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Anatomy of the stems of seedling palms

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Abstract. The anatomy of stem in 19 species of seedling palms is described in representative species from all the sub-families of Palmae, except Nypoideae and Phytelephantoideae. Morphologically, the stem of juvenile palm is an obconical structure, and that of the adult palms mostly solitary columnar. The cortex of stems in young palms is very wide, and often exceeds the diameter of central cylinder in contrast to very narrow cortex in adult palms. The number of vascular bundles increases several-times from the lower to the upper level of juvenile axis, whereas the number of bundles more or less, remains the same at different levels of the stem in adult palms. There is a wide meristematic zone towards the tip of axis and just below the bases of the young leaves which is responsible for widening of the seedling stem until it attains the mature stem diameter. The xylem of central vascular bundles in young palms is mostly composed of protoxylem elements but, in adult palms, they include well-developed metaxylem vessels. The central ground parenchyma is compact in young palms, spongy and lacunose in adult palms.

Keywords. Anatomy; stem; meristematic cap; palms.

1. Introduction

The family palmae comprises about 2,800 species in over 200 genera (Moore 1973). An admirable study on the anatomy of vegetative organs of 250 adult species is by Tomlinson (1961). His investigation is chiefly confined to lamina, although in some species he has studied the stem and root as well. The literature on the anatomy of stems of seedling palms is very limited (Helm 1936; Tomlinson and Zimmermann 1966; Davis *et al* 1975, 1978). The present anatomical investigation on the stems of 19 species of seedling palms attempts to compare and contrast the structure of young and adult palms.

2. Materials and methods

This present investigation deals with the stem of following 19 species of seedling palms:

Sub-families	Species	Age (months)
Coryphoideae	-*Livistona rotundifolia* (Lam.) Mart.	10
	Rhapis excelsa (Thunb.) Henry	12 (sucker)
Phoenicoideae	-*Phoenix reclinata* Jacq.	8
	P. rupicola Anders.	10
	P. sylvestris (L.) Roxb.	16
	P. pusilla Trimen	16

Borassoideae	-*Borassus flabellifer* L.	8
	Hyphaene dichotoma (white) Furtado	15
Lepidocaryoideae	-*Calamus tenuis* Roxb.	12 (sucker)
	Salacca zalacca Reinw.	12
Caryotoideae	-*Arenga pinnata* (Wurmb) Merr.	30
	Caryota urens L.	12
Arecoideae	-*Areca catechu* L.	24
	A. triandra Roxb.	19
	Chrysalidocarpus lutescens H A Wendl.	16
	Roystonea regia (H B K) cook	11
	Veitchia merrillii (Becc) Moore	10
Cocoideae	-*Cocos nucifera* L.	12
	Elaeis guineensis Jacq.	12

The seedlings were mostly raised at the Crop Garden of the Indian Statistical Institute, Calcutta. According to their availability, the seeds were sown at different intervals, for a few species, seeds were not available, and investigations are limited only to Ca 1-year old suckers: *C. tenuis* and *R. excelsa.*

As the stems of seedlings are rather small, the material was cut vertically into two or four equal pieces, and fixed in FAA. After 12 h, to soften and desilicify the tissue, it was soaked in commercial (48%) hydrofluoric acid and glycerol-alcohol (10% glycerol, 70% ethanol) for 4 to 5 days (Uhl 1969). The treated pieces were washed in running water for about 8 h, dehydrated with graded ethanol series, infiltrated with chloroform-paraffin wax, embedded in wax, 14–22 μm transverse sections were cut at different levels from apex to base, and stained in safranin and fast-green.

3. Results

3.1 General anatomy

The stems of palm seedlings are obconical, but those of adult palms are variable, mostly columnar (figure 1).

In a seedling stem the epidermis is more or less uniform, usually cutinized, and comprises isodiametric or cubical cells. The epidermal cells are slightly columnar, e.g., in *Chrysalidocarpus* and *Roystonea.* Trichomes are rare (e.g., *Caryota*). Stomata are present in some plants, e.g., in *Areca* and *Rhapis.* Each guard cell has two conspicuous ledges. The sub-stomatal chamber is absent. The hypodermis is inconspicuous. The cortex is very wide at the lowest level of stem, may be as much as the radius, or more, of the central cylinder (figure 2). It becomes narrower at higher levels. The cortex is largely made up of ground parenchyma cells containing numerous fibrous strands (figures 3–5), and a few vascular bundles, some bundles are inversely oriented. The peripheral cortical cells are smaller than the ground parenchyma of central cylinder, e.g., in *Areca.* A ligno-suberized cork sometimes occurs on the outer cortex, and below this zone is an etagen type of meristem in *A. triandra* (figure 4). The cortex includes numerous longitudinal fibrous strands. Frequent horizontal leaf traces often pass from the cortex to the periphery of central cylinder (figure 3). A few radially arranged parenchyma cells are present in the outer peripheral region of cortex (e.g., *Areca*), or in the middle cortex (e.g.,

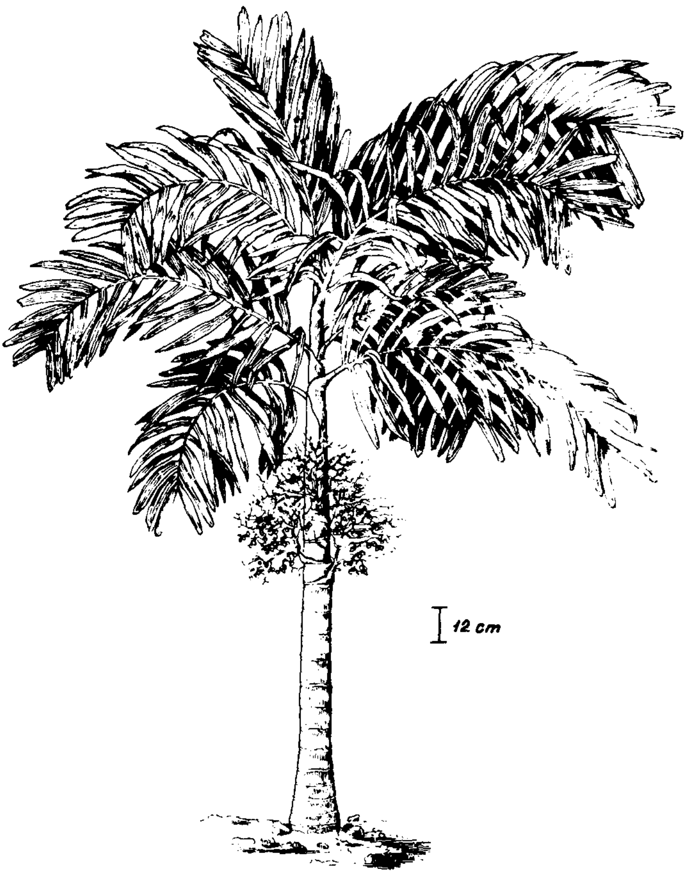
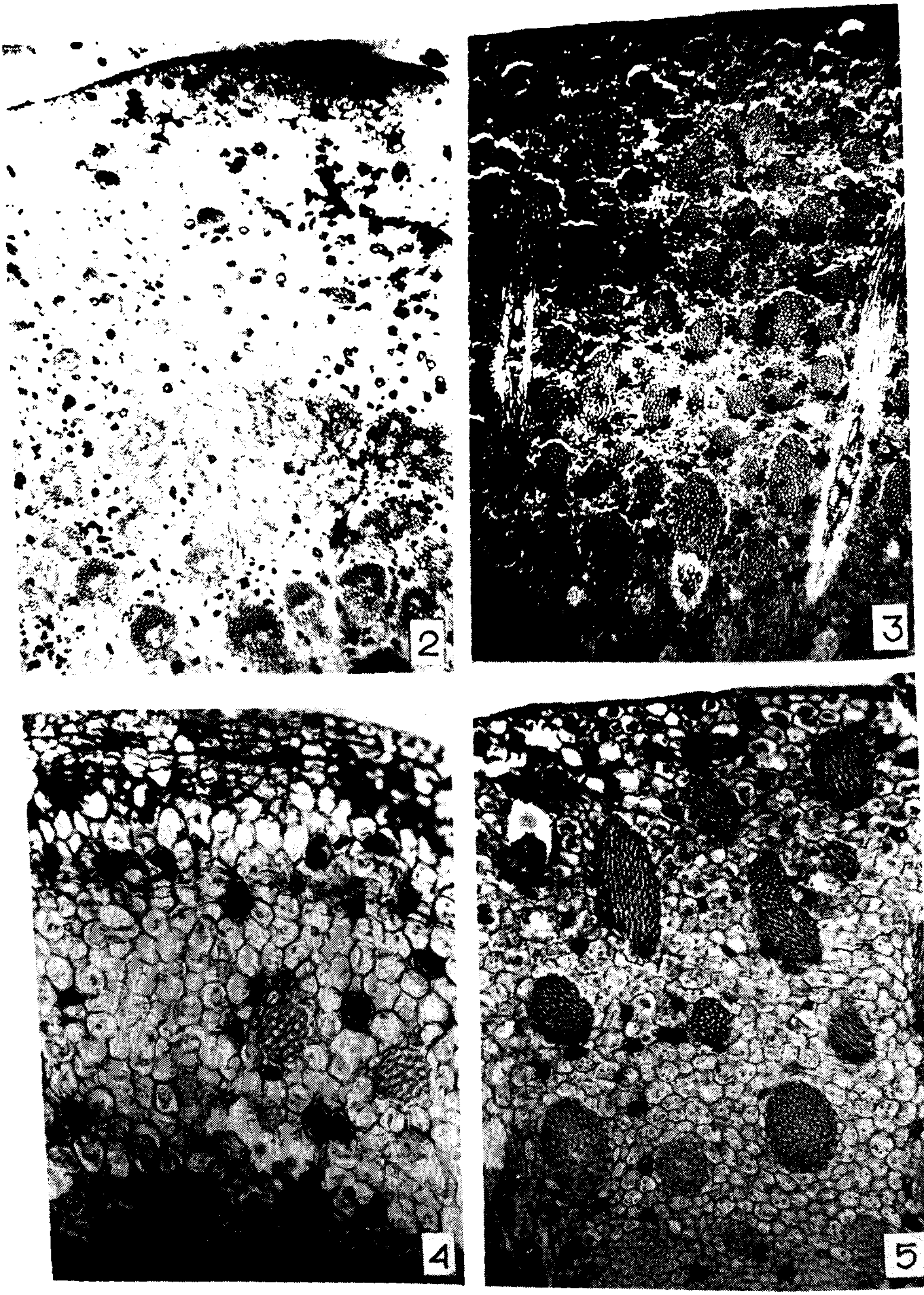


Figure 1. *A. catechu*, adult plant with columnar stem.

Cocos), and are tangentially expanded. Cortical parenchyma cells often contain abundant starch grains (figures 4, 5) tannin cells, and raphide sacs. Stegmata (silica cells) are present adjacent to each fibrous strand, and fibrous phloem sheath of the cortical vascular bundles which may be spherical (*Phoenix*) or hat-shaped (*Arenga*).

The central cylinder can be distinguished from the cortex by a peripheral zone of congested vascular bundles (figures 2, 7, 8). Sometimes more than two peripheral vascular bundles become confluent, as in *Elaeis* (figure 7) and *Rhapis*. Usually, a layer of cells does not separate the cortex from the central cylinder but, in some palms, like *Cocos*, a sclerotic narrow discontinuous zone (4–6 layers) occurs 10·5 mm above the base of stem. The sclerotic cells are tangentially extended, and widely pitted; 10·2 mm from the base the sclerotic zone disappears. The sclerotic zone seems to be a large root-trace. At higher levels towards the tip of the axis and just below the bases of young leaves, a wide meristematic zone (figure 6) occurs in a semi-convex manner. This meristematic zone is responsible for widening of the stem in the seedlings until it attains the mature stem diameter. Within this zone some procambial strands run almost horizontally which form the future vascular bundles. The shoot apex proper is very small. During early development the stem diameter increases progressively, so that each successive inter-node becomes wider than the



Figures 2–5. Transections of stems. **2.** *E. guineensis*, cortex and part of central cylinder (× 32). **3.** *P. sylvestris*, cortex (× 40). **4.** *A. triandra*, cortex, note 'etagen' phellogen at peripheral region (× 112). **5.** *L. rotundifolia*, cortex (× 82).

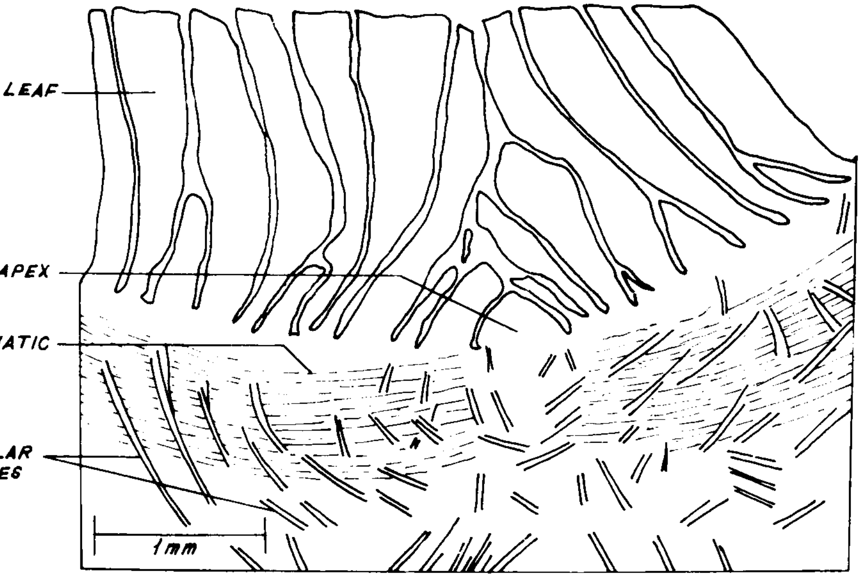


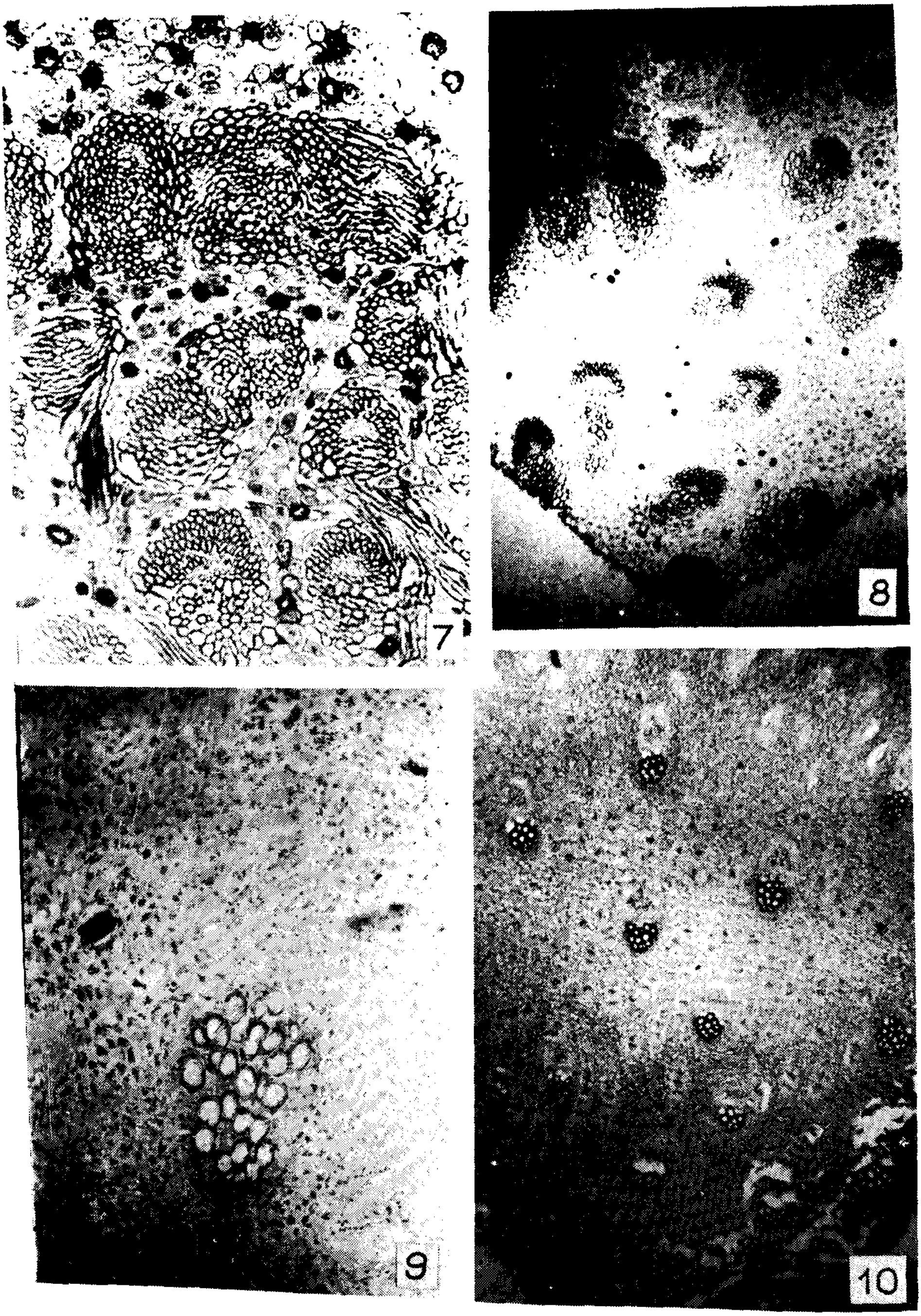
Figure 6. *P. sylvestris*, median longitudinal section of stem showing meristematic cap.

preceding one. Due to this type of early development the seedling stem has an obconical shape. Each peripheral vascular bundle has a moderately-wide fibrous phloem sheath. The phloem is usually narrow. The xylem is sheathed by slightly sclerotic parenchyma cells, and has 1–3 comparatively large and a few small vessels, mostly of protoxylem origin. The peripheral vascular bundles are smaller, and more congested than diffusely distributed large central bundles (figures 7, 8). Some leaf-traces pass from the periphery of the cylinder to the cortex; a few traces also occur at the centre of stem. Root traces at the peripheral region of central cylinder are common (figure 7). Rarely, a few peripheral vascular bundles develop obliquely, or are inversely oriented (e.g., *Borassus*). The number of vascular bundles rapidly increases from a few bundles at the lower-most level of the axis to as many as 260 bundles (e.g., *A. catechu*) at the higher level, just a few mm above the obconical base of stem. Central vascular bundles are scattered, circular in transection, large, and each has a well-developed fibrous phloem sheath; the xylem is surrounded by parenchyma cells (figures 7, 8). Metaxylem vessels are inconspicuous, narrow, and usually indistinct from the protoxylem vessels (figure 9). Protoxylem is well-developed, becomes more pronounced at the uppermost level, just before the bundles enter into leaf. The phloem strand is usually undivided but, sometimes, they divide into two separate strands by a narrow median sclerotic partition (e.g., *Calamus*). According to the composition of xylem and phloem of the central vascular bundles, 5 categories are recognized in the species investigated:

(i) Vascular bundles mostly with one wide vessel; phloem strand undivided—*R. excelsa*.

(ii) Vascular bundles mostly with one wide metaxylem vessel; phloem strand divided into two separate strands—*C. tenuis*.

(iii) Vascular bundles mostly with two inconspicuous, wide vessels; phloem strand undivided (figures 7, 8)—*A. catechu, A. triandra, A. pinnata* and *E. guineensis*.



Figures 7–10. Transections of stems. **7.** *E. guineensis*, part of central cylinder (×85). **8.** *A. catechu*, centre of stem (×40). **9.** *B. flabellifer*, vascular bundle from centre of stem; also note raphide sac (×78). **10.** *P. sylvestris*, part of central cylinder (×40).

(iv) Vascular bundles mostly with narrow protoxylem vessels; phloem strand undivided (figure 10)—*C. urens*, *C. lutescens*, *C. nucifera*, *L. rotundifolia*, *P. reclinata*, *P. rupicola*, *P. sylvestris*, *P. zeylanica*, *R. regia*, *Salacca zalacca* and *V. merrillii.*
(v) Vascular bundles mostly with more than two wide protoxylem vessels; phloem strand undivided (figure 9)—*B. flabellifer* and *Hyphaene indica.*

The ground tissue of central cylinder is parenchymatous, more or less uniform and compact, including starch grains, tannin cells, and frequent raphide sacs. Air canals are absent. Fibrous strands are usually absent in the central cylinder, although they are occasionally present in *Cocos* and *Salacca.*

3.2 *Chief anatomical differences between young and adult palms*

Young plants	Adult plants
The stem is obconical	Mostly columnar (Tomlinson 1961)
The cortex is very wide, often exceeding the diameter of central cylinder	The cortex is very narrow
The etagen-type meristem in outer cortex observed only in *A. triandra*	The etagen-type meristem reported in *A. catechu*, *Chamaedorea*, *Metroxylon*, *Rhaphea* and in many other plams
The xylem of central vascular bundles comprises protoxylem elements or, rarely, narrow metaxylem vessels	The xylem of central vascular bundles contains one or more wide, dominant metaxylem vessels
The number of vascular bundles increases from the lower level to the upper level	The number of vascular bundles per unit area of stem is approximately the same at all levels
The ground parenchyma tissue is compact	The ground parenchyma tissue is lacunose

4. Discussion

Morphologically a seedling of a palm differs in many ways from its adult predecessor. For example, the leaves of seedlings are usually simple where as in adult they are palmate or pinnately compound (Tomlinson 1960). Similarly the stem of adult palms is mostly columnar and it is obconical in young plants.

The internal structure of stems of young palms shows variable characters quite different from that of adult axis. The formation of an obconical axis in the seedling is caused by a meristematic cap (Zimmermann and Tomlinson 1970) just below the apex and leaf bases. At the seedling stage the function of this cap is only to add cells laterally causing to form a wide stem base, and vertical elongation occurs when the base attains its mature width. This growth in diameter is progressive, that means each successive internode becomes wider than the preceding one, causing an obconical shape. The establishment of mature girth at an early age is produced by the activity of a primary thickening meristem (Schoute 1912; Helm 1936; Ball 1941; Eckardt 1941), and the subsequent, elongation of the trunk occurs by the maturation of cells below the apex. The gradual increase in girth of the stem has been termed establishment growth (Zimmermann and Tomlinson 1970; Tomlinson and Esler 1973).

The abundance of protoxylem elements and the presence of a few narrow metaxylem elements in the seedling stems in contrast to wider metaxylem elements in adult axis is an interesting finding. Wide metaxylem vessel elements are quite common in roots of both seedlings and adult plants (Ghose 1984, 1987). Hence, it supports the view of Cheadle (1943) that the vessels first originate in the root and only later in the stem and leaf.

The compact ground parenchyma tissue in the central cylinder of the seedling stem is another contrasting character with the adult axis where the initially isodiametric cells elongate and separate to form the large intercellular spaces (schizogenous lacunae) which are responsible for the sponginess of the central zone in the mature axis (Mohl 1824; Zodda 1904; Schoute 1912; Tomlinson 1961; Waterhouse and Quinn 1978). According to Zodda (1904), two phases of growth are involved—a phase of cell-division preceded that of cell expansion. This type of growth in the adult axis has been termed as diffuse secondary growth by Schoute (1912) and Tomlinson (1961). Monoyer (1925) called it as sustained primary growth. Hence, as the diffuse secondary growth occurs only in the adult palms, spongy parenchyma of the ground tissue is absent in the seedling stems.

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