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Studies on Bentinckia condapanna: I. The Fruit and the Seed

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Among the native palms of south India, *Bentinckia condapanna* Berry is one of the rare palms occurring in the area of the Western Ghats at an altitude of 1,000–1,400 m. It is a graceful species with beautiful foliage. Large stands occur along the edge of the high-rising peaks of the Travancore hills, where wild elephants roam and feed on the soft and tender foliage. Sporadic occurrence of isolated groups of this slender palm among the vegetation of once dense *sholas* of the Palni hills in the northern region provides evidence for a wider distribution in the past and a history of destruction and deforestation. This rare palm is among the endangered species facing extinction due to human activities even in its native land. The inflorescence of this species, known as the "hill arecanut" and as "varikamugu" in the native Tamil language, is used for decorative purposes during ceremonial occasions.

The description of *B. condapanna* given in the Flora of Madras (Gamble 1935) is based on the information culled from Bourdillon's manuscript notes lodged with the Kew Herbarium. According to this description, the palm bears a slender annulate stem with a crown of pinnate leaves and inflorescences below the crown (Fig. 1). The male and female flowers are small and occur on the same spadix sunken in pits. The female flowers bear tricarpellate, but pseudomonomerous gynoecia—with normally only one carpel fertile. The subspherical fruits develop from single carpels and the other two carpels abort. Our observations show that the fruits that may occasionally form from two or three carpels fall before the initiation of cellular endosperm. The seed is enclosed by a hard endocarp which has a basal operculum. Bourdillon's notes describe the seed as non-ruminate and sinuately grooved or ridged.

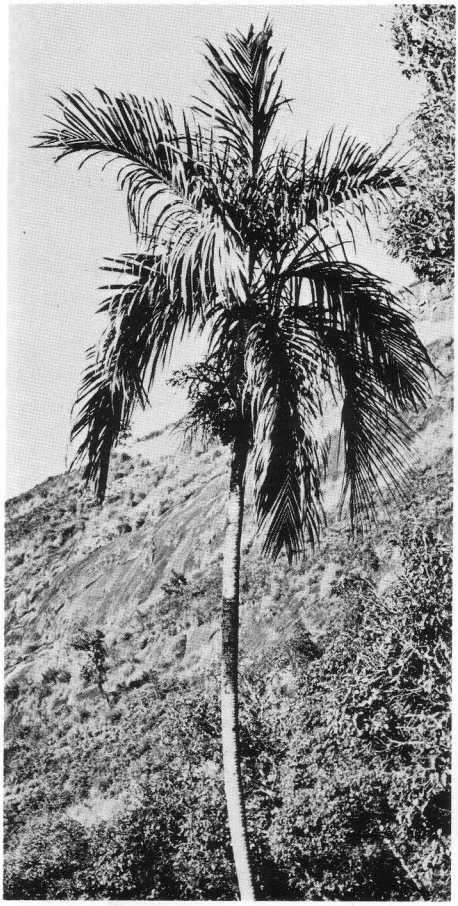
The present series is aimed at publishing studies on this rare palm and providing information useful in its conservation. The study of fruit structure presented in this paper is intended to provide a basis for extending the work to germination. At present, no published account of the details of fruit structure is available.

Materials and Methods

The fruits were collected and fixed in FAA. The materials for microtechnique were processed through the tertiary butyl alcohol series (Johansen 1940) for infiltration and embedding in paraffin wax. Sections were cut with a rotary microtome at 10–14 μm and stained with tannic acid–ferric chloride–safranin combinations (Foster 1934).

Observations

Anatomy of the fruit and seed. The ripe fruit of *Bentinckia* is dark pur-



1. *Bentinckia condapanna*. Habit of a tree growing at Courtallam Hills, South India $\times 1/65$.

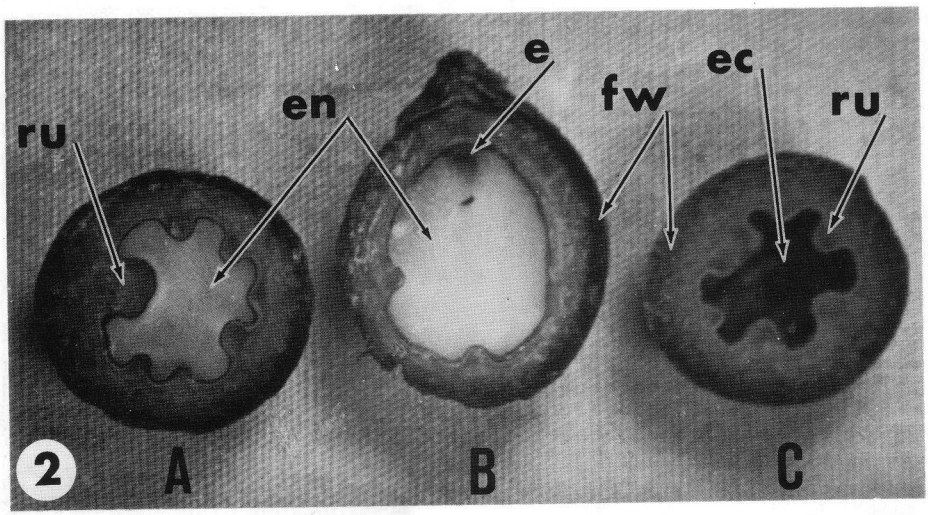
plish in color and measures 14 mm in diameter (Fig. 2). The pericarp is differentiated into exocarp, mesocarp and endocarp. The outer epidermis is of tabloid cells with cutinized tangential walls. The exocarp also includes a few subepidermal layers and tannin-containing cells. The subepidermal layers are of thin-walled, oblong parenchymatous cells. Subjacent to this region there is a zone of tannin- or crystal-containing parenchymatous cells and fibers (40–50 μm in diameter, Fig. 7A).

The mesocarp is made of isodiametric parenchymatous cells some of which are slightly compressed. Many of these cells show crystalline inclusions (raphides). Numerous fibers and fibrous vascular bundles (400–700 μm in diameter) are scattered in this region (Fig. 7A).

The endocarp (100 μm thick) is organized by the locular epidermis whose thick-walled cells form a palisade layer. Absence of vascular bundles associated with the endocarp in *B. condapanna* is a noteworthy feature (Fig. 7B–D).

Development of fruit and seed. The post-fertilization ovule shows a 10–15-layered integument with a distinct outer epidermis composed of radially elongated cells. The inner epidermis of the fruit wall is composed of small rectangular cells with dense cytoplasm and prominent nuclei. The hypodermal parenchymatic layers of the fruit wall become progressively enlarged and vacuolated. The fruit, the developing seed, and the embryo sac enlarge even during the nuclear phase of the endosperm and thus push the seed coat close to the fruit wall.

The outline of the embryo sac remains even during the early post-fertilization stages and becomes progressively undulate with advancing age (Fig. 2A–C). The undulations result from localized inward growth of the parenchyma tissue in the fruit wall adjoining major vascular bundles and subjacent to the inner epidermis (Fig. 6). The pattern of growth in the tissue is interesting. Cell elongation occurs more intensely in the interior while the cells of the hypodermal layer enlarge to a limited extent but show a few divisions prior to enlargement. To keep pace with differential cell enlargement and elongation, the epidermis also undergoes divisions. As a result, the contour of the epidermis undergoes a



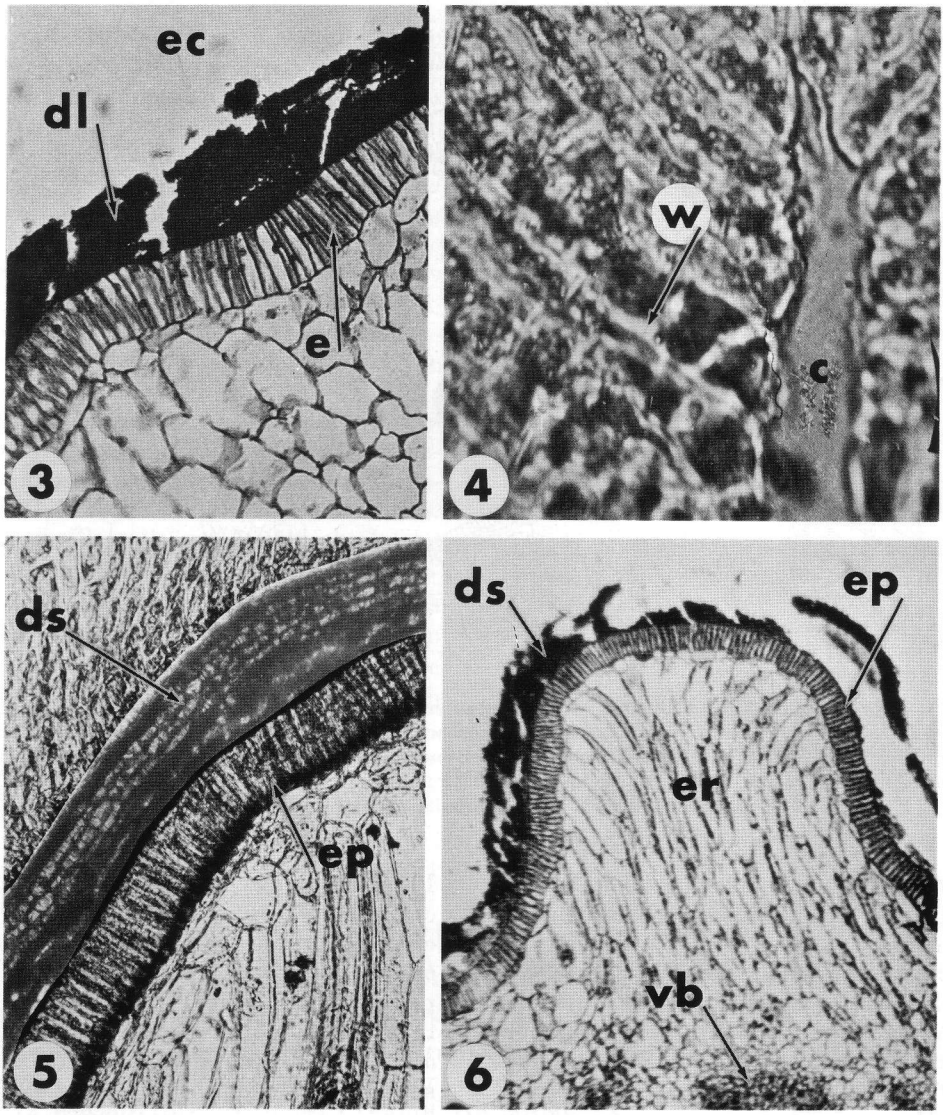
2. *Bentinckia condapanna*. Sectional views of fruits at young and mature stages ×2½. A. Cross sectional view of mature fruit showing lobed endosperm and fruit wall-seed coat complex. B. Vertical section through a mature fruit showing endosperm tissue and fruit wall-seed coat complex. C. Cross section of fruit before formation of cellular endosperm. Details: ec, central cavity of embryo sac at nuclear endosperm stage; emb, embryo; en, mature endosperm; fw, fruit wall; ru, sculpturing caused by fruit wall ingrowth.

change, initiating undulations. The outer epidermis of the seed coat becomes stretched and flattened. By this time, the locular epidermal cells have elongated radially and their walls have become thickened (Figs. 3, 5, 6). At this stage, the endosperm consists of a central vacuolar cavity filled with sap (Fig. 2C) and a peripheral layer of cytoplasm with numerous free nuclei. Subsequently, cell wall formation takes place in the endosperm in a centripetal manner. With advancing development, the cells of the endosperm completely occupy the embryo sac (Fig. 2A, B) but for a narrow central cavity (Fig. 4). By this time, the reserve materials are deposited in the walls of the endosperm which, as a consequence, becomes unevenly thickened (Figs. 4, 7). Transverse sections of the fruit show that the endosperm takes the undulate outline already laid down (Fig. 2B).

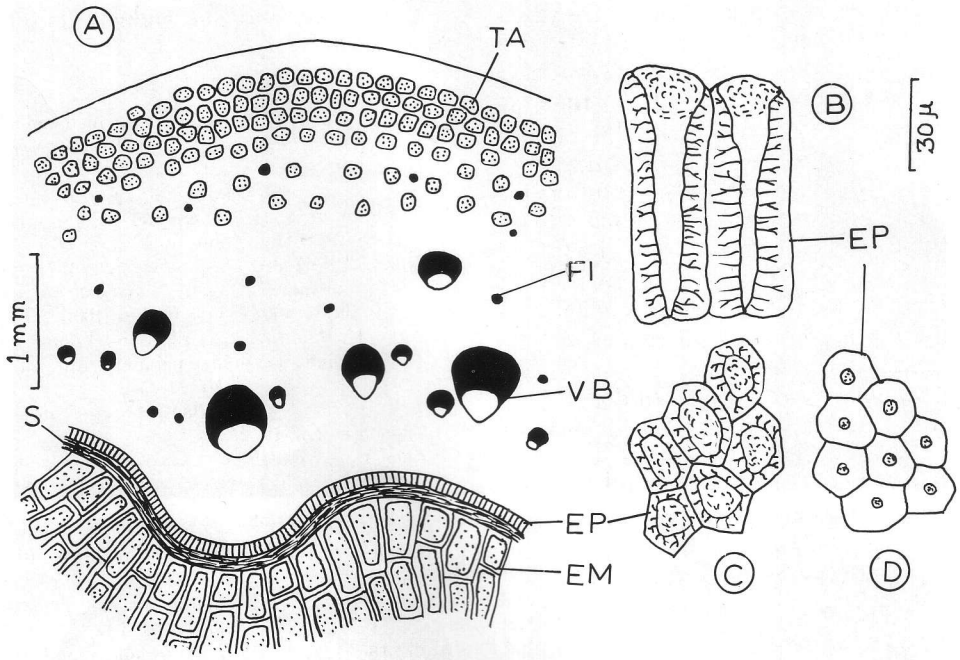
The fate of the seed coat layers during late ontogeny is worth mentioning. Initially, the layers of the seed coat are thin-walled. With the formation of the cellular endosperm, the inner layers begin to accumulate tanniniferous compounds (Fig. 3). The cells of the exocarp at this stage also begin to accumulate dark tanniniferous materials (Fig. 7A). The locular epidermis composed of radially elongated cells (Figs. 3, 5) becomes highly thickened and forms the endocarp. The lumen is much reduced and the wall is sculptured with ramifying pits. These thickened cells are sclereids (Fig. 7B–D).

Discussion

Development of grooved seeds in *B. condapanna* is in line with similar records for various arecoid palms. Grooved seeds have been recorded in *Ptychococcus*, *Brassiophoenix*, *Balaka*, *Ptychosperma* (Essig 1977) and in *Physokentia* (Moore 1969). The en-



3–6. *Bentinckia condapanna*. Photomicrographs showing internal structure of maturing fruit. Fig. 3. Part of the seed coat showing degenerating cell layers of seed coat and radially elongated cells of the endocarp ×125. Fig. 4. A part of mature endosperm tissue showing wall thickenings of the constituent cells ×270. Fig. 5. A part of the seed coat-fruit wall complex of a mature fruit ×125. Fig. 6. Details of an ingrowth of the fruit wall. Note cell elongation between vascular bundle and epidermis ×30. Details: cv, central cavity of the endosperm; dl, dark remains of the degenerated layers of the seed coat; ds, degenerating cell layers of seed coat; ec, central cavity of the embryo sac; ep, endocarp; er, elongated cells of the fruit wall causing ingrowth; w, wall thickening in mature endosperm cells; vb, vascular bundle.



7. *Bentinckia condapanna*. Diagrams illustrating external and internal structure of fruit and endocarp. A, cross sectional view of fruit; B, macerated endocarp cells showing highly thickened cell wall with ramifying pits and highly reduced lumen; C, outer end view of endocarp cells; D, inner end view of endocarp cells. Details: em, endosperm; ep, endocarp cells; fi, fiber; s, seed coat; ta, tannin cells; vb, fibrous vascular bundles.

docarp in palm fruits has been the subject of several investigations (Guérin 1949, Murray 1971, 1973, Essig 1977, Robertson 1977, Wessels-Boer 1968). The nature of the endocarp and its development have been taken as important criteria in attempted classifications and typifications of palm fruits (Murray 1973, Essig 1977). Accordingly, the fruit of *Bentinckia* could be assigned to Type I of Murray (1973).

An endocarp consisting of a single layer has been reported in caryotoid, chamaedoreoid, and pseudophoenicoid groups (Murray, 1973). The cells of this layer in *Bentinckia* are exceedingly thick-walled sclereids. The lumen is much reduced and the pits are ramifying. A similar structure was reported in *Orania aruensis* (Guerin 1949). A parallel situation apparently occurs in *Hyophorbe lagenicaulis*, a chamaedoreoid palm, and *Pseudophoenix sargentii*, a pseudophoenicoid palm (Murray, 1973). The structure of the endocarp of *Bentinckia condapanna* differs from that reported for the species of *Ptychosperma* (Essig 1977) in the absence of vascular bundles associated with it.

The occurrence of vascular and fibrous bundles in the pericarp of arecoid palms is subject to much variation. The vascular bundles occur concentrated at the inner half of the pericarp in *Veitchia joannis*, *Carpentaria acuminata*, *Drymophloeus subdistichus*, *Balaka burretiana*, *Ptychosperma schefferi*, and *P. lauterbachii* (Essig 1977). In *Bentinckia*, the large

bundles are distributed some distance away from the endocarp as in *Normanbya normanbyi* and *Ptychococcus* aff. *elatus* (Essig 1977). Even though distributed in the outer half of the pericarp, the fiber bundles in *Bentinckia* are not concentrated below the outer epidermis as recorded in palms of the *Ptychosperma* alliance described by Essig (1977). However, dense accumulation of tannin-bearing cells occurs in the hypodermal region in the fruit of *B. condapanna*.

The endosperm. The cellular structure of the endosperm in *B. condapanna* is similar to that of other investigated genera of the arecoid palms. The cell walls are highly thickened with hemicellulose deposits. The outline of the endosperm shows grooves corresponding to similar structure in the fruit wall. After the decay of the fleshy pericarp, the seed is left with large grooves on its surface. Longitudinal sections of the fruit show up the grooves as inpushings of the seed coat and endocarp into the endosperm (cf. Moore 1969).

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