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BOTANY

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The genus *Areca* began as a monospecific genus in Linnaeus's *Species Plantarum* (1753), being founded on *Areca catechu* L., the betelnut palm widely cultivated in tropical Asia. Bentham and Hooker (1883) in their treatise *Species Plantarum*, described the genus as the first one in the family Palmae under the tribe Areceae. The genus expanded rapidly from its monospecific status and is at present believed to contain about 76 species. Among these, *A. catechu* is the only cultivated species, the nuts of which is chewed as a mild stimulant, though nuts of a few other species such as *A. triandra* Roxb. are also used as a masticatory.

There has been some speculation regarding the origin of the generic name *Areca*. De Candolle's (1886) hypothesis with regard to its origin from "Telenga name" did not receive much supporting evidences in literature (Bavappa, 1964). The possibility of the generic name coined by Linnaeus based on popular Malayalam name 'Adeka' or a variant Kannada name was indicated by Bavappa (1964). According to Mc Currach (1960) the name *Areca* was derived from a Malayan word meaning "cluster of nuts".

I. Taxonomy

1. Limits of the genus *Areca*

Martius (1832–1850) was the first to attempt to restrict the limits of the genus *Areca;* but the attempt was not satisfactory as the limitations were not based on real affinities. The genera now recognized as *Dictyosperma, Oncosperma, Dypsis, Acanthophoenix* etc. were retained in the genus *Areca,* while the closely related palms were excluded from it. Blume (1836) separated various species till then grouped under *Areca* into different genera, based on the nature of albumen, the position of ovule, the distribution of male and female flowers on the spadix, and limited the genus to close relatives of the type of the genus, *Areca catechu*.

Blume's arrangements however was not accepted by Martius (1832–1850), Griffith (1850) and Miquel (1868, cited by Furtado, 1933) among others. Bentham and Hooker (1883) listed 24 species under *Areca* and disagreed as to the limits placed on the genus by Scheffer (1871, cited by Furtado, 1933) and Beccari (1919). In ascribing only 14 species to the genus *Areca*, Drude (1889, cited by Furtado, 1933) followed Bentham and Hooker (1883) in excluding *Mischophloeus* from *Areca*, but included only those species which Scheffer (1871) and Beccari (1919) had retained under the genus. The views of Bentham and Hooker (1883) and Drude (1889) have been followed by Blatter (1926). But Furtado (1933) found it impossible to maintain *Mischophloeus* as a genus and amalgamated it with *Areca*. For the sake of convenience and for the purpose of bringing out better affinities, he divided the reconstituted genus *Areca* into two subgenera *Blumeoareca* and *Beccarioareca*. The character that distinguishes these two subgenera is the arrangement and the glomerules of the male flowers, being unilateral or distichous in *Blumeoareca* and spiral in *Beccarioareca*. Furtado (1933) again subdivided *Blumeoareca* into three sections, *Arecella* Wendl. et Drude, *Oeotheanthe* Scheff. and *Axonianthe* Scheff. The subgenus *Beccarioareca* was also subdivided into two sections. The first section was called *Microareca* Furtado, consisting of small plants known to occur only in Malay peninsula, Lingga Island and Borneo. The other section *Mischophloeus* (Scheff.) Becc. included massive palms known only from the region between Celebes and the Solomon Islands.

The generic characters of the genus *Areca* as furnished by Blatter (1926) are:

Stem erect, smooth green in the upper portion, annulate. Leaves pinnate; base of the petiole expanding into smooth green amplexicaul sheath; leaflets thin, often confluent, with several midribs, attached to the rachis in a vertical line.

Spadix androgynous, below the leaves, branched, bearing numerous closely set spikes; spathes several. Male flowers many, minute, occupying the upper portion of the spikes; sepals small, petals much longer, obliquely lanceolate, valvate; stamens 3 or 6; filaments short; anthers basifixed, erect. Female flowers much larger, few at the base of the spikes; perianth accrescent, sepals and petals orbicular, imbricate, the petals with acute valvate tips; ovary 1-celled; stigma 3, sessile; ovule 1, basal, erect.

Fruits ovoid or oblong, supported by persistent perianth; mesocarp fibrous. Seeds with a truncate base; endosperm deeply ruminate; embryo basilar.

An annotated list of the *Areca* species according to their sections as given by Furtado (1933) is enumerated below; and their distribution is illustrated in Fig. 2.1.

Subgenus 1. *Blumeoareca* Furtado

Species coming under the subgenus are having female flowers seated between two male flowers although the latter may often fall prematurely. The male glomerules normally consist of two flowers, though in some portions of the spikelets, principally in the terminal ones, solitary male flowers may sometimes be observed. The male flowers in the terminal parts may also frequently be observed to have dropped off prematurely.

Section 1. *Arecella* Wendl. et Drude

Species with three stamens and soboliferous stems are widely distributed from Indo-Malaysia southwards to Trinity Bay on the east coast of Australia and eastwards to Cochin-China, but are not known from the Philippines, Celebes and New Guinea. Many variations or forms occur. Species with solitary stems and three stamens are known only from the Andamans and the Malay peninsula southwards to Java and eastwards to Borneo. Species with six stamens are known only from the Philippines, excepting one from Laos.

A. Stamens 3

B. Stem solitary

1. *A. borneensis* Becc. Referred doubtfully and not certain whether the stem is solitary or not. If soboliferous, then it may be a form of *A. triandra.*
2. *A. latiloba* Ridl. (= *A. pumila* Bl.)
3. *A. laxa* Buch. – Hamilt. Not well known, and may be a variety of *A. triandra* Roxb.
4. *A. montana* Ridl. The spadix is simply branched and almost every branch has a female flower at its base so that, were it not for the disposition of the male flowers the spadix would be easily confused with that of the section *Axonianthe.*

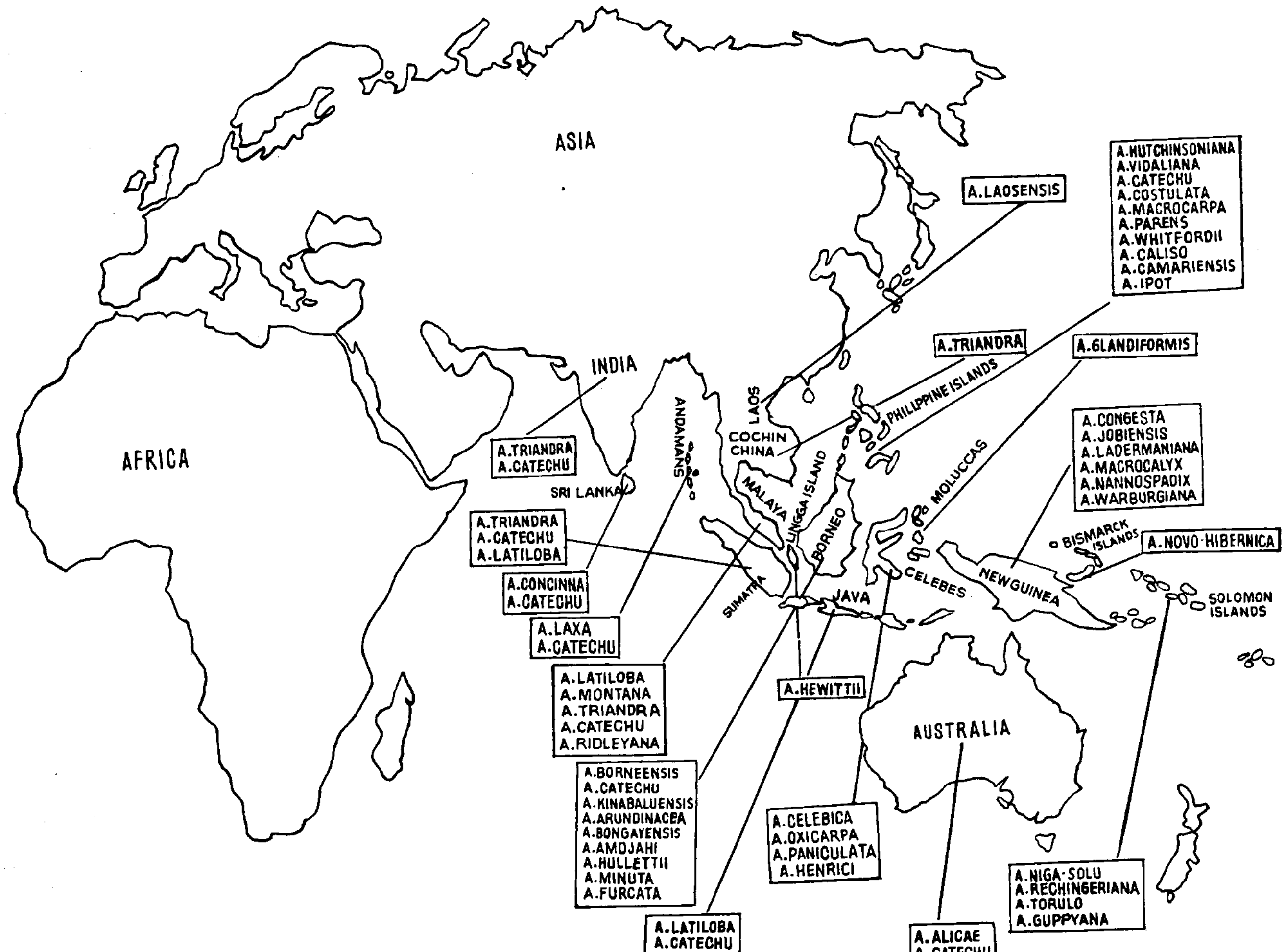

Fig. 2.1 Geographical distribution of *Areca* species (Furtado, 1933)

BB. Stems soboliferous

5. *A. alicae* F. Muell. It appears to be a variety of *A. triandra* Roxb.
6. *A. triandra* Roxb. (=*A. pumila* Ridl.)

AA. Stamens 6, stem apparently solitary

7. *A. hutchinsoniana* Becc.
8. *A. vidaliana* Becc.
9. *A. laosensis* Becc.

Section 2. ***Oeotheanthe*** **Scheff.**

Distributed in the Philippines, Celebes and North Borneo and *A. catechu* L. in this section is widely cultivated throughout the tropics. *A. concinna* Thw. is reported to be wild in Sri Lanka.

10. *A. catechu* L.
11. *A. celebica* Burr. This may be a form of *A. oxycarpa* Miq.
12. *A. concinna* Thw.
13. *A. costulata* Becc.
14. *A. kinabaluensis* Furtado.
15. *A. macrocarpa* Becc.
16. *A. oxycarpa* Miq.
17. *A. parens* Becc.
18. *A. whitfordii* Becc.

Section 3. ***Axonianthe*** **Scheff.**

The disposition of the male flowers is important in recognising this section. The main axis of the spadix may sometimes divide into two or more branches, but these in their turn function like the main axis of the unbranched spadix and bear simple floriferous branchlets on all sides. The distribution of the species are limited to the region between Celebes westward to the Solomon Islands and northward to the eastern regions of the Philippines.

19. *A. caliso* Becc.
20. *A. camariensis* Becc.
21. *A. congesta* Becc.
22. *A. glandiformis* Lam.
23. *A. ipot* Becc.
24. *A. jobiensis* Becc.
25. *A. ledermaniana* Becc.

26. *A. macrocalyx* Becc.
27. *A. nannospadix* Burr.
28. *A. niga-solu* Becc.
29. *A. rechingeriana* Becc.
30. *A. torulo* Becc.
31. *A. warburgiana* Becc.

Subgenus II. *Beccarioareca*

Section 4. *Microareca* **Furtado**

In most cases fully mature fruits are not known. One species in this section comes from the southern parts of the Malay peninsula, one from the Lingga Island and the rest from the northern parts of Borneo.

A. Stamens 6.

B. Leaves entire, bifid at apex

32. *A. arundinacea* Becc.
33. *A. bongayensis* Becc.
34. *A. hewittii* Furtado

BB. *Leaves divided*

35. *A. amdjahi* Furtado Spec. nov. Leaf segments 2 or 3 on each side of the rachis; the leaves larger than in the next two species.
36. *A. hullettii* Furtado. The male flowers are not known and the species is doubtfully placed. The leaves have three pairs of segments.
37. *A. minuta* Scheff. The leaves have two pairs of segments
38. *A. furcata* Becc.

AAA. Stamens 21–24. Leaves flabelliform

39. *A. ridleyana* Becc.

Section 5. *Mischophloeus* **(Scheff.) Becc.**

Distributed from the Celebes westward to the Bismarck Archipelago and Solomon Islands, but not known from the Philippines.

40. *A. guppyana* Becc. The species appears to be very close to *A. novo-hibernica* Becc. The entire spadix is not known, but judging from the fragment, it appears to be simply divided as in *A. novo-hibernica* Becc.

41. *A. henrici* Furtado. It has a compoundly divided spadix and is easily distinguished from all the other species in this section by its narrow leaflets.

42. *A. novo-hibernica* Becc.

43. *A. paniculata* (Miq.) Scheff.

2. *A. catechu* and its cultivars

i. *Nomenclature*

As to the correct specific epithet of betelnut palm, there is some disagreement among the taxonomists. Linnaeus (1747, cited by Moore, 1959) first used the epithet *catechu* in connection with *Areca* in his treatise *Flora Zeylanica.* The same author in his *Species Plantarum* (1753) used the term *cathecu* for the specific name of the arecanut palm, but in the index to the volume used the term *catechu* as well. According to Bailey (1949) the name is commonly misspelled as *catechu* and they adopted *cathecu* as the correct specific epithet. McCurrach (1960) and Bhat, Murthy and Rao (1963) also maintained *A. cathecu* as the correct name of the species. Moore (1959) dealing with the nomenclatural history of the taxon, derived evidences to show that the valid name for arecanut is *Areca catechu.* Based on the supporting evidences available, greater usage and provisions in the International Code of Botanical Nomenclature, *Areca catechu* is to be accepted as the correct botanical name of arecanut palm (Furtado, 1960; Bavappa, 1964).

ii. *Botanical description*

The botanical description of *A. catechu* (Blatter, 1926) is given below:

Trunk solitary, quite straight, 12–30 m high, usually about 20 inches in circumference, uniformly thick, leaves 1.2–1.8 m, leaflets numerous, 30-60 cm, upper confluent, glabrous.

Spathe double, compressed, glabrous. Spadix much branched, bearing male and female flowers. Rachis stout, compressed, branches with filiform tips. Male flowers very numerous, sessile, without bracts; calyx 1-leaved, small, 3-cornered, 3-parted; petals 3, oblong, rigid striated; stamens 6, anthers sagittate. Female flowers solitary or 2 or 3 at or near the base of each ramification of the spadix, sessile, without bracts; sepals 3, cordate, rigid, fleshy, permanent; petals 3, like the sepals permanent; staminodes 6, connate, styles scarcely any; stigmas 3, short, triangular. Fruit 3.8–5.0 cm long, smooth orange or scarlet.

iii. *Cultivars of* A. catechu

Rau (1915) described a new cultivar of arecanut from Mysore based on the sweet kernels of mature fruits and designated it as *A. catechu* var. *deliciosa.* Beccari (1919) recognised four cultivars of arecanut from the Philippines and termed them as *A. catechu* var. *communis, A. catechu* var. *silvatica, A. catechu* var. *batanensis* and *A. catechu* var. *longicarpa,* based on the size and shape of fruits and kernel. Cultivars available in Malaya, Sri Lanka and South India have been designated by local names (Sands, 1926; Grist, 1926; Molegode 1944; Nambiar, 1954; Aiyer 1966). According to Kannangara (1941) there are apparently no distinct varieties of arecanut in Mysore, though some palms bear yellow and green fruits. The range of variation in flowers, size and shape of fruits in different cultivars of *A. catechu* occurring in Assam was described by Raghavan and Baruah (1956b). Murthy and Bavappa (1962) identified 64 cultivars based on fruit size, from Kerala, Karnataka and Maharashtra and discussed the pattern of variation in relation to the topography of the tract. Based on the variation in number and size of nuts and stomatal characters pertaining to four cultivars of *A. catechu,* Bavappa (1966) concluded that cultivars could be identified based on the number of stomata per unit area. Bavappa and Pillai (1976) found highly significant differences in respect of number of leaves shed, spadices and female flowers produced, nut set, number of nuts harvested and weight and size of nuts among thirteen cultivars of *A. catechu* from eight countries.

The occurrence of a dwarf arecanut palm was reported by Naidu (1963b) from Hirehalli (Karnataka). According to his description, the 40 year old mutant palm had attained a height of only 4.57 m and had suppressed internodal spaces so that the annular scars appeared as superimposed. The inflorescence and floral characters were similar to *A. catechu.* The nuts were of medium size and slightly elongated.

II. Morphology

Arecanut is a graceful, erect and unbranched palm reaching varied heights depending upon the environmental conditions. The stem has scars of fallen leaves in a regular annulated form. The crown is compact with pinnate leaves which are partly free and partly fused. The basal region of the leaves forms a broad sheath which completely encircles the stem so as to protect the developing inflorescence until a few days prior to opening,

1. The root

Arecanut palm has an adventitious root system, typical of monocots (Fig. 2.2). The first root of arecanut is formed from the pro-stem of a germinating nut, earlier to the development of the first leaf. This takes place in about 30 days after sowing. The root at this stage is about 0.6 cm in length. Within 20 days, more roots are produced from the region of the first root. The later-forming

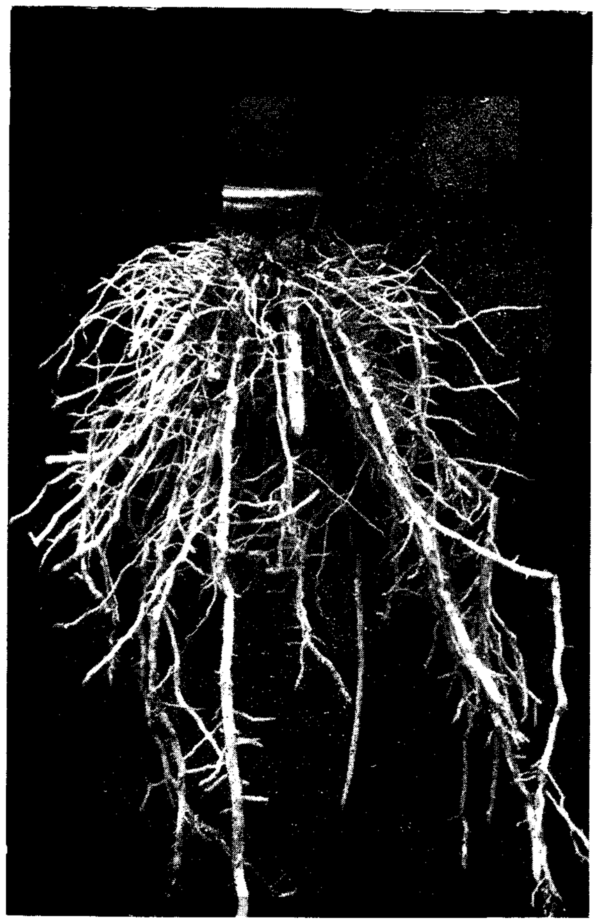

Fig. 2.2 Root system

roots emerge from the points opposite to the emergence of the first root. Rootlets of various sizes are formed in about 90 days after sowing. The cotyledon grows almost to its full size in about 50 days after sowing and by this time the sprout is visible outside the husk (Bavappa and Murthy, 1961).

As the age of the seedling advances, more and more roots are produced from the nodes formed as a result of leaf fall, in the initial three years of growth. A fully grown up base of the palm is found to have about 10–12 rows of roots corresponding to the number of leaves shed within the first three years of growth. It is quite possible that the root production is mainly confined to the nodes formed by the leaf-fall. This root producing zone which has the shape of an inverted cone is about 28 cm in length and 23 cm in diameter, with a slant distance of 32 cm and may be termed as 'bole'. The 'bole' starts decaying from the apex and extends upwards in older palms (Bavappa and Murthy, 1961).

The root tip is protected by a root cap which is having a diameter greater than that of the roots. The absorbing zone of the growing root is found to be located just behind the root cap and is normally white in colour. The vertical penetration capacity of the roots is rather low and most of the roots spread laterally. The main roots measure 1.96 m in length on an average. They are fairly uniform in thickness ranging from 9 mm to 18 mm. The main roots produce large number of laterals which further branch profusely. Normally many roots are not formed above the 'bole' region even when buried in the ground.

Numerous short conical out-growths resembling a flower-bud, attached to the roots with a constricted filament, are found to be distributed all over the roots. Middle-aged and old palms have larger number of such outgrowths than the young ones. It appears that these outgrowths perform breathing function and may be termed as pneumatophores. They originate like rootlets, but remain short and bulged. Their cortical cells develop prominently and get hardened to some extent enclosing numerous micropores which are impervious to water. These cavities have direct connection with the aerenchyma of the root from which the pneumatophores originate and thereby enable the root tip buried under water or in marshy soil to have contact with the atmosphere (Bavappa and Murthy, 1961; Davis, 1961).

The roots radiate from all the sides and generally grow in the direction in which they start. The number of roots in a palm depend upon its age and have been estimated to be about 175 in a 10 year old palm, 385 in a 35 year old palm and 78 in a 60 year old palm. In older palms, the earlier formed roots are found to decay. The maximum concentration of roots in a middle aged palm is within the first 60 cm depth from the ground level, and within a radius of 60 cm from the palm (Table 2.1).

Table 2.1. *Number of roots per 30 cm² at varying depths and distance from the palm*

Depth from ground level	Distance from the palm				
	30 cm	60 cm	90 cm	120 cm	150 cm
30 cm	29.50	10.00	2.0	2.25	2.25
60 cm	57.75	11.25	3.0	2.25	2.50
90 cm	17.75	6.50	0.5	0.50	0.75
150 cm	1.50	0.75	0.5	0.75	0.50

The colour of roots vary with age. The roots produced by a seedling upto an age of one year are creamy white in colour, thereafter they slowly change into light brown during the next two years of growth. These roots become darker in colour with age and by the time they are about 10 years old, they become dirty brown. Bavappa and Murthy (1961) observed that pruning of the roots of seedlings before transplanting affects adversely the field establishment, subsequent root production and growth.

The transverse section of the root of areca palm is about 9.3 mm in diameter and has a layer of piliferous lignified square cells. Below it lies the lignified hypodermis. The cortex is very extensive having numerous small irregular round fibre bundles which are closely packed and large fibre bundles lying scattered. The cortex is interrupted by vertical rows of air spaces. A broken ring of sclereids and an incomplete ring of pigment cells occur in the inner cortex. Raphide sacs are numerous and a few mucilage cells are present in the cortex. The endodermal cells belong to the "C" type and are followed by one layer of large pericycle cells (Raghavan, 1957; Mahabale and Udwadia, 1960). According to Drabble (1904) pericycle is two-layered in small roots. The stele consists of 80–90 arches of xylem and phloem and lies in a continuous mass of conjunctive, thick-walled and lignified parenchyma. It is thrown into rays enclosing islands of xylem and pholem below the pericycle. Xylem groups are either "I" or "V" shaped. Each xylem strand consists of 4–5 cells arranged in radial plates and terminates in a relatively large metaxylem which constitutes the apex of "V" shaped xylem strand. Such large metaxylem cells are completely included in the conjunctive parenchyma. They generally have a single layer of thin-walled unlignified parenchyma around them. The conjunctive tissue is thrown to zig-zag lobes on its inner margin. The central pith, 3520μ broad, contains numerous fibre bundles of different sizes, all hydrocentric (Fig. 2.3)

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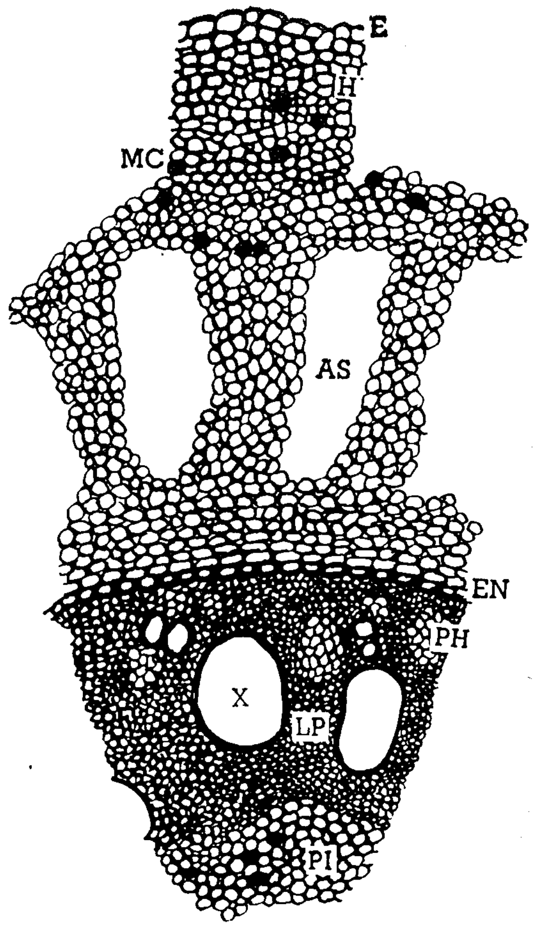


Fig. 2.3 Transverse section of root. *E-Epidermis; H-Hypodermis; MC-Mucilage cells; AS-Air space; EN-Endodermis; X-Xylem; PH-Phloem; LP-Lignified parenchyma; PI-Pith.*

The occurrence of aerial roots in arecanut was reported by Murthy and Bavappa (1959) and Davis (1960; 1961)

2. The shoot

The stem is marked with scars of fallen leaves in a regular annulated form. According to Murthy and Bavappa (1960a) the stem becomes visible when the palm is about three years old. The girth of the stem generally depends on the genetic variation and soil conditions. In the initial stages of growth of the palm, the girth of the stem is the maximum. Subsequently the girth gets reduced and thereafter maintains it under normal conditions of growth. In the case of young palms (about 10 years), the girth varies from 38 to 60 cm. Under unfavourable conditions and with advancing age, the stem may gradually become thinner.

The arecanut stem grows erect under almost all circumstances. Due to the absence of secondary growth, any injury caused to the stem remains unrepaired. It cannot withstand much damage and is liable to break due to such injury. Since the stem is thin, it possesses great mechanical flexibility so that the palm oscillates in strong wind and thus escapes breakage. The bud produces the leaves in succession and when the leaves are shed, permanent scars are left on the trunk. The age of the palm can be approximately gauged by the count of the scars on the stem. The growth of the stem is rather rapid particularly in the initial stage. The internodal distance at the tenth internode of young palms vary from 13.9 to 34.3 cm and thereafter there is gradual reduction in the rate of growth as the age advances (Murthy and Bavappa, 1960a). The mean internodal distances at the bottom, middle and top portions of the stem of a middle-aged palm are 10.5 cm, 6.8 cm, and 1.7 cm respectively. The length of the stem varies with the intensity of population, climate etc.

The erect unbranched stem is typically cylindrical throughout and is derived from a single terminal growing point situated at the top of the trunk enveloped by leaves in various stages of development. The stem is green when young and greyish brown when old, sometimes with epiphytic growth of lichens. (Fig. 2.4) (Murthy and Bavappa, 1960a).

The epidermis of the stem in the early stage is covered by a heavy layer of cuticle and the cells are more or less isodiametric with the presence of stomata. In the older stem, the outer cortex including the epidermis and hypodermis become thick–walled and as a result of the meristematic activity of the etagen–type a distinct layer of ligno-suberised cork is produced (Fig. 2.5A) (Tomlinson, 1961). In younger stages, the hypodermal cells contain abundant chloroplasts. Vascular bundles are numerous and typically monocotyledonous. A girdle of sclerenchyma cells is invariably found associated with the bundles (Fig. 2.5B). The ground tissue consists of symmetrically arranged rows of cells which form a sort of spongy net work towards the centre of the stem with small air spaces. Due to the absence of cambium there is no secondary thickening. The stem of the seedling increases in growth due to meristematic activity producing more and more cells and vascular bundles and results in a thick stem (Raghavan, 1957).

Transformation of inflorescence to vegetative branches due to injury of the growing point has been attributed to be the cause of branched arecanut palms reported by Jacob (1940), Davis (1950a, 1950b), Murthy and Bavappa (1959), Naidu (1963a) and Thomas (1964). Abnormalities like stem-splitting at the base at different heights, stem twisting, twisting of crown to a side caused by the twisting of internodes, and longitudinal splitting of the stem have also been reported (Murthy and Bavappa, 1959; Naidu, 1959, 1963a).

Fig. 2.4 Arecanut stem showing nodes and lichen growth

3. The leaf

The crown of the palm located at the top of the trunk, subtended by the leaf sheaths, has leaves at various stages of development. The number of leaves varies depending on the age and vigour of the palm, nutritional status of the soil etc. One-year old seedling has normally 4-5, two-year old 6-7 and three-year old 7-8 leaves on the crown. In adult palms the number of open leaves on the crown ranges from 7 to 12. In the arrangement of leaves on the crown, the

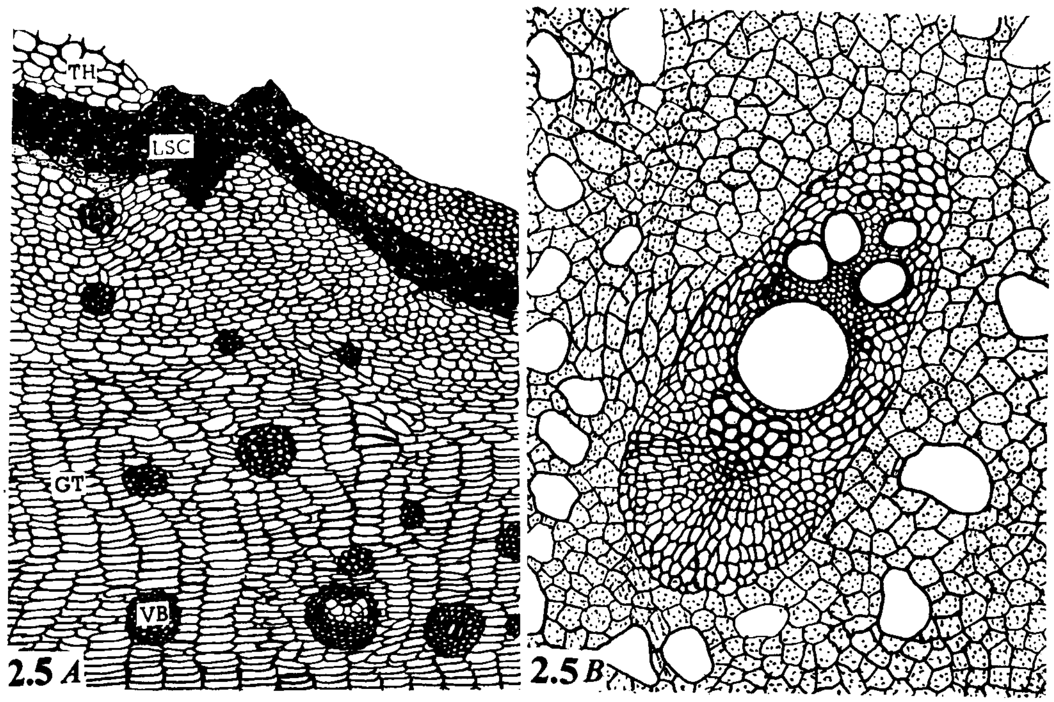
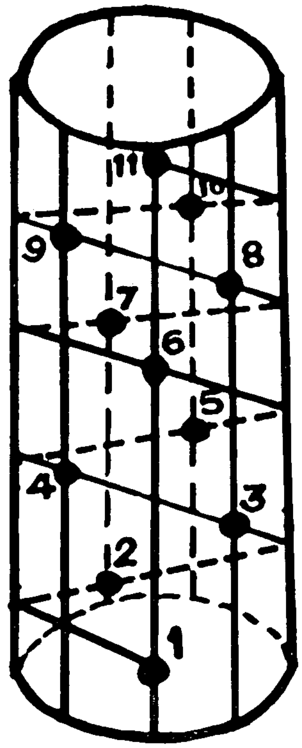


Fig. 2.5A Transverse section of stem. *TH–Thick walled hypodermis; LSC–Ligno-suberised cork; VB–Vascular bundle; GT–Ground tissue.*
Fig. 2.5B Transverse section of stem showing vascular bundle.

6th leaf stands over the first with a spiral of two circles and the eleventh leaf over the sixth with similar spiral. Thus, there are five rows of leaves (orthostichous) placed at 2/5 distances of the circle, (Fig. 2.6A) giving a phyllotaxy of five ranked or pentastichous with an angular divergence of 144° (Fig. 2.6B).

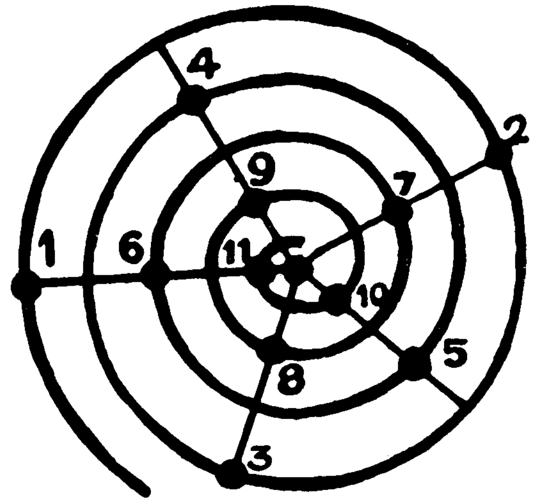
The bud produces leaves in succession and the young leaf makes its appearance in the centre of the crown with all the leaflets held together and is termed as the spindle. As the leaf gets older, it bends and during this process the leaflets get opened. The longevity of the leaf after its emergence is about two years. The mean interval between successive leaf emergence and leaf fall is more or less the same, *i.e.*, 43 days.

The leaves are pinnatisect and consist of a sheath, a rachis (leaf-stalk) and leaflets. The leaf-stalk extends as the midrib till the end of the leaf and ends as leaflets. The leaf sheath completely encircles the stem forming a protective



A

Fig. 2.6A Phyllotaxy in arecanut palm



B

Fig. 2.6B Angular divergence 144°

covering for the developing inflorescence. The sheath is about 54 cm in length and 15 cm in breadth. The average length of the leaf is 1.65 m and varies with the vigour of the palm and fertility of the soil. The total number of leaflets situated on either side of the leaf is about 70. The leaflets near the base are about 62.5 cm in length and 7.0 cm in breadth. Those near the apex are 30.0 cm in length and 5.8 cm in breadth whereas in the centre they are 69 cm in length and 7 cm in breadth. The leaflets are partly fused and partly free and arranged alternatively on either side of the petiole. At the distal end of the petiole, two or three pairs of leaflets of each side are fused to form a bifid tip (Fig. 2.7). The leaflets have one or more mid ribs. The leaf blade is leathery and soft. The colour of the leaves depends on the shade, heavier shade giving a dark green colour (Murthy and Bavappa, 1960b).

The anatomy of the leaflet shows an upper epidermis consisting of a single layer of cells with a thick cuticle, palisade parenchyma, vascular bundles,

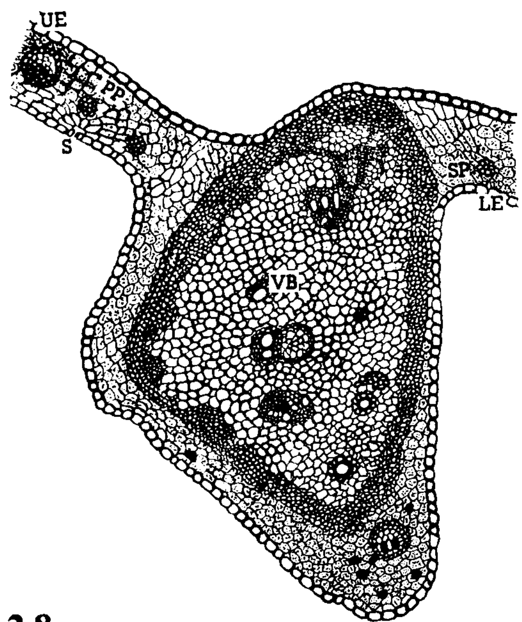
Fig. 2.7 Arecanut leaf showing bifid tip

spongy parenchyma and lower epidermis (Fig. 2.8). The vascular bundle consists of xylem and phloem and the number of spongy parenchymatous cells are much less. The stomata are small and distributed on the centre of the surface (Fig. 2.9). The mean number of stomata and epidermal cells per unit area, stomatal index and the correlation coefficients of the number of epidermal cells of four cultivars of arecanut are given in Table 2.2 (Bavappa, 1966).

Bhat (1962) noticed two leaves in the same node of an arecanut palm arranged in an opposite fashion, enclosing two productive spadices. The occurrence of two spadices enclosed by a single leaf also has been reported by him.

4. The inflorescence

When grown under the best conditions, arecanut palm flowers in about four years (Sands, 1926). In 'South Kanara' cultivar, the first inflorescence appears at the tenth node at a height of about 1.52 m from the ground (Murthy and Bavappa, 1960b).



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2.9

Fig. 2.8 Transverse section of leaflet. *UE–Upper epidermis; PP–Palisade parenchyma; S–Stomata; SP–Spongy parenchyma; LE–Lower epidermis; VB–Vascular bundle.*
Fig. 2.9 Distribution of stomata in the leaf.

The inflorescence of arecanut is a spadix which is produced in the leaf-axils (infra-foliar). Each spadix is completely enclosed in a sealed, boat-shaped spathe having a mean measurement of 75.0 cm long and 45.9 cm wide. The spathe is very thin in texture and the expanding spadix easily bursts the spathe along its upper side in a central longitudinal line and frees itself (Nair, 1962).

Table 2.2. *Stomatal index and correlation coefficient between number of stomata and number of epidermal cells in four cultivars of* A. catechu

Cultivar	No. of stomata/ unit area	No. of epidermal cells/unit area	Stomatal index	Correlation coefficient
South Kanara	104.2	832.3	11.1	0.9474**
Shimoga	58.4	748.6	7.2	0.9148**
Palghat	50.0	701.4	6.7	0.6472**
Coimbatore	35.9	658.4	5.2	0.6683**

** *Significant at 1 per cent level of probability*

The number of spadices depends upon the number of leaves produced. The absence of bunch in any node must be due to abortion of the young spadix. The mean number of spadices produced by a young, middle-aged and old palms are found to be 3.8, 3.5 and 3.1 respectively (Murthy and Bavappa, 1960a).

The spadix is short-stalked, 69.0 cm long with a main rachis giving rise to 12-16 secondary rachis which in turn bears the tertiary rachis. The female flowers are confined to the tertiary rachis and to the distal end of the secondaries. The male flowers are produced on filiform branches (15-25cm long), which arise below and beyond the female flowers. The male flowers are arranged in pairs of two rows along the upper part of the thin branches but occasionally one or two are found adjoining a female flower (Fig. 2.10). The spadix of a grown-up palm produces 0-644 female flowers and 15,000-48,000 male flowers. Some

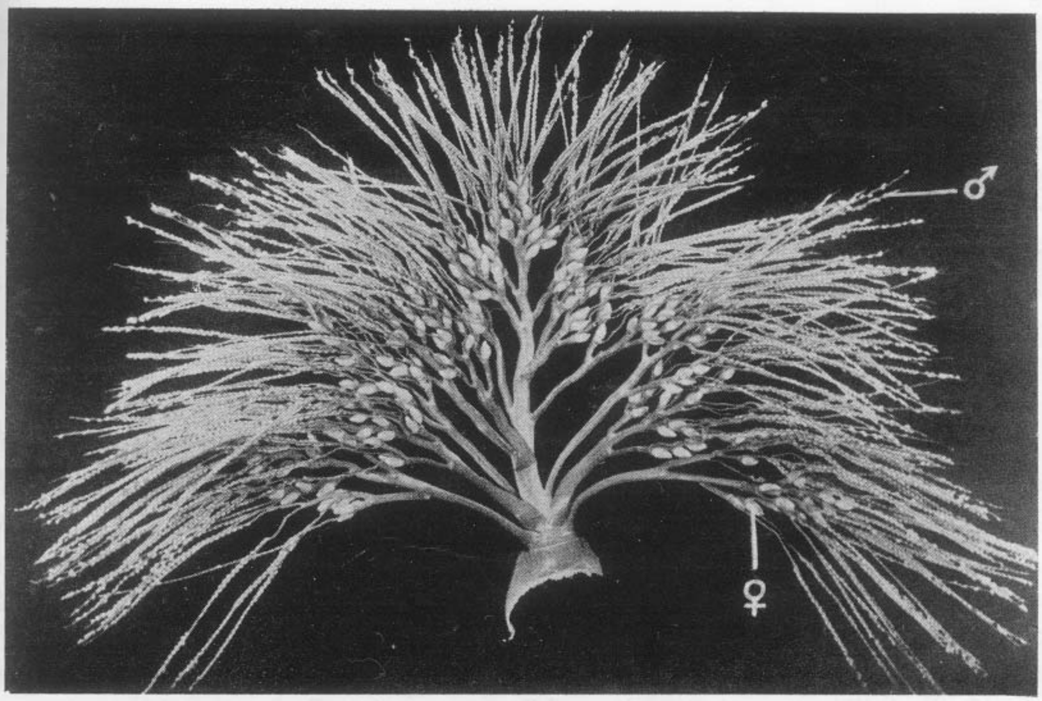


Fig. 2.10 Inflorescence showing male and female flowers

palms in *Malnad* area (Karnataka) have been observed to produce upto 1,457 female flowers (Raghavan, 1957; Murthy and Bavappa, 1960a; Murthy, 1977).

In the first flush, an inflorescence bears a hundred or more of female flowers. Towards the end of the flowering period when the reserve food materials which the palms are known to accumulate in abundance becomes exhausted, the number of female flowers in an inflorescence become progressively reduced till in the last produced ones only a dozen or less female flowers are found. It is also seen that in the region of transition between the female and male parts of the spike in which the food material becomes attenuated, bisexual flowers or sterile female flowers are produced (Rao, 1959).

A detailed study on floral initiation in *A. catechu* was conducted by Bavappa and Rao (1970). The crown of a ten year old palm has 8–9 opened leaves, one spindle leaf and 10–13 leaves and leaf primordia at varying stages of development. Inflorescence initiation is noticed in every leaf axil upto the growing point. The inflorescence primordium is initiated along with leaf primordium. The rate of growth of inflorescence is slow till it reaches the sixth leaf axil. Thereafter the length of inflorescence doubles in each of the successive leaf axil. The inflorescence primordia at the fourth unopened leaf shows the initial differentiation of primary rachis and the inflorescence in the second unopened leaf differentiates into secondary rachis. The spathe covering the spadix also differentiates at this stage. The inflorescence located in the first unopened leaf has tertiary rachis and filaments. The initiation of male flowers commences from the inflorescence subtended by the spindle. Female flowers begin to develop when the inflorescence is in the axil of the first opened leaf. Initiation of male and female flowers is complete in the inflorescence at the sixth leaf axil.

i. *Structure of male flowers*

In *A. catechu*, the male flowers are sessile, creamy white, triangular with two whorls of perianth consisting three minute sepals and three large stiff lanceolate petals. The sepals are imbricately arranged and is about 0.1 cm in length. The petals are about 0.35–0.4 cm in length with acute valvate tips. The stamens, which are six in number have basi-fixed anthers and are situated in a ring next to the petals. The rudimentary ovary (pistillode) situated in the centre is trifid and slightly larger than the stamens. The anthers are closely adpressed to the pistillode (Fig. 2.11A) (Murthy and Bavappa, 1960a; Bavappa, 1966).

ii. *Structure of female flowers*

The female flowers are sessile with two whorls of perianth (3+3), the outer boat-shaped green whorl of sepals and an inner whorl of ovate petals

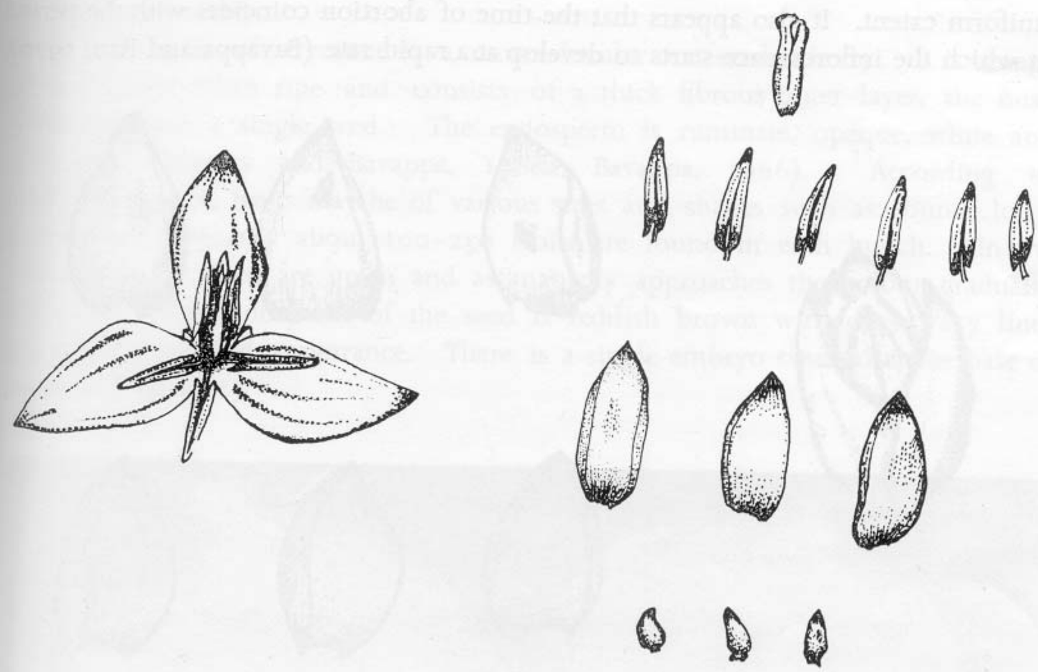


Fig. 2.11A Structure of male flower

in imbricate aestivation. The petals which are closely adpressed to the ovary are also imbricately arranged. There are six flattened minute staminodes whose bases are joined together encircling the base of the ovary. The ovary has a dome shaped trifid stigma formed by three stiff stylar projections (Fig. 2.11B) (Raghavan and Baruah, 1956a; Murthy and Bavappa, 1960a; Bavappa, 1966).

iii. *Abortion of inflorescence*

Murthy and Bavappa (1960a) recorded the presence or absence of inflorescence in the leaf axil regularly in 300 progenies of 10 mother palms, for seven years from the commencement of their bearing. They observed considerable variation in the production of inflorescence in different months of the year (Table 2.3) as well as between different years. More than 50 per cent inflorescence aborted, in leaves shed in July, August and September. The percentage of inflorescence abortion was considerably high under neglected condition (Bavappa and Rao, 1970).

Aborted inflorescences had more or less equal length, indicating that abortion in all the inflorescences took place after they had grown to a uniform extent. It also appears that the time of abortion coincides with the period at which the inflorescence starts to develop at a rapid rate (Bavappa and Rao, 1970).

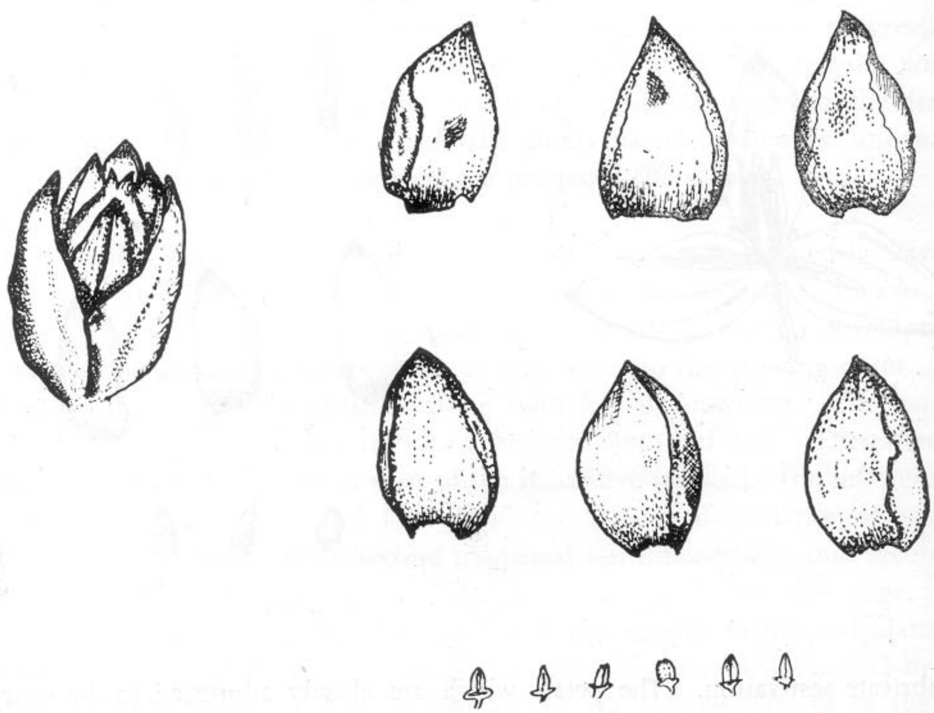


Fig. 2.11B Structure of female flower

Table 2.3. *Seasonal variation in leaf fall and inflorescence production*

Month	Average number of leaves shed from 1575 trees	Average number of inflorescences developed in 1575 trees	Percentage of inflorescences to the leaf fall
July	549.5	101.0	18.5
August	543.5	86.5	15.9
September	541.5	118.5	21.9
October	871.5	286.0	32.8
November	1014.0	552.5	54.5
December	391.5	678.5	76.1
January	1205.5	1048.5	87.0
February	1208.5	1063.0	88.0
March	1206.5	1124.5	93.2
April	1006.0	866.0	86.1
May	851.0	491.5	57.9
June	611.5	148.0	24.2

5. The fruit

The fruit of arecanut is a mono-locular one-seeded berry. It is orange red to scarlet when ripe and consists of a thick fibrous outer layer, the husk which encloses a single seed. The endosperm is ruminate, opaque, white and astringent (Murthy and Bavappa, 1960a; Bavappa, 1966). According to Raghavan (1957), fruits may be of various sizes and shapes such as round, long, oblong etc. Usually about 100-250 fruits are found in each bunch. In the younger stages, they are green and as maturity approaches the colour gradually changes. The endosperm of the seed is reddish brown with dark wavy lines giving it a marbled appearance. There is a single embryo situated at the base of the seed (Fig. 2.12).

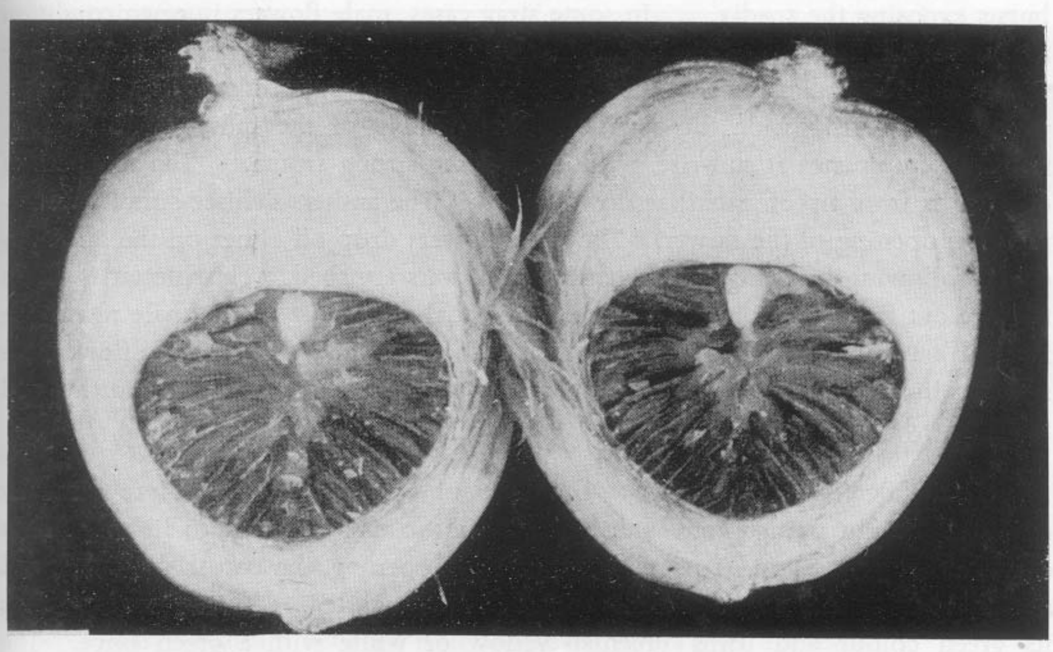


Fig. 2.12 Split nut showing embryo

In arecanut, a mature fruit consists of three zones, exocarp, mesocarp and endocarp which are more or less distinct in structure. The exocarp consists of the epidermis covered by a cuticle and parenchymatous cells inter-mixed with stray collenchyma and separate strands of thin fibres. The upper 10-12 layers of parenchyma contain chloroplasts. The mesocarp which is a continuation of exocarp is characterised by more or less parallel rows of parenchyma cells with lignified fibres. About four fibres per unit area occur both as separate strands and as sheath or bundle caps associated with vascular bundles. The endocarp consists of highly pitted and elongated parenchymatous cells covered by thick-walled inner epidermis. The cuticle is also thick (Bavappa, 1966).

III. Floral biology, pollination and fruit development

1. Floral biology

Arecanut palm is monoecious with male and female flowers occurring on the same spadix. It is essentially a cross-fertilized species (Bavappa and Ramachander, 1967).

Male flowers start opening on the same day or 1–11 days after the spathe bursts exposing the spadix. In some stray cases, male flowers in open condition are found shedding in large numbers along with the bursting and falling of the spathe, thereby indicating that the male phase must have commenced in the spadix while it was still inside the spathe. The opening of the individual flowers is found to commence at sun-rise, with a persisting strong aroma. The sequence of opening is from tip of rachillae downwards. The anthers dehisce simultaneously with the opening of the flower. The male flowers drop off either on the same day or the following morning. After the male flowers are shed, a clear nectar is found to ooze out from the point of attachment of male flowers. The male phase (the interval between the opening of the first male flower and the last male flower in a spadix) in arecanut lasts 25–46 days, the mean being 31 days (Murthy and Bavappa, 1960a; Bhat, Murthy and Rao, 1962b).

The female flower buds at the time of opening of spathes are generally cream coloured turning green within about a week after exposure to light. They open between 2 a.m. and 10 a.m. Just prior to opening, the corolla lengthens and attains an attractive colour of shiny cream or ivory white. The calyx also looses its green colour and turns greenish yellow or white with a green tinge. The initial opening of the flower is indicated by the formation of a very minute slit at the corolla and this aperture, which attains a 'y' shape widens slightly in the course of the next five or six days by the slight falling apart of the tip of the free petals, exposing the stigma. Generally the female phase extends from three to ten days.

The maximum receptivity of the stigma is on the day of opening of the flowers under Coimbatore condition. The stigma continues to remain receptive on the second and third days and thereafter there is a rapid decline in receptivity

(Bhat et al., 1962b). Under Dakshina Kannada condition, the stigma remains receptive upto six days (Murthy and Bavappa, 1960b). The maximum receptivity is between the second and fourth day of opening. Beyond the 6th day, stigma looses its receptivity. Middle aged palms have a higher stigmatic receptivity than the young and old palms (Table 2.4). It has been estimated that about 13% inter-spadix and 4% intra-spadix overlapping of male and female phases take place in arecanut (Murthy and Bavappa, 1960a).

Table 2.4. *Stigmatic receptivity (percentage of fruit set) of palms of different age groups*

No. of days after opening	Percentage of fruit set			
	Young palm	Middle aged palm	Old palm	Mean
1	16.7	27.5	13.4	19.8
2	19.9	41.9	13.6	25.1
3	30.1	31.1	8.5	23.2
4	23.3	35.2	8.1	22.3
5	14.1	21.8	5.4	13.8
6	8.7	6.0	4.6	6.4
7	–	–	–	–

2. Pollination

i. *Pollen dispersal*

Murthy and Bavappa (1961) studied the dispersal of *Areca* pollen in a garden isolated all round by 5 km using aeroscope, for catching pollen. They could obtain pollen catch upto a distance of 1.2 km. Pollen intensity was maximum at 8 a.m. Gradual reduction was observed in the total pollen from the first week of March to the last week of April. Maximum pollen was obtained at 12 m height and nearest to the garden. According to Raghavan (1957), the pollen dispersal was maximum between four and seven hours after anthesis.

Male flowers are visited by various bees and other insects which appear to collect and feed on pollen grains. The role of insects in pollination is doubtful, since no insect visitors are reported on female flowers. Pollen is carried by wind and that the flowers are usually cross pollinated. Only under exceptional circumstances self-pollination takes place (Sands, 1926; Raghavan and Baruah, 1956a; Murthy and Bavappa, 1961). However, while studying the pollination aspect of the arecanut palm, Bhat, Murthy and Rao (1961) observed two species of thrips and other insects such as ants, visiting the flowers.

Floral abnormalities such as abnormal male flower (Raghavan, 1957) proliferation of flowers (Murthy and Bavappa, 1959), perianth lobes ranging from 4 to 10 arranged in two or more whorls, bisexual flowers and their occurrence with male flowers (Raghavan and Murthy, 1954; Bavappa and Murthy, 1961) have been reported.

ii. *Pollen germination*

Under normal conditions arecanut pollen remains viable for 8–9 hr (Raghavan and Baruah, 1956a). Bhat et al., (1962b) reported increased longevity of pollen from 15 to 21 days by storing in a desiccator at room temperature. Pollen grains germinate rapidly in nutrient media, the percentage depending on the medium employed, its concentration and the type of grains used. A medium consisting of 0.5% sucrose and 0.1% agar was found ideal for pollen germination in arecanut at Vittal (Anonymous, 1967). Further it was observed that addition of boric acid at 100 ppm and gibberellic acid at 500 ppm to the above mentioned medium increased the germination percentage (Anonymous, 1969). Raghavan and Baruah (1956a) obtained optimum pollen germination in a basic medium of carbohydrates consisting of sucrose 0.75% or glucose 0.5% or starch 0.5%. Addition of growth substances like, 3-indoleacetic acid, 3-indolebutyric acid and 2-naphthalene acetic acid to the medium stimulated germination of pollen grains. The length of pollen tubes varied from 15 to 600μ depending on the type of nutrients used. The percentage of germination in crushed aqueous stigmatic extracts had no appreciable variation and the length of pollen tubes did not, in any concentration exceed 320μ in 24 hr. The optimum temperature for germination of pollen was found to be 28°C whereas 15°C, 30°C and 35°C were inhibitory (Raghavan and Baruah, 1956a).

iii. *Crossing technique*

The hybridisation technique in arecanut consists of removing the portion of rachillae having male flowers soon after the emergence of the inflorescence (Fig. 2.13A) and covering the spadix bearing female flowers with a cloth bag (Fig. 2.13B). When the female flowers open, the anther from the desired male parent is rubbed against the stigma or the pollen is dusted on the stigmatic surface, by removing the bag (Fig. 2.13C). The bag is replaced over the inflorescence immediately after pollination (Fig. 2.13D). The process is repeated daily till all the female flowers in the spadix open (Murthy and Bavappa, 1960a).

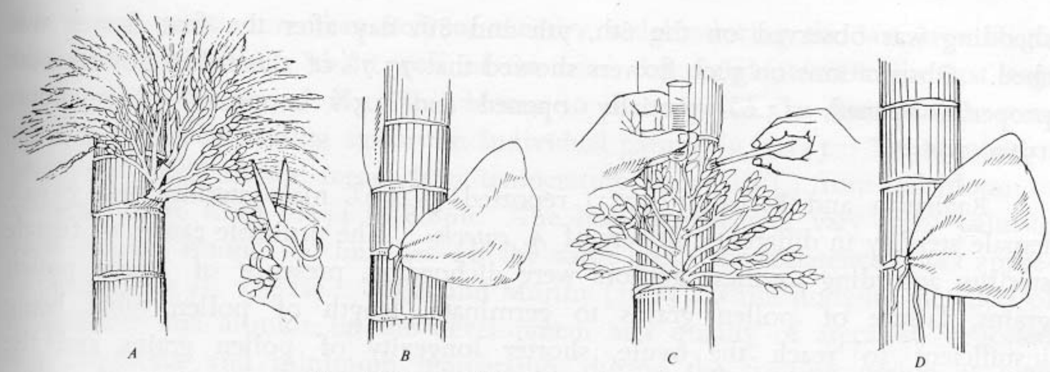


Fig. 2.13A–D Hybridisation technique

Bhat (1963, 1965) reported a method of artificial pollination for *Areca*. In this technique, fully opened male flowers are collected from the selected palms and are transferred to a reagent bottle containing 0.5% solution of sucrose and the bottle is shaken gently. The pollen grains thereupon get released in the aqueous solution. The solution with the pollen grain in suspension is transferred to an ordinary hand atomizer and sprayed on to newly opened female flowers. The spraying may have to be done three to four times as all the female flowers do not open at the same time. He obtained more than 14% increase in fruit set by this method (Table 2.5), and concluded that the method could be successfully used in the commercial crop production and hybridisation in arecanut.

Table 2.5. *Assisted pollination and fruit set in arecanut palm*

Treatment	No. of palms selected	Total female flowers	No. of flowers set	Percentage of set
Sprayed with aqueous solution of sucrose	36	8969	1080	12.0
Sprayed with pollen held in suspension in sucrose solution	36	10352	2727	26.4
Control (open pollination only)	36	7960	958	12.0

3. Fruit development

i. *Fruit set*

Under Dakshina Kannada conditions only about 30% of the female flower in *Areca* get set. The problem of low fruit set was investigated from various angles and it was observed that lack of pollination was one of the causes for shedding of female flowers. Fungal as well as insect association also was observed in the case of dropped female flowers and tender nuts. Maximum shedding was observed on the 6th, 7th and 8th day after the first flower was shed. Observations on such flowers showed that 77.7% of these shed flowers were properly opened, 13.0% partially opened and 2.3% unopened (Anonymous, 1967, 1969).

Raghavan and Baruah (1956a) reported 3–100% male sterility and 3–54% female sterility in different cultivars of *A. catechu*. The probable causes of female sterility according to these authors were dichogamy, presence of sterile pollen grains, failure of pollen grains to germinate, length of pollen tubes being insufficient to reach the ovule, shorter longevity of pollen grains and the receptivity of stigma and effect of temperature on the germination of pollen grains.

Investigations on the male and female fertility by Bavappa (1974) showed that in *A. catechu* which had a high pollen fertility (82.7–98.2%), the nut set was less than 50%. The fruits set in this species varied from 12.0 to 42.2% in different cultivars.

According to Yadava, Murthy and Pillai (1974), spraying emerging inflorescences with 100 ppm GA, or 50 ppm 2, 4–D, or 200 ppm B–995 increased fruit set in arecanut. The source and type of pollen also influenced fruit set to a greater extent. Pollination of palms with bulked pollen from selected palms gave 60% fruit set against 32% observed by open pollination (Pillai and Murthy, 1972a). A palm producing only barren nuts gave 50% fruit set when pollinated with pollen from another palm of the same source and 66% fruit set with bulk pollination (Pillai and Murthy, 1972b).

ii. *Fruit development*

Bhat, Murthy and Rao (1962a) studied various stages of fruit development in arecanut. Growth of the fruit during the post fertilization period takes place in three stages. In the first stage, there is a rapid increase in length, diameter and volume of fruits. The second stage is characterised by increase in volume and a heavy increase in dry matter accumulation in the kernel, during which period the embryo becomes macroscopic and develops rapidly; and in the third stage the final swell of the fruit takes place. The fruit looses its green colour completely and floats when placed in water. The region of most rapid growth is that enclosed by the perianth. The diameter, volume and green weight of the fruit exhibit a cyclic growth pattern, while the dry matter accumulation takes place continuously though at a slower rate during the first 15–20 weeks of growth. The dry weight of the entire fruit is influenced to a great extent by that of seed.

The kernel gains more than 80% of the dry weight during the last two stages while the husk attains about 50% of the total dry weight even in the first stage itself. The total period from full bloom to maturity of the fruit ranges from 35 to 47 weeks depending upon the individual palm (Fig. 2.14). The number of heat units (total of the mean daily temperature above 10°C) from full bloom to maturity range from 7,244 to 8,866. The heat requirement vary from palm to palm though among the bunches on the same palm the difference is not appreciable (Bhat et al., 1962a). Pillai and Murthy (1973), while studying the effect of temperature and altitude on the development and quality of arecanut, reported that maximum and minimum temperature during the fruiting period at high elevation were highly inadequate for the proper development and hardening of the kernel.

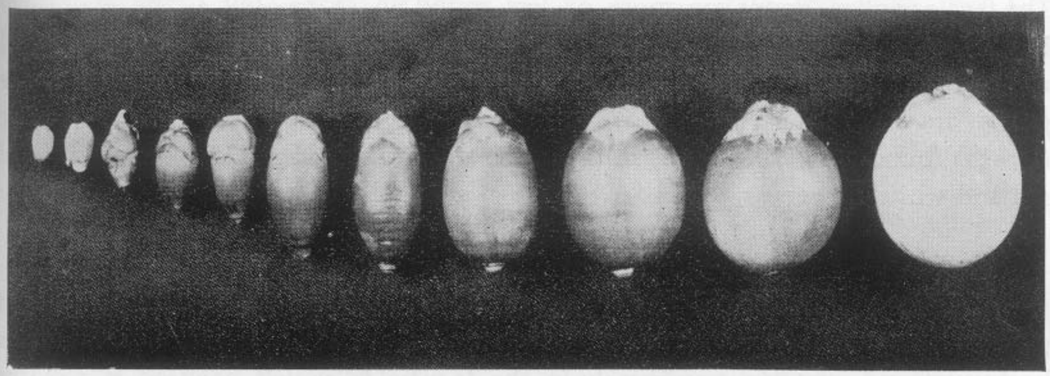


Fig. 2.14 Stages of nut development

Nair (1965b) gave an account of a rare occurrence of double fruit having increased number of perianth lobes and two embryos. Polyembryony, polycarpy, vivipary etc. in arecanut have been reported by Murthy and Bavappa (1959) and Das (1966). Stray occurrence of fruits without seeds has been reported by Bhat (1962). Abnormalities of young palms such as suckering, fused leaflets, very narrow and long leaves, chimera, and chlorophyll deficiency have been reported by Murthy and Bavappa (1959) and Nair (1965b).

The number of days required for starting and completion of germination of the nuts has been found to be 53 and 94 days respectively. In general, 94% of seeds germinate. However, failure of germination due to embryo rot, death of embryo and absence of embryo has been reported (Bavappa, Patel and Bhat, 1957).

Development of the embryo which leads to germination starts by about 20 days after sowing. The differentiation of plumule and radicle and emergence of the first root take place about 30 days after sowing, and a small shoot which emerges out above the husk is visible in another 20 days.

IV. Embryology

1. Microsporogenesis and male gametophyte

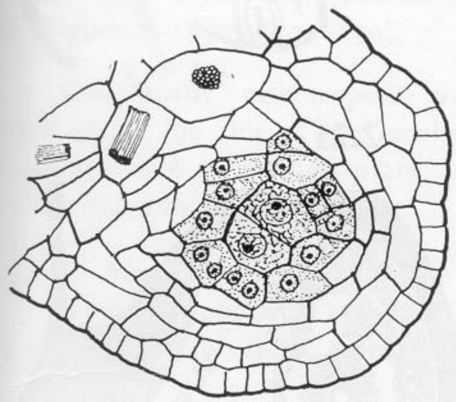
In *A. catechu* the primary sporogenous cells function directly as microspore mother cells (Figs. 2.15 and 2.16). Microspore tetrads are usually tetrahedral (Fig. 2.17) though decussate and bilateral tetrads are occasionally met with. Mature pollen grains are 2–celled, ellipsoidal or nearly spherical and monocolpate. The exine shows reticulate thickening. The vegetative cytoplasm is packed with starch and the generative cell is crescent shaped (Figs. 2.18 and 2.19) (Rao, 1959). The fertile pollen grains are more or less round in shape, but sterile grains are ellipsoid to sharply defined oval structures. The fertile grains have been classified as big oblong, big round and small oblong. The average sizes of fertile and sterile grains are 29.5–34.0μ and 29.0-31.5μ respectively (Raghavan, 1957). Nair (1965a) found wide differences in the shape and ornamentation of pollen grains of red and white flowers.

2. Ovary and ovule

In *Areca* the ovule primordium is basal in origin and strongly curved (Fig. 2.20). By the time the megaspore mother cell is fully grown, it becomes horizontal and stretches transversely in the locules, in which position it remains throughout its development (Figs. 2.21 and 2.22). At first the funicle is as thick as the body of the ovule. Since ovule grows vertically in the chalazal region, the body of the mature ovule becomes perpendicular to the funicle (Fig. 2.23) (Rao, 1959).

The ovules are hemianatropous and transverse in *Areca*. A few vascular bundles enter the funicles of young ovules, but these increase in number and branch profusely as the ovules grow (Figs. 2.24, 2.25, 2.26 and 2.27). The funicle of young ovules is lined by radially elongated glandular cells. These divide and give rise to extensive tissue which functions as obturator (Fig. 2.28).

The initials for both the integuments become demarcated simultaneously (Fig 2.24). The outer integument is as a rule more massive than the inner. The cells of the outer integument and chalazal region accumulate tannin from early stages (Swamy, 1942). Due to the growth of the ovule, mainly in the chalazal



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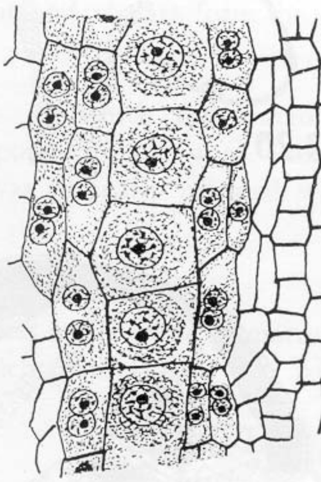

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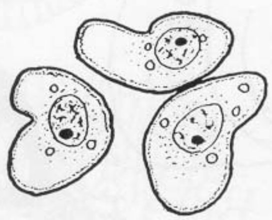

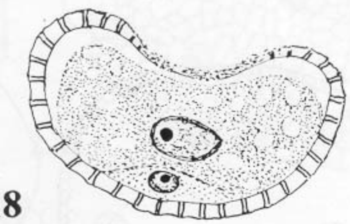

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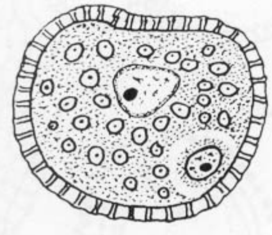

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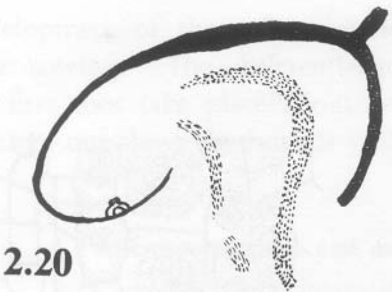
Fig. 2.15 Transverse section of anther locules. Fig. 2.16 Longitudinal section of anther locules. Figs. 2.17—2.19 Developing pollen grains.



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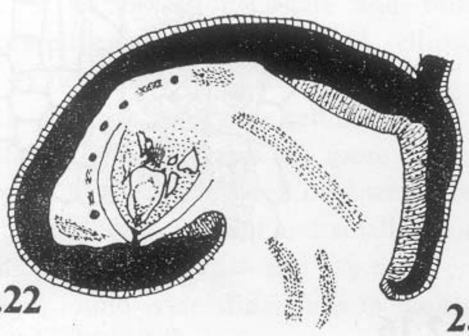

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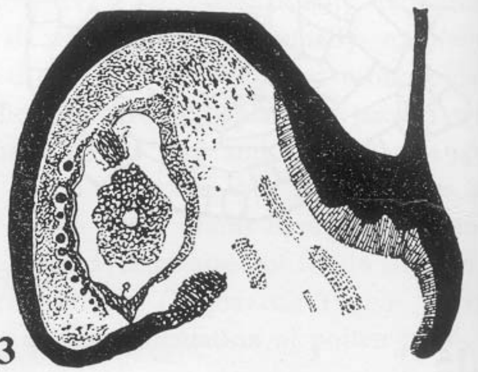

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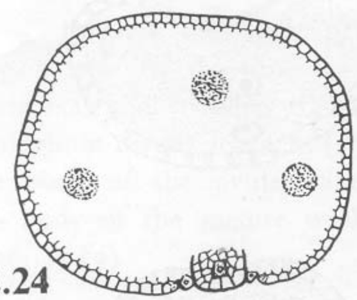

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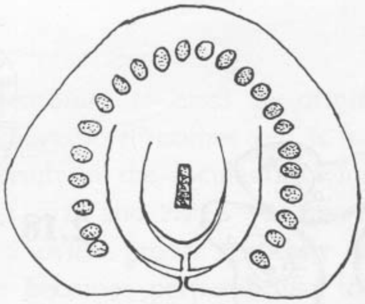

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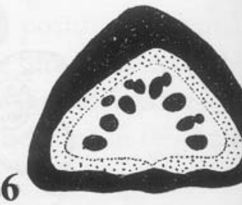

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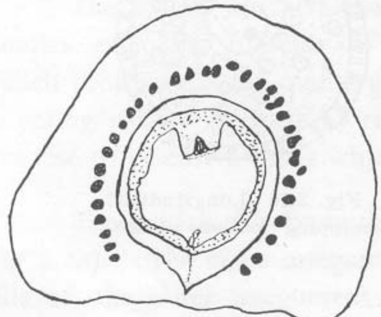

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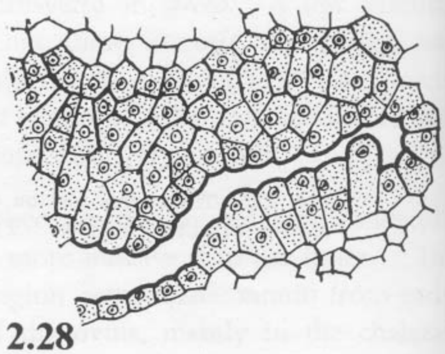


2.28

Figs. 2.20—2.23 Development of megaspore mother cells.
Figs. 2.24—2.27 Longitudinal section through ovules at different stages of development. Fig. 2.28 Cells from the funicle of the developing ovules.

region, the integuments are separate from each other only for a small distance around the micropyle. Ruminations develop from the chalaza and outer integument. The whole of the inner integument becomes crushed early in the course of seed development and the outer integument and chalaza form the seed coat (Raghavan, 1957; Rao, 1959).

Occasionally orthotropous ovules or those in which the micropyle pointed against the side of the locules have been reported (Rao, 1959). Rarely two ovules were seen in an ovary, of which one was normally oriented while the other was abnormal and sterile.

3. Megasporogenesis and female gametophyte

A single hypodermal archesporial cell differentiates in the ovule primordium (Fig. 2.29) and cuts off the primary parietal cell which gives rise to 2–3 layers

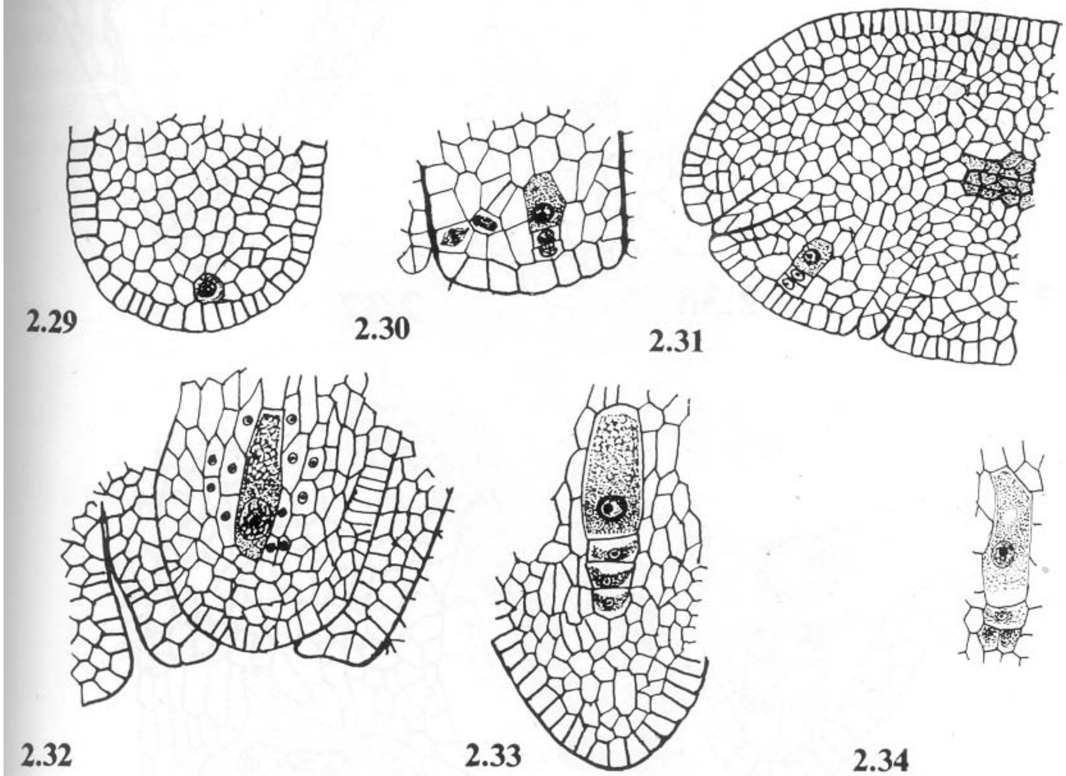
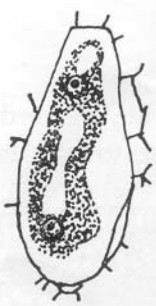


Fig. 2.29 Longitudinal section of ovule primordium with archesporium. Figs. 2.30—2.31 Formation of parietal layers. Fig. 2.32 Nucellus with full grown megaspore mother cell. Fig. 2.33 Linear shaped megaspore tetrad. Fig. 2.34 T shaped megaspore tetrad.

of parietal tissue (Figs. 2.30 and 2.31). The full grown megaspore mother cell has the characteristic elongated and tapering form (Fig. 2.32). The megaspore tetrad may be linear (Fig. 2.33) or T shaped (Fig. 2.34). The embryo-sac develops according to the normal type (Figs. 2.35, 2.36 and 2.37). The synergids show either rounded protuberances or hooks on their free sides and the polar nuclei fuse



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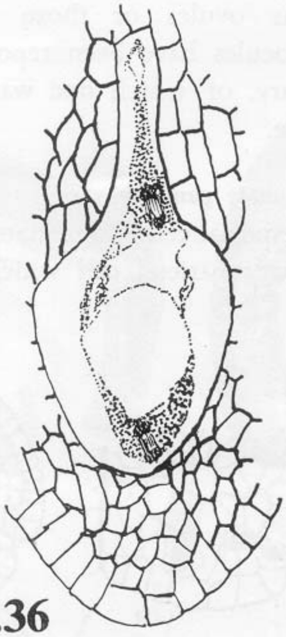

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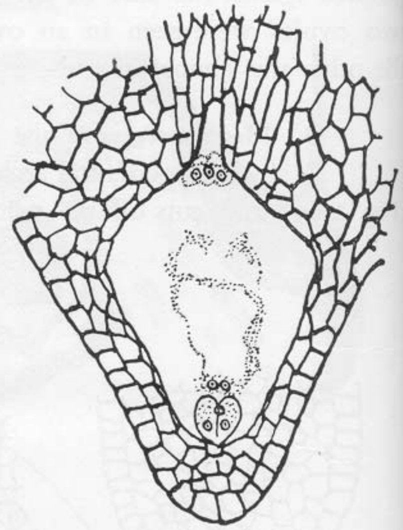

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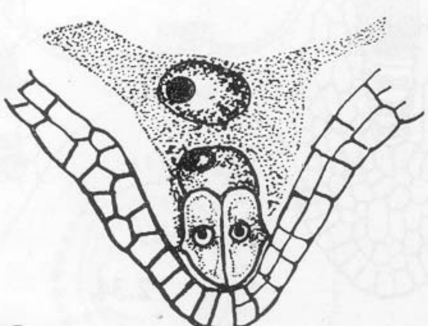

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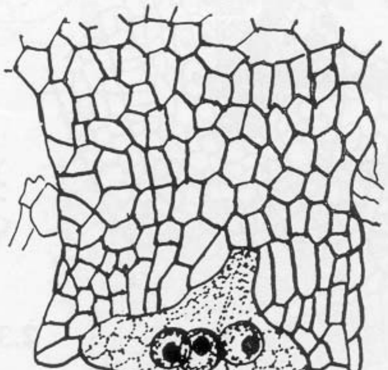


2.39

Figs. 2.35—2.37 Stages in the development of embryo sac. Fig. 2.38 Micropylar part of the embryo showing synergids. Fig. 2.39 Antipodals from enlarging embryo sac.

before fertilization (Fig. 2.38). The antipodals enlarge considerably. Their lower ends extend to the base of the socket like depression in the postament and their upper ends become large and sac like (Fig. 2.39) (Rao, 1959).

4. Endosperm and seed development

The endosperm is of the nuclear type, a few endosperm nuclei are formed by the time syngamy is completed. The endosperm nuclei become distributed in a thin peripheral layer of cytoplasm which is distinct from the main mass of cytoplasm filling the central part of the sac. At about 4–celled stage of the embryo, a central vacuole appears, which persists till a late stage in seed development.

Endosperm in *Areca* is ruminate. The ruminations are already apparent in the mature ovule and become prominent after fertilization. In the mature seed they appear as branched or unbranched plates. The ruminations usually develop to the inside vascular bundles and sometimes the branches of the vascular bundles extend into the rumination (Fig. 2.40). The vascular strand is surrounded by some colourless and tannin bearing cells. (Rao, 1959)

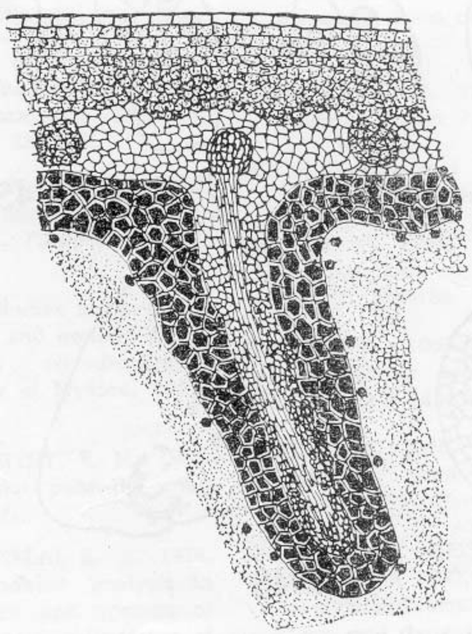


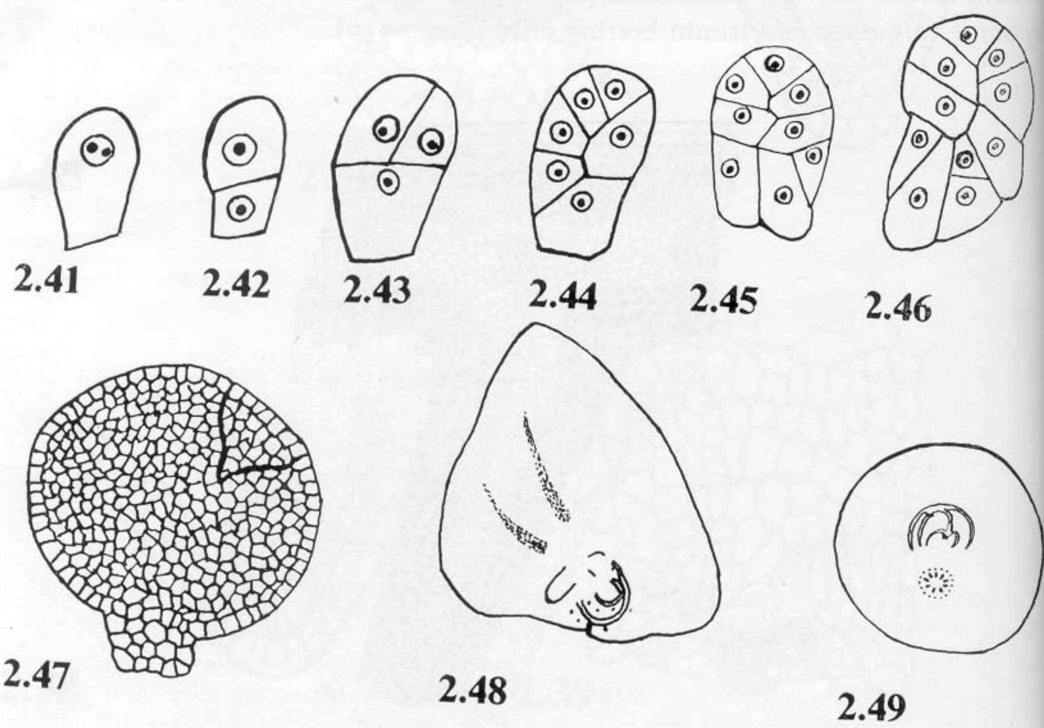
Fig. 2.40 Longitudinal section through rumination

5. Embryo

The fertilized egg divides transversely and gives rise to two cells (Figs. 2.41 and 2.42). The upper cell divides obliquely and gives rise to a larger and a smaller cell (Fig. 2.43). The larger cell undergoes another oblique division and forms a triangular epiphyseal cell and a rectangular cell. The smaller cell gives rise to two similar cells (Fig. 244). The derivatives of the lower cell of the first division give rise to a massive suspensor (Figs. 2.45, 2.46, 2.47 and 2.48) which becomes detached and absorbed during the course of the development (Rao, 1959).

The cotyledon becomes massive and surrounds the plumule, leaving a small pore for its emergence during germination (Fig. 2.48). In the mature embryo the plumule and radicle are oriented towards the micropyle. The hypocotyl shows a ring of vascular bundles, branches from which extend into the cotyledon and radicle (Fig. 2.49).

The fully developed embryo is conical, 4–4.5 mm in length and 3–3.5 mm in diameter at the base. The single cotyledon completely encircles the plumule,



Figs. 2.41—2.48 Stages in the development of embryo. Fig. 2.49 Transverse section of embryo.

leaving only a pore for its emergence during germination. It shows several leaf primordia, each with some procambial strands. Vascular strands also extend nearly to the tip of the cotyledon from the procambial strands of the primary axis. The cells of the embryo are devoid of reserve food materials. The embryo is surrounded by copious ruminated endosperm in which hemicellulose and starch are stored. (Rao, 1959).

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