups as claimed by DRUDE (1887), POTZTAL (1960) and MOORE (1973).

The raphide sacs are found right from ovary level in all the studied species and increase in number as the fruits develop. In *Pritchardia* almost all of them undergo sclerosis to form idioblastic sclereids in mature fruit. In *Sabal*, *Thrinax* and *Coccothrinax* number of them get dissolved to form large lysigenous cavities.

Though the ovules are bitegmic, the seed coat is single-zoned and tannin filled in all the species studied. The seed coat ruminations form characteristic features of *Coccothrinax*. In this genus, ruminations develop due to the infoldings of the seed coat into the developing endosperm. In all the ruminated palms studied so far the ruminations are supposed to originate due to the ingrowths of developing integument (PERIASAMY, 1962).

All the species are characterised by ingrowth of the chalazal tissue as a central cylindrical vasculated rod protruding in the centre of the seed. In *Pritchardia* and *Licuala* this central cylinder often branches to give ruminated appearance to the endosperm. The chalazal ingrowth has also been reported in other species of this group investigated by RAO (1959) and forms the diagnostic feature of the seeds of this group. However, they have been reported to be absent in a few genera like *Corypha* (PANDEY, 1979).

As in all the palms, in the investigated species also, the endosperm is of free nuclear type. At maturity, its cells become thick-walled due to the deposition of hemicellulose with prominent plasmodesma strands between the adjacent cells.

ACKNOWLEDGEMENTS

Our thanks are due to University Grants Commission, New Delhi, for providing fellowship to one of us (GNR).

REFERENCES

BIRADAR, N. V. & MAHABALE, T. S. (1969). Studies on palms, fruits, seeds and seed germination in the genus *Phoenix L. Proc. Indian Acad. Sci.*, **70** (2) : 55-56.

DRUDE, O. (1887). 'Palmae' *in* Englar and Prantl. *Die naturlichen Pflanzenfamilien*, ed. 1 Teil 2, Abt. 3, 1-93.

GUERIN, H. P. (1949). Contribution la etude de fruit et de la graine der palmiers. *Ann. der. Sc. Nat. Bot. Serie.* 11, **10** : 21-69.

JULIANO, J. B. (1926). Origin, development and nature of the stony layer of coconut (*Cocos nucifera* L.). *Philip Jour. Sci.*, **30** : 187-200.

KULKARNI, A. R. & PANDEY, S. B. (1978). Trends of organisation of endocarp in palm fruits. *Ghosh Commemoration Volume*, Calcutta, Ed. A. K. Sharma : 185-193.

LLYOD, F. R. (1910). Development and maturation of the embryo, seed and carpel in date, *Phoenix dactylifera* L. *Report Missouri Bot. Gard.* 21.

LONG, E. M. (1943). Developmental anatomy of the fruit deglet-noor. *Bot. Gaz.*, **104** : 426-436.

MAHABALE, T. S. & KULKARNI, K. M. (1975). Studies on palms, fruits, seeds and their germination in *Livistona chinensis* R. Br. *J. Bombay nat. Hist. Soc.*, **27** : 655-661.

MOORE, H. E. (1973). The major groups of palms and their distribution. *Gentes Herbarum*, **11** (2) : 27-141.

MURRAY, S. G. (1973). The formation of endocarp in palm fruits. *Principes*, **1** (3) : 91-102.

PANDEY, S. B. (1979). Studies on palms. Contribution to the anatomy of fruits and seed. *Ph. D. Thesis, Univ. of Bombay.*

PERIASAMY, K. (1962). The ruminate endosperm. Development and types of ruminations. In *Plant Embryology—A Symposium*, C.S.I.R., New Delhi : 62-64.

POTZTAL, E. (1960). Eine Neue Palme von Celebes. *Willdenowia*, **7** (4) : 628-633.

RAO, C. V. (1959). Contributions to the embryology of palmae : Part-I, Sabaleae. *Proc. nat. Inst. Sci. India.*, **25** : 134-164.

ROBERTSON, F. (1977). Fruit anatomy of *Jubacopsis caffra. Principes*, **21** : 23-29.

UHL, N. W. & MOORE, H. E. JR. (1971). The palm gynoecium. *Am. J. Bot.*, **58** : 945-992.

EXPLANATION OF PLATE

PLATE 1

1-6. Transverse sections of developmental stages of fruits in *Thrinax parviflora.*

1. T.S. of fertilized ovary in sector showing endocarp initials forming a cylinder of elongated cells, ×650.
2. T.S. of fertilized ovary with ovule in L.S. Note vascular tissue ending in chalaza, ×420.

3-5. Developmental stages in fruits, ×400.

6. Mature fruit ×400.

7-12. Transverse sections of developmental stages in fruits and seeds of *Coccothrinax argentea.*

7. Sector of pericarp showing differentiating endocarp, ×400.
8. Mature pericarp ×250.

9-11. T.S. of developing seeds in sector showing stages of ruminations, ×400.

12. Mature seed sector showing rumination, ×400.

PLATE 2

13-18. Transverse sections of developmental stages of fruits in *Livistona chinensis.*

13. T.S. of ovary, ×400.
14. T.S. of fruit in sector showing developing endocarp initials, ×400.

15-17. Developmental stages in fruits, ×400.

18. T.S. of mature fruit sector showing endocarp, ×550.

19-24. Transverse sections of developmental stages of fruits in *Licuala grandis.*

19. T. S. of ovary, ×400.
20. T.S. of fruit in sector showing developing endocarp & subhypodermal sclerenchyma, ×400.

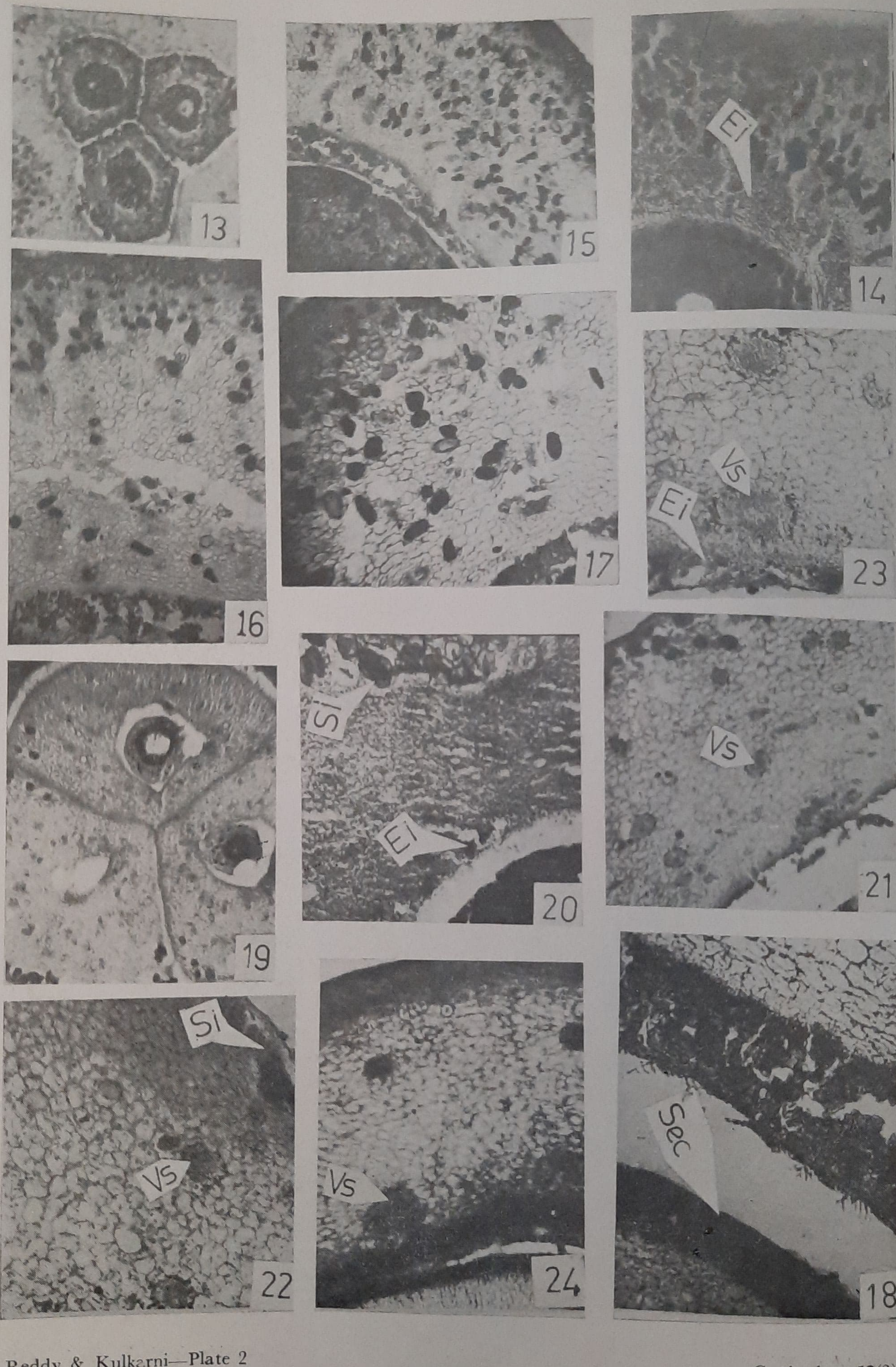
21-23. Developmental stages in fruits, ×400.

24. T.S. of mature fruit, ×120.

PLATE-3

25-30. Transverse sections of developmental stages of fruits in *Pritchardia pacifica*.
25. T.S. ovary, ×400.
26. T.S. of fruit in sector showing developing subhypodermal & endocarp initials, ×400.
27, 28, 29. Developmental stages in fruits, ×400.
30. T.S. of mature fruit, ×400.
Figs. 31-35. Transverse sections of developmental stages of fruits in *Sabal* sp.
31. T.S. of ovary, ×400.
32. T.S. of fruit in sector showing subhypodermal sclerenchyma initials, ×400.
33-35. Developmental stages in fruits, ×400.
(*Ci*—Chalazal intrusion, *Ei*—Endocarp initials, *Rs*—Raphide sac, *Sec*—Seed coat, *Si*—Subhypodermal sclerenchyma initials, *Vs*—Vascular strand).


El
Vs
1
Rs
2
3
Cl
4
5
6
7
8
11
9
10
12



Reddy & Kulkarni—Plate 2


25
Ei
Si
26
Vs
28
27
30
31
32
29
Si
33
34
35